2007-06

Feasibility study and cost benefit analysis of thin-client computer system implementation onboard United States Navy ships

Arbulu, Timothy D.; Vosberg, Brian J.

Monterey, California. Naval Postgraduate School

https://hdl.handle.net/10945/10233

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Feasibility Study and Cost Benefit Analysis of Thin-Client Computer System Implementation Onboard United States Navy Ships

---

By: **Timothy D. Arbulu, and**
Brian J. Vosberg

June 2007

Advisors: **Douglas E. Brinkley**
John E. Mutty

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2007	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE Feasibility Study and Cost Benefit Analysis of Thin-Client Computer System Implementation Onboard United States Navy Ships			**5. FUNDING NUMBERS**
6. AUTHOR(S) Timothy D. Arbulu and Brian J. Vosberg			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

The purpose of this MBA project was to conduct a feasibility study and a cost benefit analysis of using thin-client computer systems instead of traditional networks onboard United States Navy ships. The project examined the technical capabilities of thin-client computer systems to ensure they will operate with the required shipboard software and in a shipboard environment. A cost benefit analysis was also conducted to identify the possible cost savings to the Navy through the shipboard use of thin-client computer systems.

The results of this analysis showed that thin-client computer networks are a cost-effective, long-term network solution for use onboard United States Navy ships. Because of the incompatibility of some current shipboard software and software systems with thin-clients, a thin-client network including a small number of personal computer workstations may be required until the software is made compatible.

14. SUBJECT TERMS Thin-client, network centric computing, shipboard network			**15. NUMBER OF PAGES** 109
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

FEASIBILITY STUDY AND COST BENEFIT ANALYSIS OF THIN-CLIENT COMPUTER SYSTEM IMPLEMENTATION ONBOARD UNITED STATES NAVY SHIPS

Timothy D. Arbulu
Lieutenant, United States Navy
B.S., Southern Illinois University, 1999

Brian J. Vosberg
Lieutenant Commander, United States Navy
B.S., University of Wisconsin-River Falls, 1995

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2007

Authors: ________________________________
Timothy D. Arbulu

____
Brian J. Vosberg

Approved by: ________________________________
Dr. Douglas E. Brinkley
Lead Advisor

____
John E. Mutty
Support Advisor

____
Robert N. Beck, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

FEASIBILITY STUDY AND COST BENEFIT ANALYSIS OF THIN-CLIENT COMPUTER SYSTEM IMPLEMENTATION ONBOARD UNITED STATES NAVY SHIPS

ABSTRACT

The purpose of this MBA project was to conduct a feasibility study and a cost benefit analysis of using thin-client computer systems instead of traditional networks onboard United States Navy ships. The project examined the technical capabilities of thin-client computer systems to ensure they will operate with the required shipboard software and in a shipboard environment. A cost benefit analysis was also conducted to identify the possible cost savings to the Navy through the shipboard use of thin-client computer systems.

The results of this analysis showed that thin-client computer networks are a cost-effective, long-term network solution for use onboard United States Navy ships. Because of the incompatibility of some current shipboard software and software systems with thin-clients, a thin-client network including a small number of personal computer workstations may be required until the software is made compatible.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I. INTRODUCTION...1

II. EXPLANATION OF THIN-CLIENT COMPUTING THEORY 3
- **A. BACKGROUND INFORMATION 3**
- **B. DESCRIPTION OF CLIENT TYPES 7**
  - **1. Fat or Thick-Clients...7**
  - **2. Thin-clients 8**
  - **3. Tubby-Clients 9**
  - **4. Windows Based Terminals...9**
  - **5. Low Spec PCs 10**
  - **6. Internet Terminals..10**
  - **7. Disabled PCs..10**
  - **8. Blade PCs...11**
- **C. ADVANTAGES AND DISADVANTAGES OF THIN-CLIENT NETWORK USE 11**
  - **1. Advantages of Thin-client Network Computing 12**
    - ***a. Lower Administrative Costs...12***
    - ***b. Improved Security 13***
    - ***c. Lower Hardware Costs 14***
    - ***d. Lower Energy Consumption Costs..15***
    - ***e. Lower Chance of Theft 16***
    - ***f. Fewer Moving Parts Means Decreased Internal Dust and Increased Safety..17***
    - ***g. Small Footprint and Lower Bandwidth Requirements..........18***
    - ***h. Easy Upgrades with Little or No Network Service Interruptions 20***
  - **2. Disadvantages of Thin-client Networks 21**
    - ***a. Increased Server Requirements..21***
    - ***b. Poor Multimedia Application Performance...........................22***
    - ***c. Lack of Compatibility With Some Applications and Need for Improvements in Thin-Client Network Management Software...23***
    - ***d. Resistance to Change..24***
    - ***e. Single Point-of-Failure Requires a Full Back-Up Server.....24***
- **D. CHAPTER SUMMARY...25**

III. CURRENT AND PROPOSED SHIPBOARD NETWORKS................................27
- **A. CURRENT SHIPBOARD NETWORKS 27**
  - **1. Integrated Shipboard Network System 27**
  - **2. Special Compartmented Information Automated Digital Network System 28**
  - **3. Combined Enterprise Regional Information Exchange System....29**
- **B. PROPOSED SHIPBOARD NETWORK SOLUTION...............................32**

C. THIN-CLIENT NETWORKS PREVIOUSLY FIELDED ON U.S. NAVY SHIPS 34
1. Network Centric Computing 34
2. USS *Coronado* (AGF-11) 35
D. CONCLUSION AND CHAPTER SUMMARY....41

IV. SHIPBOARD SOFTWARE....43
A. COMMON SHIPBOARD NETWORK SOFTWARE....43
1. Common PC Operating System Environment (COMPOSE)....43
2. Naval Tactical Command Support System (NTCSS)....45
a. Relational Administrative Data Management Application (R-ADM)....45
b. Relational Supply (RSupply) 46
c. Organizational Maintenance Management System-Next Generation (OMMS-NG)....46
d. Naval Aviation Logistics Command Management Information System (NALCOMIS) 47
3. Sensitive Compartmented Information (SCI)....47
B. COMPATIBILITY OF EXISTING SOFTWARE WITH THIN-CLIENT NETWORKS....47
1. Common PC Operating System Environment (COMPOSE)....47
2. Naval Tactical Command Support System (NTCSS) and Sensitive Compartmented Information (SCI)....49
C. SOFTWARE TESTING....50
1. Rich Streaming Media (NPS Classroom) 50
2. Rich Streaming Media (Sun Microsystems Lab)....51
3. Rich Streaming Media (Fat Client)....51
D. CONCLUSION 52

V. COST-BENEFIT ANALYSIS OF SHIPBOARD THIN-CLIENT NETWORKS....53
A. DESCRIPTION OF CANES LITE BLADE SERVER NETWORK MODEL 53
1. Workstations 53
2. Servers....54
3. Software 56
4. Miscellaneous Network Equipment....58
B. DESCRIPTION OF ULTRA-THIN-CLIENT CANES LITE NETWORK MODEL....59
1. Workstations 59
2. Servers....60
3. Software 61
4. Miscellaneous Network Equipment....61
C. IDENTIFICATION OF RELEVANT COSTS 62
1. Work Stations....62
2. Servers....62
3. Software 62

D. COSTS COMPARISON ... 63
1. Hardware and Software Costs ... 63
2. Refresh Costs ... 63
3. Energy Costs ... 64
4. Administration/Manpower Costs ... 66
5. Intangible Benefits ... 66
6. Risks ... 67
7. Final Cost Comparison ... 67
8. Recommendation ... 70
VI. CONCLUSION ... 73
A. PROJECT SUMMARY ... 73
B. RECOMMENDATIONS FOR FUTURE RESEARCH ... 75
APPENDIX A. CANES LITE DDG COST MODEL ... 77
LIST OF REFERENCES ... 87
INITIAL DISTRIBUTION LIST ... 91

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1. Thin-Client Network Architecture Using Sun Ray Servers and Clients 9
Figure 2. Hewlett-Packard Thin-Client Total Cost of Ownership Savings Compared to a Standard PC..12
Figure 3. Annual Energy Consumption Formula 15
Figure 4. Physical Characteristics of the Wyse S90 Model Thin-client 18
Figure 5. Wyse S90 Mounted on the Back of a LCD Monitor 19
Figure 6. Operational Concept for CENTRIXS Use with U.S. and Allied Forces 30
Figure 7. Overview of CENTRIXS Use with Multi-National Coalition Forces.............31
Figure 8. A POE injector (which puts electrical power into the Ethernet cable) and a POE power splitter (which draws electrical power from the cable). 33
Figure 9. UTC Construction and User Mobility Illustration...35
Figure 10. NCC Architecture and information distribution and display...........................36
Figure 11. Comparison of NCC Desktop Environment Using PCs and Using UTCs 37
Figure 12. Breakdown of Windows NT and Main Server Racks in Q-70 Architecture ..38
Figure 13. Benefits Associated with the AN/UYQ-70 NCC Architecture 39

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1. Average Bandwidth Use by Client Type 20
Table 2. COMPOSE COTS software that is available for installation on servers.........44
Table 3. COMPOSE default workstation software load. 44
Table 4. COMPOSE Software Applications Tested Successfully on a Thin-Client Network...48
Table 5. CENTRIXS-M Block II Main System Components 49
Table 6. CANES Lite Workstations..54
Table 7. CANES Lite Blade Servers and Chassis..55
Table 8. CANES Lite COMPOSE Server Software 56
Table 9. CANES Lite SOA Estimate..57
Table 10. CANES Lite Other COMPOSE Server Software 57
Table 11. CANES Lite COMPOSE Workstation Software...58
Table 12. Ultra-Thin-Client Network Model Workstations 59
Table 13. Ultra-Thin-Client Network Model Session Servers 60
Table 14. Ultra-Thin-Client Network Model Virtual Desktop Software 61
Table 15. Relevant Hardware and Software Cash Outlays (First Ten Years) 64
Table 16. Ultra-Thin-Client Energy Cost Savings..65
Table 17. Ultra-Thin-Client Network Net Present Value (Six-Year Refresh).................69
Table 18. Ultra-Thin-Client Network Net Present Value (Nine-Year Refresh) 70

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

We express our sincere thanks to our advisors, Dr. Douglas E. Brinkley, Commander, Supply Corps, United States Navy (Retired) and Professor John E. Mutty, Captain, United States Navy (Retired), and the faculty of the Naval Postgraduate School for their insight, knowledge and direction.

We also would like to thank our acquaintances at Science Applications International Corporation for their time and knowledge of Navy networks and the folks at Sun Microsystems for their time and knowledge of thin-client networks.

Finally, we would like to thank our families, who are always there to support us whether at home, on deployment, or completing an MBA Project.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

Today, technology in terms of speed, utility, and capacity effectively doubles every two years and has been doing so for the past twenty years. It seems that this trend will not slow in the foreseeable future. Indeed, if there is to be a change in the pattern, it will be to increase capacity at an even greater rate of change.

This trend, while remarkable and indeed a testament to humankind's ingenuity and thirst for improvement, also comes with a price. In fact, it is an especially high price in terms of its financial effect on government operations. The rising costs of updating and maintaining current information technology (IT) systems or replacing obsolete or non-serviceable systems have created a strain on the Navy's operations and maintenance budgets. The recent resurgence in the popularity of thin-client network (TCN) technology may ease some of the pressure and limit the expense to the U.S. Navy's Surface Warfare community as dollars for information technology become more and more limited.

The purpose of this MBA Project was to determine the feasibility of implementing thin-client computing technology aboard ship and conduct a cost-benefit analysis of its use. To that end, this Professional Report begins with an explanation of what thin-client computing is and why it has received so much attention as a favorable solution to the problems of security, bandwidth, and overtaxed information technology professionals who are charged with keeping their organization's computer systems up-to-date and fully functional at all times. Included in Chapter II is a literary review on the subject to give the reader a better understanding of what other researchers have said and found out about thin-client networks in general as well as their specific use with applications used by military organizations. Furthermore, the advantages and disadvantages of thin-client networks are presented to the reader.

The authors of this report then explored the potential suitability of thin-client computer networks as a replacement for or supplement to existing standard personal computer (PC) local area networks (LANs) currently in-use aboard the Fleet's surface ships. The project examined the compatibility of software applications currently used by the Fleet with TCNs, which operate much like the systems of "dumb terminals" and mainframe servers used in the early days of mainstream computer use.

Finally, the authors conducted a cost-benefit analysis (CBA) of TCN use and implementation as compared to the blade server-PC network being implemented in the Surface Fleet. From the findings and conclusions of the CBA, the authors determined which option, traditional or thin-client would likely be the best for the Surface Navy to use aboard ships.

NOTE TO THE READER AND DISCLAIMER OF ENDORSEMENT:

Throughout this report, several brand names of thin clients that were tested by the authors of this paper will be listed and described. As a point of clarification, it should be noted that at no time are we, the authors, endorsing one specific brand of thin-client or another. The authors' sole intent is to offer the reader as much information about each type of thin client available as possible, so that the best and most informed decision can be made about the feasibility and cost-effectiveness of thin-client network implementation.

II. EXPLANATION OF THIN-CLIENT COMPUTING THEORY

A. BACKGROUND INFORMATION

Network computing has never been more popular and is becoming more and more interwoven into the very fabric of modern society. The Internet allows parties at opposite ends of the globe to interact and share information instantaneously. Intranets and LANs allow computer users within a defined group to share documents, view reports, and utilize data rapidly and efficiently in order to better serve their organization. The use of PCs within the workplace has even created jobs to support the maintenance and security of the organization's computers, their network servers, as well as all associated hardware and software to support normal operations. With the rising cost of maintaining and replacing equipment and software, "thin-client" computing is making a comeback to mainstream network-centric organizations. The following is a brief history of thin-client computer development and use in networks.

The first computer systems commonly used by businesses consisted of a mainframe computer, which did all of the real processing, and multiple "dumb terminals" which served as purely input and output conduits to the user. Control was very centralized and the terminal users had very few operations and applications available to them. This configuration was popular well into the mid-1980s, since at the time, the majority of software that was being used was developed for mainframe computers. The programs were essentially thin-client applications since the server did almost all of the processing and the dumb terminals acted as the primary user interface. The dumb terminals lacked the processing power necessary to do much more than display output and receive input from the operator.[1]

The centralized nature of this configuration was advantageous for several reasons. For one thing, it allowed the network managers to update software on a single server rather than at each workstation. The "stateless" nature of the applications used gave the user the appearance of real-time interaction with the program, while in actuality, nearly all of the actual processing was being conducted by the server. The server spent most of its time waiting for another command to process while the clients were idle awaiting more input from the user and not consuming any system resources such as the Central Processing Units (CPUs), memory, or bandwidth. Furthermore, this type of network was more secure since the risk of a malicious software ("malware") application attack was minimal and viruses were nearly non-existent at the time. [2]

The invention of the IBM PC and the development of the "thick-client" system changed everything. A "thick-client" (also known as a "fat-client") is a networked system of computers that keeps most its computing resources installed locally at the individual workstation, as opposed to being installed on the server and being distributed to the workstations via the network as is the case with thin-client systems. They have, thus far, been vastly preferred to thin-client systems due their ease of customization, greater user controllability and increased specific system configuration.[3]

"Fat-clients" use the network to share information but perform their own processing chores. This changes the role of the network server to more of a traffic cop vice a centralized source of processing. The PC offered the user more control over the applications he or she wanted to run since PCs have much more processing power in the form of their own CPU and memory. Internet development and growth, along with the widespread growth of intranet use within local area networks, opened the door for continual growth in the use of "thick-client" computers. The expenses associated with PC-based networks are numerous when one considers that the IT professional for the organization has to purchase software or software licenses for all of the organization's PC "thick-clients."

---

1 Dharmesh Shah (2006, May 28). The thin-client, thick-client cycle. Retrieved February 13, 2007, from http://onstartups.com/home/tabid/3339/bid/161/The-Thin-Client-Thick-Client-Cycle.aspx.

2 Ibid.

3 SearchSMB.com (2006, January 3). SearchSMB.com Definitions. Retrieved February 13, 2007, from SearchSMB.com Web site: http://searchsmb.techtarget.com/sDefinition/0,,sid44_gci1155689,00.html.

Additionally, the average lifespan for PCs has diminished from about five years in 1990 to only two years, with regards to processing power and hardware, according to a study by the International Data Corporation.[4] The costs of replacing a single workstation can exceed $2,000, which, in the business world, can result in increased variable overhead and ultimately lower the company's bottom line. Furthermore, the cost of updating PCs in terms of man-hours is high, as it is a labor intensive task to install new software on each workstation every time a new update, change, or component replacement is required.

A need to reduce the above-described costs led to the eventual resurgence of thin-client networks. The re-emergence was due to a need for increased processing speeds and performance at a lower cost. The shift came largely in the late 1990s with the thin-client becoming a "much smarter dumb terminal" taken in the form of an internet web browser such as kiosk terminals which provide the user limited information for very specific purposes on preprogrammed websites. Several factors contributed to this trend.

One factor was that it was troublesome to manage so many applications on so many desktop computers. This created a nightmare for IT managers, who incessantly had to update workstations for their organizations. Additionally, there were several types of applications that needed more processing "horsepower" and data storage than the typical PC possessed and thus, needed to be run on servers instead. Furthermore, the advent of newer and less complicated internet protocols facilitated the development of applications that would function with a myriad of hardware platforms and operating systems such as Windows XP and Mac OS X.[5] The newly released Windows Vista is reported to also be compatible with most thin-client units, but further testing is required to make this statement with certainty. The new thin-client model solved a great deal of problems associated with the thick client applications. The users were able to leverage the

---

4 Ditch that shabby two-year-old PC (2000, February 3). PC World. Retrieved April 18, 2007, from: http://www.pcworld.com/article/id,15122-page,1/article.html.

5 Dharmesh Shah (2006, May 28). The thin-client, thick-client cycle. Retrieved February 13, 2007, from http://onstartups.com/home/tabid/3339/bid/161/The-Thin-Client-Thick-Client-Cycle.aspx.

resources of the large servers to do things that they could not do with a desktop computer, with a consistent set of behaviors and reliability from hundreds of applications that were accessible with just a mouse-click on their web browsers.[6]

The need for a greater amount of security, given today's risks of viruses and data security, further influenced the thin-client networks resurgence in popularity. The centralized nature of the system allows administrators near-absolute control of what programs or applications go on the server and ultimately are available to the end-user at one of the thin-client work stations. Since these systems are configured so that data are kept on a server, sensitive or classified information is not jeopardized in the case of a lost, damaged or stolen work station.

Whenever applications need to be updated on the system, it is only the central servers that need to be updated with the new software, as opposed to all of the individual work stations throughout the network. International Data Corporation analyst, Bob O'Donnell, recently stated that people are recognizing that if information is centralized and more tightly managed, they can decrease their costs and minimize security-related issues, since there are fewer things that would require monitoring.[7]

The basic operation of a thin-client network is fairly simple. They are usually small solid state devices which are designed to run applications from the server, unlike PCs that perform operations locally. Thin-clients lack the hard drives, CD or DVD-ROMs, floppy disk drives or expansion slots possessed by PCs to perform these operations. Thus, they are much more compact and take up almost no space on the desk.[8] Indeed, the thin-client itself is commonly mounted on the back of the attached flat-panel monitors, which are more commonly found in the work-place today than the outdated CRT monitors. The TCN servers often use a Citrix/UNIX model of data exchange

6 Shah, Dharmesh (2006, May 28). The Thin-client, Thick-client Cycle. Retrieved February 13, 2007, from OnStartups.com Web site: http://onstartups.com/home/tabid/3339/bid/161/The-Thin-Client-Thick-Client-Cycle.aspx.

7 Christopher Lawton (2007, January 30). 'Dumb terminals' can be a smart move. Wall Street Journal, p. B3.

8 Krysztof K. Felisiak & Pavel S. Grunt (2006). Evaluating thin-client computers for use by the Polish Army. Naval Postgraduate School thesis, p. 5.

between the clients and the server. This allows the server to monitor and control all operations taking place on the individual clients. The terminals often operate in a virtual Windows environment utilizing Windows XP's Remote Desktop Protocol subsystem, which gives the users the ability to operate as they normally would on a PC without the need for applications loaded at the work-station. They are also able to share files and send jobs to print on networked printers as any other thick-client system would, but instead of sending the complete data package back and forth across the network, from client to server and from server to printer and back again, all operations are completed on the server and the data are only sent once to the printer, saving precious system bandwidth and speeding up operations considerably.

B. DESCRIPTION OF CLIENT TYPES

There are essentially eight types of clients that are used in networked computer systems today: fat-clients, thin-clients, tubby-clients, Windows Based Terminals (WBTs), Low-Spec PCs, Internet Terminals, Disabled PCs, and Blade PCs. Each type has its own characteristics that make it suitable to the specific requirements of the network in which it is used. A brief description of each type follows.

1. Fat or Thick-Clients

A "fat-client" or "thick-client" is what is generally referred to as the standard computer workstation where as much of the actual processing as possible is done at the PC or client itself and only the requisite data needed for communications and archival storage is transferred to the server.[9] This has long been the most popular network design configuration since it allows the user much more freedom over his or her work and computer. The advantage of fat-clients is that all of the applications required to do a job can be loaded directly onto the PC itself which allows the user to work independently as

9 Answers.com (2007). Thin client. Retrieved March 13, 2007, from: http://www.answers.com/thin%20clients.

they wish. The disadvantages are the high cost of maintaining such a system and the wasted computing capacity of each PC's central processing unit, since normally only a small percentage of it is used at a time.

2. Thin-clients

A thin-client is a network workstation in a client-server network that allows the central server to do all of the actual processing for it. The word "thin" has to do with the small boot image (operating system) the thin-clients use. The operating system must be kept small since the thin-client has no hard drive which requires the operating system to be embedded into the device using a solid state flash drive. The small boot image is generally just enough to start up either a web browser or a Remote Desktop connection with a CITRIX or Microsoft Terminal Server.

Thin-clients are always connected directly to a monitor for video output and a keyboard and mouse to allow the user to input commands into the system and conduct work. Figure 1 illustrates a network using Sun Ray ultra-thin-clients which communicate with and are controlled by consolidated servers that process data, retrieve and send files to and from the clients, administer e-mail traffic and provide the boot sequence for each user on the thin-client network. An important feature illustrated in Figure 1 and further expanded upon later is the fact that with this architecture, users are no longer "tied down" to a PC that must remain in one place; instead through the use of smart card technology the users log on to any one of the thin-clients on the network and have full access to their personal files and authorized network applications.[10]

---

10 Lawrence J. Brachfeld (2001, August). Network centric computing: a new paradigm for the military?, 4. STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

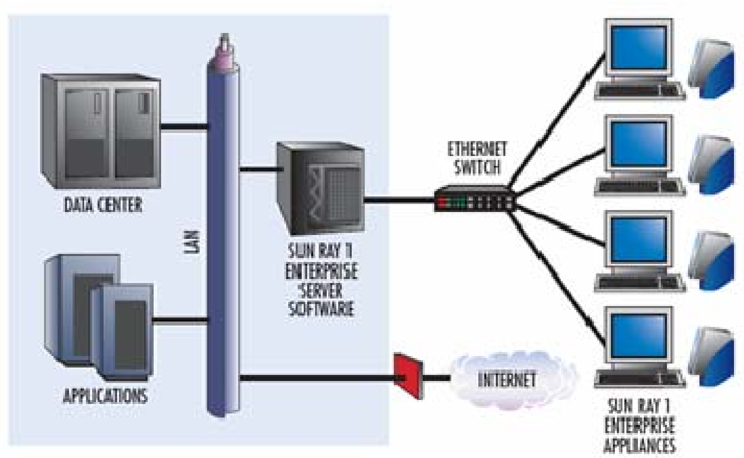

Figure 1. Thin-Client Network Architecture Using Sun Ray Servers and Clients [11]

3. Tubby-Clients

"Tubby-clients" are basically a cross between fat and thin-client systems. The main difference is that in a tubby environment, the PCs use their own processing capabilities to run most of the applications themselves but can also communicate with the server and share applications and computing capabilities. Tubby clients use a locally installed client to connect the user to the thin-client computing environment so that some or all of their applications may be utilized.[12]

4. Windows Based Terminals

Windows Based Terminals (WBT) are designed to allow the user to execute some applications, such as multimedia programs, locally at the client rather than on the server alone. These terminals are designed to coincide with the Windows Operating System (OS) and other Windows software products. There are two types of WBTs used to complement the Windows OS. The first utilizes the Remote Desktop Protocol (RDP) or the Citrix Independent Computing Architecture (ICA) to display a Windows virtual

[11] Lawrence J. Brachfeld (2001, August). *Network centric computing: a new paradigm for the military?*, p. 19. STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

[12] Barrie David (2002, March 27). Thin client benefits. ThinClient.net, p. 5. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

environment onto the user's screen. The second type of WBT shows Windows applications in a specialized proprietary operating environment designed specifically for that client with the use of an ICA such as Linux.[13]

5. Low Spec PCs

Low-spec PCs are simply older personal computers that are configured with the bare minimum components necessary to run very few basic applications. This solution is based upon the fact that thin-client network "clients" run only a few small applications themselves.[14] Therefore, it is easy to turn the older and modestly configured computer into a basic terminal through which the user can access the network server's processing capabilities and mass data storage files.

6. Internet Terminals

Internet terminals are "dumb terminals" embedded with a web browser with which the user can access the internet and view information directly from the client. Web-mail or e-mail may also be accessed and used via this configuration.[15]

7. Disabled PCs

Disabled PCs are simply standard personal computers with disabled or removed floppy disk drives and/or CD ROMs. They are configured to perform thin-client tasks on the network and do not allow the user to input new programs or load new applications onto the workstation.

---

13 Kenneth J. Landry (2006, June). The performance and compatibility of thin-client computing with fleet operations, p. 8.

14 Krysztof K. Felisiak & Pavel S. Grunt (2006). Evaluating thin-client computers for use by the Polish Army. Naval Postgraduate School thesis, p. 7.

15 Tom Sheldon (2001). Thin clients. In Encyclopedia of Networking and Telecommunications [Web]. Mc Graw-Hill. Retrieved March 14, 2007, from http://www.linktionary.com/t/thin_client.html.

8. Blade PCs

Blade PCs are computers that are arranged in a central bank. Each station is connected to a remote terminal on the network. The maintenance is centralized and communication between the terminal and computer is done via thin-client operating principles.[16] Under the Blade PC architecture, the PCs are utilized as individual "high-density" servers that are maintained in a central location where a "manager server" performs load balancing between them to optimize resource allocation and efficiency. This technology is primarily used for the purpose of clustering, which is the process of connecting many low-cost computers to be used as one larger computer.[17]

A Blade PC user's monitor, keyboard, mouse and other peripherals are connected to a connection device on the desktop which in turn connects to the Blade PC itself through the network using standard CAT-5 cables.[18] The main goal behind this configuration is to better enhance and maintain the security and manageability of the desktop environment. For example, the updates, fixes, and patches that once plagued the IT professional, who had to install them on each individual PC, can now be implemented in the central data center. This also reduces network or workstation downtime as well as decreased software and labor costs. Furthermore, the user's physical environment is a quieter one without the whirring noise of the desktop PC's loud internal fan.

C. ADVANTAGES AND DISADVANTAGES OF THIN-CLIENT NETWORK USE

To properly gauge the feasibility and costs versus benefits of implementing a shipboard thin-client network, it is necessary to identify both the advantages and disadvantages associated with thin-clients themselves. There are many benefits for using thin-client computers. The most recognized is its lower total cost of ownership (TCO).

---

16 Becta ICT Research, (2006, November). Thin client technology in schools: case study analysis. Retrieved March 13, 2007, from Becta Government and Partners Web site: http://partners.becta.org.uk/index.php?section=rh&catcode=_re_rp_ap_03&rid=11414.

17 Kenneth J. Landry (2006). The performance and compatibility of thin-client computing with fleet operations. Naval Postgraduate School thesis, p. 9.

18 Krysztof K. Felisiak & Pavel S. Grunt (2006). Evaluating thin-client computers for use by the Polish Army. Naval Postgraduate School thesis, p. 8.

TCO includes all costs, both hard and soft. Hard costs include capital costs involved in the procurement of the system's hardware as well as its software and licensing costs. Soft costs are a bit more intangible and include downtime and training costs. Hewlett-Packard's thin-client website describes an 80% reduction in maintenance performed per year, a 34% reduction in maintenance costs and a 25% savings in capital costs after switching from a PC-based fat-client network to a thin-client network.[19]

80% less maintenance per year

25% capital cost savings

34% less in maintenance costs

23% less to operate

25% productivity increase

*Source: Zona Research, Intelliquest, META Group Study[20]

Figure 2. Hewlett-Packard Thin-Client Total Cost of Ownership Savings Compared to a Standard PC

The most commonly acknowledged concern with a thin-client network is its limited abilities in multimedia presentation and a general resistance by the general public to change. These pros and cons will be discussed further in the paragraphs to follow.

1. Advantages of Thin-client Network Computing

a. Lower Administrative Costs

The lower IT administration costs associated with thin-client networks is a major benefit of their use, since the program applications and system software are all managed by the system server and its IT managers. Therefore, the hardware has fewer points of failure and the local environment is restrictive so it is safe from malicious lines

19 Why buy thin clients? Hewlett-Packard. Retrieved April 5, 2007, from: http://h20331.www2.hp.com/hpsub/cache/295747-0-0-225-121.html.

20 Ibid.

of code that could devastate the systems security. Since software is only loaded onto the server, the IT professionals avoid the time costs it would take to update individual workstations and thus they are freed up to work on other tasks.

According to representatives from Sun Microsystems, Sun reported a reduction in their IT department from about 3,800 IT technicians to only 400 after implementing TCNs throughout the company in 2001. The remaining IT personnel manage the servers for the whole company. Problems that are encountered with the thin-client terminals at each individual office site are corrected by non-technical personnel by simply removing the defective Sun Ray client and replacing it with a new unit. The unique “plug-and-play” characteristic of the Sun Ray thin-client allows even the most novice user to take immediate corrective action to his or her system without losing valuable production time while their workstation is down awaiting repairs as is the case with most PC-based networks. The savings in time and manpower are significant and remain one of the top reasons for thin-client systems’ recent growth in popularity amongst computer systems in the business world today.

b. Improved Security

Thin-client networks are inherently more secure since no application data exist on the client itself. This design prevents users from adding un-screened programs and applications that could have some malicious lines of code with or without the knowledge of the user. Since the system is designed to keep information on the server, sensitive data are less vulnerable and are not lost if a terminal is lost, broken or stolen. If security programs or applications need to be updated, the new software is installed only on the central servers, not the individual PCs scattered throughout the network as is the current practice. According to Bob O’Dell, an analyst for the research firm International Data Corporation (IDC), “People have recognized if you start to centralize this stuff and more tightly manage it, you can reduce your cost and reduce the security-related issues, because you have fewer things to monitor.”[21]

---

21 Christopher Lawton (2007, January 30). 'Dumb terminals' can be a smart move; computing devices lack extras but offer security, cost savings. The Wall Street Journal, p. B3.

Although no system can be completely immune from attacks and viruses, having a centralized level of control contributes greatly to the security of the network. The lack of floppy drives or CD-ROMs prevents data from being copied and taken elsewhere or corrupted by outside systems. This design also keeps unwanted or unsafe applications from being loaded onto the system.[22]

c. Lower Hardware Costs

The minimal hardware cost of a thin-client terminal is yet another reason for the growing popularity of thin-client networks. Because thin-clients do not contain disks within them, their costs are very low. For example, the average Wyse thin-client costs about $280, not counting the cost of the flat panel monitor, which itself costs about $170.[23] When one compares this to the retail price of an average office PC tower (not including the monitor), $1,800, it is plain to see that a firm could purchase a thin-client workstation's hardware for about one quarter of the price for one PC workstation.

Another cost benefit of thin-clients is the fact that unlike the standard PC, which has to be replaced at the very latest every five years, a much longer time can pass between thin-client upgrades or replacements since the IT professional need only to update the server, not individual workstations. This is so because a thin-client system utilizes the server's central processing unit (CPU) to do the vast majority of the processing and calculations required by the user rather than the fat-client station whose CPU does all of the processing but actually remains idle 70% of the time in a given twenty-four hour period.[24] This is not only a waste of resources and underutilization of processing capacity; it is also a waste of electricity.

Jack Wilson, enterprise architect for Amerisure Mutual Life Insurance Company, projected a potential savings of a $3.6 million over the course of six to nine years by not having to "refresh" or replace the 750 networked computers in eight offices

---

22 Barrie David (2002, March 27). Thin client benefits. ThinClient.net, p. 8. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

23 Thinstore. Retrieved April 1, 2007, from: http://www.thinstore.net/.

24 Condor High Throughput Computing. Idle Machine Statistics. Retrieved: April 22, 2007 from: http://www.cs.wisc.edu/condor/goodput/idle.html.

every three years at an expected cost of $1.2 million each time. He states that he can now bypass two or three refreshes before having to upgrade again. These savings alone are significant enough to Wilson to make the project of replacing his PCs with thin-clients very much worthwhile.[25]

d. Lower Energy Consumption Costs

The energy savings of a thin-client terminal over a PC is yet another strong argument for its use. For example, the Wyse 8230LE model thin-client unit itself draws only 8 Watts of power during a session and only 93 Watts with a standard desktop Cathode Ray Tube (CRT) monitor. With the use of a Liquid Crystal Display (LCD) monitor the power consumption is even less. Compare this to the whopping 170 Watts of power drawn by the standard desktop PC with a CRT monitor.[26]

n*p*h*52 = the number of kWh your client computers use each year where:

n is the number of desktop devices

p is the power (in kilowatts) used by each device

h is the number of hours each week that the devices are turned on

52 is the number of weeks in a year

Figure 3. Annual Energy Consumption Formula[27]

For example, suppose there were 100 personal computers on a network consuming 170 Watts of power each. If these clients are powered on 55 hours in a given work week and the price for electricity is $0.25 per kilowatt-hour, then the total energy cost for the network per year would be $12,155 (100*0.17*55*52*$0.25). Compare this to the power consumed by the same network configured with the same number of Wyse

---

25 Christopher Lawton (2007, January 30). 'Dumb terminals' can be a smart move; computing devices lack extras but offer security, cost savings. The Wall Street Journal, p. B3.

26 Steve Greenberg & Christa Anderson (2001, September). Desktop energy consumption; A comparison of thin clients and PCs. Wyse Technology. Retrieved April 1, 2007, from: http://www.wyse.com/resources/whitepapers/energy.asp, pp. 6-8.

27 Ibid, p. 15.

8230LE thin-client units which consume only 93 Watts apiece and the total cost falls to $6,649.50 (100*0.093*55*52*$0.25). This results in a significant net savings of $5,505 per year in energy costs alone! It should also be noted that these costs would be even lower with the use of flat panel monitors. Using a flat panel monitor that consumes 35 Watts of power (Dell UltraSharp 1708FP)[28] would total 43 Watts with the thin-client. The annual cost would be approximately $3,074.50 (100*0.043*55*52*$0.25), resulting in an annual savings of $9,080.50 over the PCs and CRT monitors.

It is plain to see that the energy required to power a thin-client is significantly less than that of a PC. It can thus be inferred that using thin-clients instead of PCs will decrease the loads placed on shipboard electrical systems to support IT operations. Furthermore, this decreased load will ultimately result in fuel savings as fewer generators may be needed to run at a time to support the IT requirements along with those of the rest of the ship. This is another strong argument in support of thin-client implementation.

e. Lower Chance of Theft

Two problems that continue to plague IT departments are theft of equipment and loss of data. Because thin-clients removed from the network are virtually worthless, and contain no real memory upon which data can be stored, the chance of theft is drastically reduced. This can mean a savings in potential replacement costs for lost or stolen computers, especially laptop computers. Thin-clients have replaced laptop computers in many locations since the thin-client is not a useful item away from the thin-client network. The installation of an interface that is non-functional away from the ship or office discourages people from taking it, even if the goal was to simply use it at

28 Dell Inc., UltraSharp 1708FP flat panel LCD monitor. Retrieved April 17, 2007, from: http://accessories.us.dell.com/sna/productdetail.aspx?c=us&l=en&s=dhs&cs=19&sku=320-5294.

another location within the ship or command.[29] This is also central to safeguarding potentially dangerous information, be it matters of national security or personal information.

The recent, highly publicized security breaches with stolen laptops containing the personal information of thousands of people have increased the demand for more secure thin-client technologies and programs of centralized control. According to Natalie Lambert, an analyst with the Cambridge, Massachusetts-based Forrester Research firm:

> Of all the reasons being given by CIOs for employing new security technologies, for many the No. 1 concern is keeping their names out of the headlines that have followed high-profile laptop and computer thefts at organizations like AIG, Fidelity Investments and the U.S. Department of Veterans Affairs.[30]

With the utilization of the security benefits associated with thin-client systems, the probability of lost or stolen data or equipment is significantly minimized and mission or personnel files would be better protected from damaged hard drives and against loss or theft from dishonest personnel. This factor alone lends heavy credence and strong justification to the need for a thin-client network not only aboard ships, but throughout the entire Department of Defense.

f. Fewer Moving Parts Means Decreased Internal Dust and Increased Safety

The lack of moving parts associated with a thin-client unit is another advantage of its use. Given the sometimes dirty and dusty conditions found in a shipboard environment, especially aboard those ships that are tasked to operate in the

29 David Hancock (2006, January 3). Thin client technology enhances security. TechLINKS. Retrieved April 19, 2007, from: http://www.techlinks.net/CommunityPublishing/tabid/92/articleType/ArticleView/articleId/3503/Thin-Client-Technology-Enhances-Security.aspx.

30 Matt Hines (2006, September 25). Vendors plug thin client as security elixir. eWeek Channel Insider. Retrieved April 10, 2007, from: http://www.channelinsider.com/article/Vendors+Plug+Thin+Client+as+Security+Elixir/189624_1.aspx?kc=CZNKT03119TX1K000059.

Middle East or offshore from desert landmasses, the lack of internal fans and air intake and vents helps keep thin-client units from being clogged or damaged by atmospheric contaminants.

The clients themselves are sealed with the exception of some small air vents on the side. This design protects their internal circuitry and decreases the amount of maintenance required to keep the computers running at top notch condition. The vents prevent overheating and possibly fires in the thin-client that are more commonly found to be caused by excessive dust within standard personal computers. In addition to a savings in replacement parts and man-hours for maintenance, this is also a safety benefit that cannot be easily quantified when one considers the potential damage and injuries that can be caused by a shipboard fire.

g. Small Footprint and Lower Bandwidth Requirements

The thin-client itself takes up almost no space. The unit measures only about seven inches long and five inches wide and 1.4 inches tall, and weighs about six pounds (see Figure 4).

Physical Characteristics:	Height	1.38 inches (34mm)
	Width	6.94 inches (177mm)
	Depth	4.75 inches (121mm)
	Shipping Weight	6 lbs. (2.7kg)

Figure 4. Physical Characteristics of the Wyse S90 Model Thin-client[31]

31 Wyse Technology, Wyse S10. Retrieved April 5, 2007, from Wyse Technology Products and Services Web site: http://www.wyse.com/products/winterm/S10/index.asp.

The design tested by the authors mounted directly to the back of the 17” flat panel monitor as shown below.

Figure 5. Wyse S90 Mounted on the Back of a LCD Monitor[32]

Compared to the space required for a standard desktop PC, which has a tower cabinet in addition to the monitor, that sits either under the desk or alongside the monitor, the space (which is always at premium aboard ships) saved can be better utilized for other purposes or storage. Using thin-clients essentially reduces the footprint of the workstation to that of the monitor.

Additionally, thin-clients use less network bandwidth. Rather than clogging up bandwidth with redundant files on the LAN, PC, and printer, the thin-client’s document or program is only opened and processed at the server and then sent to the printer if necessary. In a thin-client environment, only mouse movements, key strokes, and screen updates are transmitted from one end-user to another.[33] A Microsoft Corporation study conducted by NEC and Groupe Bull showed that structured task workers are the highest bandwidth users as they generally perform the same tasks over and over again. These workers used up about 20 kilo-bits of bandwidth apiece, sending documents back and forth to different stations around the network or to the centralized network printer.

---

32 Wyse Technology, Winterm SX0. Wyse Technology. Retrieved April 5, 2007, from: http://www.wyse.com/products/winterm/S30/BackMount.htm.

33 Barrie David (2002, March 27). Thin client benefits. ThinClient.net, p. 6. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

A study of a 130-user tubby-client network in the United Kingdom yielded the following results in regards to bandwidth consumption:

	Average bandwidth utilisation	Peak bandwidth utilisation
Fat Client	40%	80%
Tubby Client	0.5%	4%

Significant bandwidth issues were being encountered during peak periods prior to the thin-client computing deployment. These figures are consistent with the Microsoft study.

Table 1. Average Bandwidth Use by Client Type[34]

The table above shows that the bandwidth used by tubby clients is less than that of fat clients. The bandwidth consumption is even less for a thin client network and the net effect is that far less bandwidth is needed and used by each user to support routine daily operations and will likely result in lower server costs and LAN sizes since not as much speed in megabytes per second (Mbps) will be needed and a less expensive LAN will be required to accommodate increased file transfer needs and e-mail storage.

h. Easy Upgrades with Little or No Network Service Interruptions

Capacity can be added to the server without taking down the entire system or each individual client. The fact that all the programs and applications reside on the server allows the system to be updated all at once rather than going PC to PC to install the latest software upgrade. Since users cannot load software, the organization is left with a standard set of tools that is easier to maintain in a more stable network environment. Mr. Wilson, from Amerisure, also reports that his trouble calls for the system have decreased 35 to 40 percent since his shift to the thin-client environment.[35]

---

34 Barrie David (2002, March 27). Thin client benefits. ThinClient.net, p. 7. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

35 John Dix (2006, October 20). The benefits of thin clients. Network World. Retrieved April 5, 2007, from: http://www.networkworld.com/columnists/2006/102306edit.html.

Furthermore, upgrades to a thin-client network are more efficient than those of a thick-client environment. Since everyone gets the updates at the same time, there is no need for different workstations to run different versions of the application in question for days or weeks while the IT division or LAN managers update each individual computer.[36] This improvement allows the frequently overtaxed IT division personnel to devote their time to troubleshooting real problems with the network or conducting preventive maintenance on shipboard systems for which they are responsible.

2. Disadvantages of Thin-client Networks

a. Increased Server Requirements

One issue for consideration regarding thin-client implementation has to do with the performance level of the servers required to run a thin-client network environment. Because thin-client systems require a higher level of performance from their servers, a higher grade server will be needed since it will do almost all of the processing.

Contributing to this issue is the fact that server performance in a thin-client environment is sometimes difficult to measure due to the very nature and function of servers in a thin-client system. Since the server does all of the processing rather than the client, the application executes on a server machine and then sends its output over the network to display on the client machine. The output display may be completely separated from the application processing on the server without concern for whether or not the application's output has been displayed on the client.

Additionally, the display updates for the application may be merged with other data or even dropped in some systems to conserve network bandwidth. Because the server processes all application logic in thin-client systems, standard application benchmarks effectively measure only server performance and may not coincide with or accurately reflect the performance as perceived by the user. Furthermore, since many

[36] Barrie David (2002, March 27). Thin client benefits. ThinClient.net, p. 9. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

thin-client systems such as those made by Citrix, Tarantella, and Microsoft are proprietary and source data are not available to the public, it is difficult to accurately measure their performance with instrumentation in order to get reliable and repeatable results.[37]

This may prove to be an expensive ordeal if it turns out that the servers currently in service aboard ships are insufficient to handle such an endeavor. The friction from the Armed Services and/or Appropriations committees in terms of funding such a project would be both expected and understandable as the average server currently in-use aboard medium-sized ships is $19,245 and is likely to be less than five years old.[38] Careful, further analysis of this issue is needed before a qualified recommendation can be made.

b. Poor Multimedia Application Performance

Another concern with thin-client is its lack of performance with media rich applications, especially those that are web-based. A 2006 Becta Corporation study of twelve schools in England examined the performance of thin-client computer networks in an intermediate school learning environment. The study found that all of the schools studied experienced difficulties with delivering the full range of multimedia applications over their thin-client networks. In fact, eleven of the twelve schools retained their "fat-client" computer networks to enable the staff and students, particularly those in music, design and technology, to use the multimedia applications that were unable to run on the thin-client network.

Some schools were able to deliver specific applications but found that if too many students used the application at the same time, the network performance slowed significantly. Some schools were able to work around this limitation by setting limits to

[37] Albert M. Lai & Jason Nieh (2006, May). On the Performance of Wide-Area. *ACM Transactions on Computer Systems*, p. 24. Retrieved April 5, 2007, from http://portal.acm.org/citation.cfm?doid=1132026.1132029.

[38] Cost for Hewlett-Packard DL385G1 server taken from Program Manager, Warfare (PMW) 160 CANES Lite Cost Model Excel spreadsheet provided by Science Applications International Corporation on April 12, 2007.

the numbers of users accessing the multimedia package at any one time, to avoid overburdening the server and network. Video conferencing also was impractical and needed to be conducted via a separate system for proper operation.[39]

c. *Lack of Compatibility With Some Applications and Need for Improvements in Thin-Client Network Management Software*

While almost all Windows programs are compatible with thin-client networks, problems with multimedia applications running on TCNs have been documented. The severity of the limitation with video varies from one brand of thin-client to another. Larger problems were encountered and documented with trying to run non-Windows applications, especially DOS-based programs, on thin-client networks. Research found that some of the older software that could not run on thin-client networks would not even run on standard PC-client networks without loading it on the PC itself. Generally speaking, thin-clients are not compatible with pre-Windows software.

Newer thin-clients such as the Wyse S90 come with an embedded Windows XP operating system built into the client which serves mainly as a conduit for initial program start/boot and for connecting to the server during a Remote Session. An issue noted with this model is that the embedded operating system requires periodic updates. This diminishes one of the main attributes associated with thin-client computing, decreased administration and maintenance. The HP Compaq †5000 series models of thin-clients come with Altris Deployment Solution software which allows network administrators client management and deployment capabilities using an industry standard software package. The Altris Deployment Solution is standard management software for most HP business devices such as PCs, thin-clients, and servers. This is helpful for those IT managers already running HP PCs on their networks, but not much good to those who have been running different types of PCs prior to the shift to HP

[39] Becta ICT Research, (2006, November). Thin client technology in schools: case study analysis. Becta Government and Partners, pp. 6 & 23. Retrieved March 13, 2007, from: http://partners.becta.org.uk/index.php?section=rh&catcode=_re_rp_ap_03&rid=11414.

clients.[40] During his thesis work during the spring of 2006, U.S. Navy Lieutenant Kenneth Landry also found that some thin-client management software was not as mature and reliable as standard PC network management software, specifically the PC Expanion Model L100. The management issues he encountered ruled out the Expanion as a viable option for thin-client computing in the Navy. An improvement in thin-client network management software is needed to facilitate a smoother implementation into popular use.

d. Resistance to Change

It is only natural that there will be a certain amount of skepticism, resentment, and unwillingness to change among the users of a system with which they are familiar. The user who has become quite comfortable with his or her setup and use of their PC will likely loathe the idea of having limited access and control over data and applications.

End-users' perceptions will greatly affect their attitude toward thin-client implementation since traditional PC users will be much more resistant to move to a thin-client network.[41] Users will not like the idea of not being able to play their favorite music compact discs (CDs) or MP3s, access a floppy disk drive or install their own personal software onto their computer (authorized or not) as they have done in the past on PCs.[42] The users will also probably not like the idea of not being able to save work on a CD or floppy disk and continue working from home on their own PC as is so commonly the custom these days.

e. Single Point-of-Failure Requires a Full Back-Up Server

Server availability in a thin-client environment will have a significant impact on end-user downtime. Since all of the users on the network share the same

[40] Hewlett-Packard Development Company, (2004, January). Thin client server computing: Benefit analysis. Hewlett-Packard, p. 14. Retrieved March 18, 2007, from: http://h20202.www2.hp.com/Hpsub/downloads/HP%20-%20TC%20TCO%20Jan%2004.pdf.

[41] P. Lowber (2001, September 28). *Thin-Client vs. Fat-Client TCO*. Gartner Group, p. 4.

[42] Kenneth J. Landry (2006). The performance and compatibility of thin-client computing with fleet operations. Naval Postgraduate School thesis, p. 34.

server, a single point failure could have a large impact on multiple end users of the system. This suggests that some type of back-up system or plan is needed in case of a server failure. Building a fault tolerant system that provides the required amount of downtime assurance will most definitely increase the overall cost of the system in terms of both hardware and software.[43]

The additional hardware costs are substantial and come in the form of the necessity for an entirely separate yet equally powerful backup server which will contain all of the same applications and data as the primary server. Backups from the primary server to the backup server would be required daily, at an absolute minimum. This would ensure that a catastrophic failure to the main server did not result in downtime of the system or much re-work/lost data for the end users.

The additional software costs come in the form of additional licenses for software applications that are to be loaded onto the secondary server. This may prove to be rather expensive if multiple licenses are required for the different applications that are to be loaded onto the secondary server.

D. CHAPTER SUMMARY

This chapter explained the history of network centric computing and described the different types of clients that are used in local area network computer systems as well as the advantages and disadvantages of thin-client networks.

The first thin-client type of computer network systems that were developed in the late 1970s used “dumb terminals” that were basically a means by which input could be entered into the central server and output from operations could be displayed for the user. The development of the personal computer in the early 1980s led to the creation of thick-client networks where users could use their own desktop PCs to do the majority of the calculations and processing necessary to complete their work. The server in the fat-client network became more of a process and flow control device than the main processor as it had been in previous networks that used the dumb terminal configuration. Thin-client

[43] Chris Haddad & Doug Simmons (2004, December 22). *Thin Client Architecture Study*, p. 71.

networks regained popularity in the 1990s as life cycle costs and the total cost of ownership of PCs grew. Thin clients offer a lower TCO and require less maintenance than their PC counterparts since all calculations and processing is conducted by the network servers vice the clients themselves.

There are eight different types of clients available in network computing. They are: fat-clients, thin-clients, thick or tubby-clients, Windows Based Terminals (WBTs), Low-Spec PCs, Internet Terminals, Disabled PCs, and Blade PCs. The characteristics and attributes of each type of client were described in this chapter.

Also discussed were the advantages and disadvantages of thin-client networks. The advantages described were: lower TCO, lower administrative costs, improved security, lower hardware costs, decreased energy costs, lower chance of theft, fewer moving parts/increased safety, smaller footprint and lower bandwidth use, and ease of upgrades with limited network downtime. Disadvantages of thin-client networks described in this chapter included: increased server requirements, poor multimedia application performance, a lack of compatibility with a small number of applications and a need for improvement in thin-client network management software, a general resistance to change by those who are already used to the standard thick-client LAN configuration, and single point of failure that is inherent in a centralized server-based network which creates the requirement for an additional server or servers to prevent lost data or network interruption.

The following chapter will discuss the different types of current and proposed shipboard networks used in the Navy today as well as discuss previous thin-client networks that have been installed and tested aboard Navy surface ships in the past decade.

III. CURRENT AND PROPOSED SHIPBOARD NETWORKS

A. CURRENT SHIPBOARD NETWORKS

1. Integrated Shipboard Network System

The Integrated Shipboard Network System (ISNS) is a program that is a derivative from the common elements that make up a number of other Programs of Record (POR) to provide the Fleet with reliable LANs on all Navy ships. The ISNS is capable of supporting all classifications of information technology including Special Compartmentalized Information, Top Secret, Confidential, General Service (GENSER), NON-U.S. and Unclassified. The ISNS program uses a combination of hardware components such as network switches, routers, hubs, servers, PCs and COTS network software applications to implement the networks aboard ships and provides the capability for connectivity to the Defense Information Systems Network (DISN) Wide Area Network (WAN) for access and dissemination of information around the globe.[44]

Furthermore, ISNS provides individual fleet units with the capability to disseminate information internally. ISNS provides the infrastructure for all Command, Control, Communications, Computers and Information (C4I) which facilitates the implementation of the Navy's IT21 plan and is the primary enabler for network centric warfare. IT21 related programs such as Naval Tactical Command Support System (NTCSS), Global Command and Control System – Maritime (GCCS-M), Voice-Video-Data (VVD) are provided a transport medium for web applications through ISNS architecture. ISNS networks support the many requirements for information processing in order to achieve "Sea Power 21" capabilities as well as establishing the backbone for information sharing and interoperability with coalition forces and joint operations. ISNS

[44] Requirements to capabilities (2004). Retrieved April 29, 2007, from Vision Presence Power: A Program Guide to the U.S. Navy – 2004 Edition, p. 128. Web site: http://www.chinfo.navy.mil/navpalib/policy/vision/vis04/vpp04-ch3.pdf.

installations are in the process of implementing the Gigabit Ethernet (GigE) architecture and current funding plans place procurement and installation funding for full operational capability by Fiscal Year 2012.[45]

2. Special Compartmented Information Automated Digital Network System

The Special Compartmented Information Automated Digital Network System (SCI ADNS) is an internet protocol (IP) – capable, network-centric, automatic communication system that is designed for real-time transmission and reception of Special Intelligence (SI) and Sensitive Compartmented Information (SCI) while maintaining information assurance (IA) computer security requirements. SCI ADNS provides a secure and reliable means of IP communications for sensitive information systems such as those supporting cryptologic, intelligence, and information operations (IO). These systems, which support the strike group commanders, include functions such as direction finding (DF) data transfer, e-mail, record messaging, chat, web browsing, and file transfer.

SCI ADNS uses open architecture standards, so it fits with and is an important component to the Navy's continuously evolving concept of network-centric warfare. Its evolutionary nature allows for constant growth and expansion through future technology insertion and it gives the Navy a mechanism to implement planned improvements as well as those that come about through advances in technology and lessons learned through the its use. SCI ADNS uses a combination of COTS, GOTS, NDI and existing systems to meet the requirements of SI communications. Full capability includes voice, video, and data transfer from ships and submarines to shore nodes via gateways within the network.[46]

[45] Requirements to capabilities (2004). Retrieved April 29, 2007, from Vision Presence Power: A Program Guide to the U.S. Navy – 2004 Edition, p. 128. Web site: http://www.chinfo.navy.mil/navpalib/policy/vision/vis04/vpp04-ch3.pdf.

[46] Ibid, pp. 136-137.

3. Combined Enterprise Regional Information Exchange System

The Combined Enterprise Regional Information Exchange System (CENTRIXS) is a global data network enterprise for U.S. and coalition forces use to share and disseminate operational and intelligence information and data from one region to another to facilitate better combined planning, decision making superiority and unity of effort in peacekeeping and contingency operations. The system is designed to meet the Combatant Commander's (COCOM) requirement for daily information sharing between the U.S. and its foreign allies and multinational partners. It possesses multiple network capabilities such as voice, data, and video transmission and reception.[47]

Figure 6, on the following page, illustrates how information is shared between different U.S. shore and at-sea commands and other allied nations' forces around the world. It is important to point out that in Central Command (CENTCOM), there are three global and three regional, completely separate networks established to separate information flow from coalition partners who may not desire any or all of its information to be shared by another member of the coalition. Each network is built on the same enterprise standard, but cannot be interconnected to another network. The separation of networks is required to prevent inadvertent release of data to nations that are not part of a specific set of information sharing arrangements.

[47] Jill L. Boardman & Donald W. Shuey (2004, April). *Combined enterprise information exchange system (CENTRIXS); supporting coalition warfare world-wide*, p. 10. Retrieved May 1, 2007 from Air Force University Web site: http://www.au.af.mil/au/awc/awcgate/ccrp/centrixs.pdf.

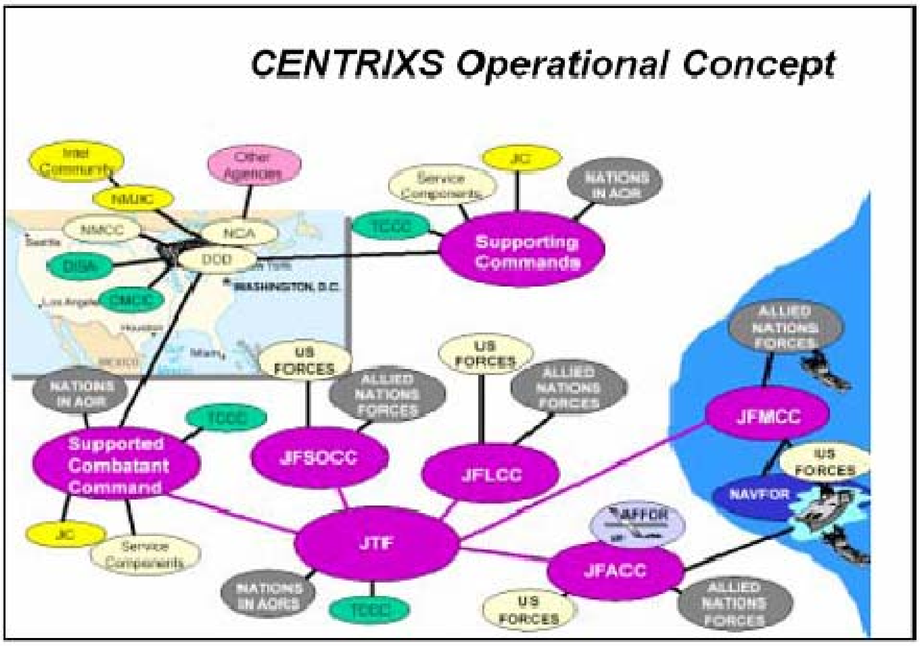

Figure 6. Operational Concept for CENTRIXS Use with U.S. and Allied Forces [48]

CENTRIXS was initially envisioned in 1999. The primary objective for multinational information sharing is to maintain shared, timely, common pictures of the battlespace with U.S. allied and coalition partners. Time is of the essence in today's hi-tech world and critical information is needed in the least amount of time possible. Time-critical information for combined operations includes: operations and intelligence information for threat assessment and battlefield awareness; theater ballistic missile defense; mission requirements for a smoother coordination and integration of coalition forces; nuclear, biological and chemical (NBC) threat warning; battlefield campaign assessment data; regional civil and military air traffic control and movement scheduling; force disposition; and combined force threat response data.

The expansion of the Global War on Terror (GWOT) and Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF) led to the accelerated development and deployment of CENTRIXS in the U.S. Central Command's (CENTCOM's) area of responsibility (AOR) since the global nature of the war on terror demanded that

[48] Jill L. Boardman & Donald W. Shuey (2004, April). *Combined enterprise information exchange system (CENTRIXS); supporting coalition warfare world-wide*, p. 7. Retrieved May 1, 2007 from Air Force University Web site: http://www.au.af.mil/au/awc/awcgate/ccrp/centrixs.pdf.

CENTRIXS shift away from the originally "regional" network area and move toward a global sharing initiative. The expansion of the GWOT led to additional gateways in the U.S. Pacific Command (USPACOM), U.S. Southern Command (USSOUTHCOM) and U.S. European Command (EUCOM). Figure 7 illustrates the concept of worldwide coverage of the CENTRIXS system of networks and information sharing with U.S. allies and coalition partners.[49]

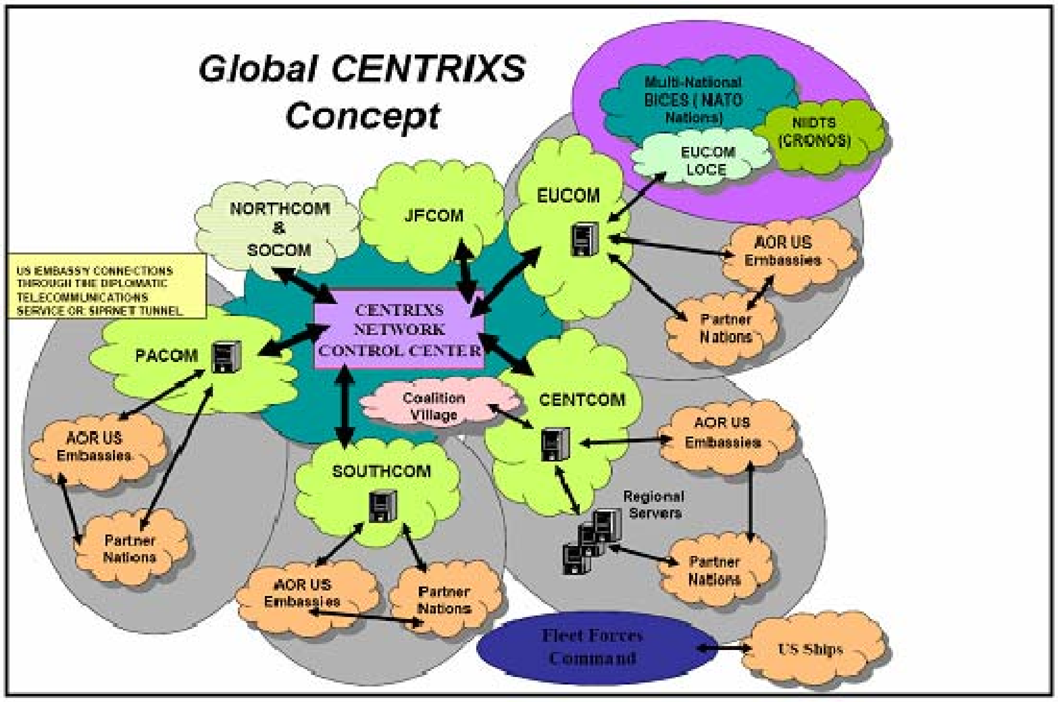

Figure 7. Overview of CENTRIXS Use with Multi-National Coalition Forces[50]

CENTRIXS is currently being used onboard ships at both the force and unit levels. The thin-client work stations used are Sun Ray 1g Virtual Display Clients. The system uses Sun Fire B240 session servers and Sun Fire B120 master session servers. On force level ships, two session servers and one master session server are used. In June 2006, SPAWAR conducted a series of system integration testing (SIT) of the

[49] Jill L. Boardman & Donald W. Shuey (2004, April). *Combined enterprise information exchange system (CENTRIXS); supporting coalition warfare world-wide*, p. 6. Retrieved May 1, 2007 from Air Force University Web site: http://www.au.af.mil/au/awc/awcgate/ccrp/centrixs.pdf.

[50] Ibid.

CENTRIXS-Maritime (CNETRIXS-M) Block II using Sun Ray ultra-thin-clients and Sun Fire servers. The servers were connected to an external network and were rack accessible via a secure KVM (keyboard, video, and mouse) switch.[51] A KVM switch is a hardware device that allows a user to control multiple computers from a single keyboard, video monitor and mouse. Although multiple computers are connected to the KVM, typically a smaller number of computers can be controlled at any given time.

In the summary of results, the team determined that trusted Solaris, UTC, Common PC Operating System Environment COMPOSE 3.0 (a software suite used by the Fleet for basic office as well as other applications that will be described later in Section IV.A.1.), and CENTRIXS-M overlay applications that were tested against loaded Block II servers had no adverse affects on the system. Furthermore, only a few minor issues with software applications were noted with thin-client use and all were resolved with relatively little difficulty.[52]

B. PROPOSED SHIPBOARD NETWORK SOLUTION

The proposed next-generation shipboard network to be fielded to the fleet is the Consolidated Afloat Networks and Enterprise Services (CANES). CANES Increment 1 will provide the next addition of ISNS capability to include wireless network support, internal and external to the ship (for Expanded Maritime Intercept Operations); disk to disk back up; and increased security. The spaces considered for wireless network drops are common spaces such as: mess decks, berthing compartments, wardroom, training classroom, library, etc. CANES Increment 2 incorporates ISNS, CENTRIX, and SCI networks all under one program.[53]

CANES-equipped ships will also benefit from a new type of electrical power distribution known as Power-Over-Ethernet (POE). POE describes a system that can

[51] Central Design Authority Team and Integration Test Facility, SPAWAR System Center, San Diego, (2006, June 21). *System integration testing (SIT) for Combined Enterprise Regional Information Systems - Maritime (CENTRIXS – M): Block II with MLTC v3.0*, p. 2-3.

[52] Ibid, p. 1-1.

transmit electrical power as well as data to remote devices via a standard twisted pair cable in an Ethernet network. This technology is useful for voice-over-IP telephones, wireless LAN access points, Ethernet hubs, webcams, and other devices where it would either be too expensive or impractical to supply power separately. POE eliminates the need for running cables for both data and power to each device on the network and it protects information technology assets since it is both backward and forward compatible with other Ethernet protocols. An attribute of a POE system is that it reduces infrastructure and rack requirements since network devices can be installed and re-located to where performance is optimal without the need for an existing AC power outlet.[54] According to SAIC/Program Manager, Warfare (PMW) 160 Engineer, John Sahlin, during a tour of the San Diego facility on 12 April 2007, POE will reduce the cost of fielding workstations by reducing the approximately $5,000 per network drop cost of installing power outlets. POE is expected to be fielded in 2008. Figure 8 shows an example of what the power sourcing equipment and powered devices that supply and retrieve electrical power from an Ethernet cable may look like.

Figure 8. A POE injector (which puts electrical power into the Ethernet cable) and a POE power splitter (which draws electrical power from the cable).[55]

[53] Program Manager, Warfare (PMW) 160, (2006, June 20). Financial management and cost estimating support performance work statement White Paper, p. 2. Retrieved May 4, 2007, Web site: http://www.anteon.com/seaport/document/879__39_Attachment_(1)_PWS_-_FINAL_-_6-20-06.doc.

[54] Panduit Corporation (2007). Power over ethernet (PoE): Technology primer and deployment considerations. Retrieved May 5, 2007, from Power Over Ethernet (PoE) Web site: http://www.panduit.com/enabling_technologies/098749.asp.

[55] Ibid.

C. THIN-CLIENT NETWORKS PREVIOUSLY FIELDED ON U.S. NAVY SHIPS

1. Network Centric Computing

Network Centric Computing (NCC) architecture is the name given to the network structure that allows users access to multiple applications through the use of multiple servers. The NCC approach to computing is designed to make information processing faster, easier, and more affordable. This architecture's delivery of applications is accomplished by the network allowing servers to run applications for multiple users including Windows-based, Unix-based, and Web-based programs. Thus, run-time environment limitations are kept only to the servers and are not passed on to all clients within the network. The clients are thin or ultra-thin and are not dependent on any specific operating system or hardware.

The clients receive high levels of service because all of the applications are available over the network architecture's redundant array of application servers, which can be accessed at any ultra-thin-client (UTC) on the network utilizing the user's common access card (CAC), also known as a "smart card". The user can move from one UTC to another without logging out or having to transfer or save work to a floppy disk or thumb-drive. There is no wait and no boot-up. Instead, the user's profile and work reappears on whatever workstation to which he or she moves and they see the exact same screen and work as they did on their previous client. The user is immediately connected to the server of their choice and can access all of the programs and applications and files as they were at the time of the user's last log-off. This makes sharing work simple since instead of having to save his or her work or bogging down the email system to send the boss a file upon which they were working, they need only insert their CAC into the boss's client and log back into the system, and their work can be easily viewed and edited right there.[56]

[56] Lawrence J. Brachfeld (2001, August). *Network centric computing: a new paradigm for the military?*, p. 3. STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

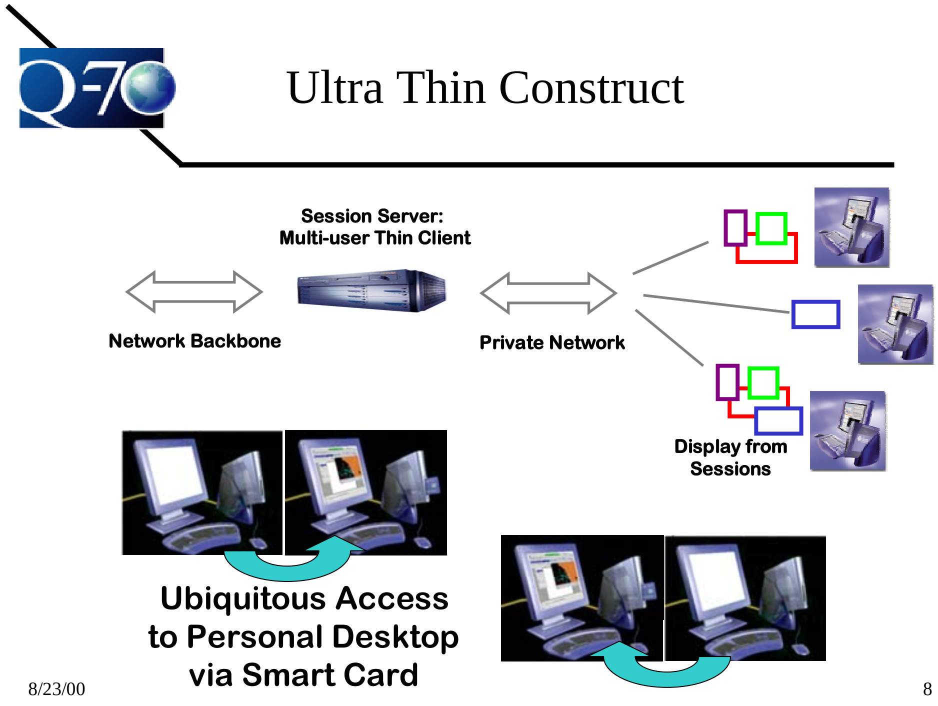

Figure 9. UTC Construction and User Mobility Illustration[57]

2. USS *Coronado* (AGF-11)

In 2000, SPAWAR PD-13 and the Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems worked together on a collaborative effort to provide a network-centric solution for the AN/UYQ-70 Advanced Display System. During the course of the project, the team developed a prototype ultra thin-client network with NCC architecture and installed it onto the USS *Coronado* (AGF-11) Sea-Based Battle Lab for an operational assessment prior to the ship's decommissioning in February 2005. The system proved itself to be quite compatible with the IT-21 Integrated Shipboard Network System (ISNS) LAN. The ship was initially outfitted with twenty-seven ultra thin-client stations and was later upgraded to 54 UTCs with access to the ISNS "backbone," which provided e-mail and standard office application functions as well as access to the Global Command and Control System –

[57] SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, (2000, August 23). *Network-centric computing: The network centric Q-70.* p. 8.

Maritime (GCCS-M). It was also slated to be compatible with future systems such as GCCS-A and Theater Battle Management Core Systems at the time it was installed. The illustration below, Figure 10, demonstrates the layout of the NCC architecture and shows how the use of clustered network and application servers allows the display information to be pushed out onto the user's client or workstation.[58]

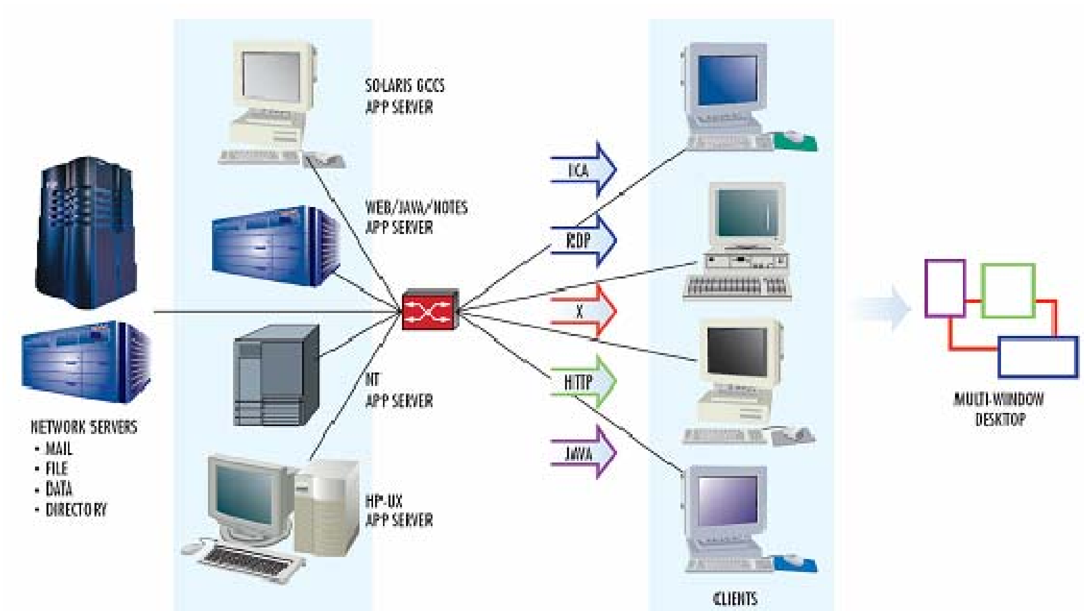

Figure 10. NCC Architecture and information distribution and display[59]

The illustration in Figure 11 shows an example of the type of clients used onboard *Coronado* and compares it to the traditional PC-LAN architecture's workstation. Note the UTC's ability to communicate and perform functions with all applications available within the server cluster described above, all from the same workstation. This design adds great utility to the thin-client solution for computing since a single client can perform any function the user desires and is able to access the central servers.[60]

---

58 SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, (2000, August 23). *Network-centric computing: The network centric Q-70*, p. 8.

59 Ibid, p. 8.

60 Lawrence J. Brachfeld (2001, August). *Network centric computing: a new paradigm for the military?*, p. 5. STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

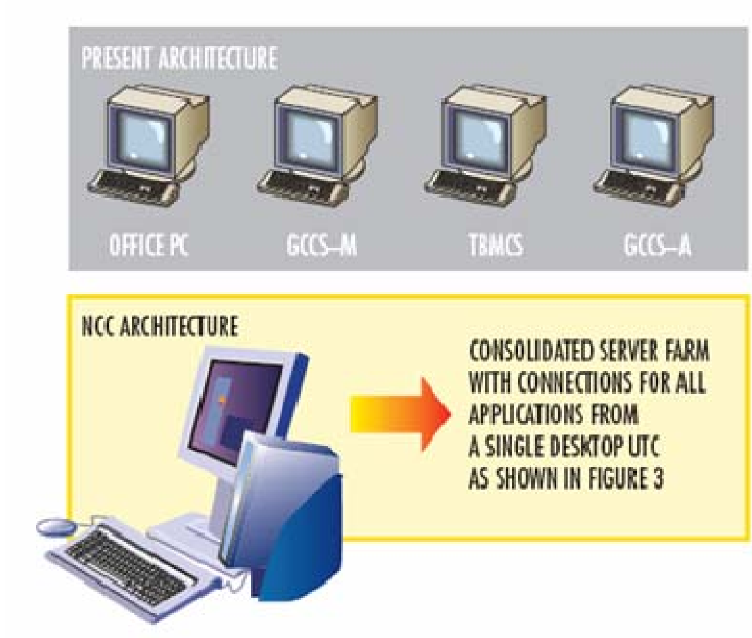

Figure 11. Comparison of NCC Desktop Environment Using PCs and Using UTCs[61]

The initial configuration consisted of two server racks, each containing two Compaq 1850R dual Pentium Windows application servers, one NT server and one main server. As illustrated in Figure 12, the Windows NT server rack possessed dual CPUs, 1GB of RAM, a CD-ROM, an 18GB hard disk drive and a 4mm Digital Audio Tape (DAT) drive for data backup use. The main server rack contained a Sun Microsystems E4500 with four CPUs, 2GB of RAM, a 9GB hard drive, a 4mm DAT, and a CD-ROM. Both racks also contained a Sun Ultra 80 GCCS application server with dual 450MHz CPUs, an 18GB hard drive, and 1,024 MB of RAM.[62]

[61] Lawrence J. Brachfeld (2001, August). *Network centric computing: a new paradigm for the military?*, p. 5. STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

[62] SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, (2000, August 23). *Network-centric computing: The network centric Q-70*, p. 5.

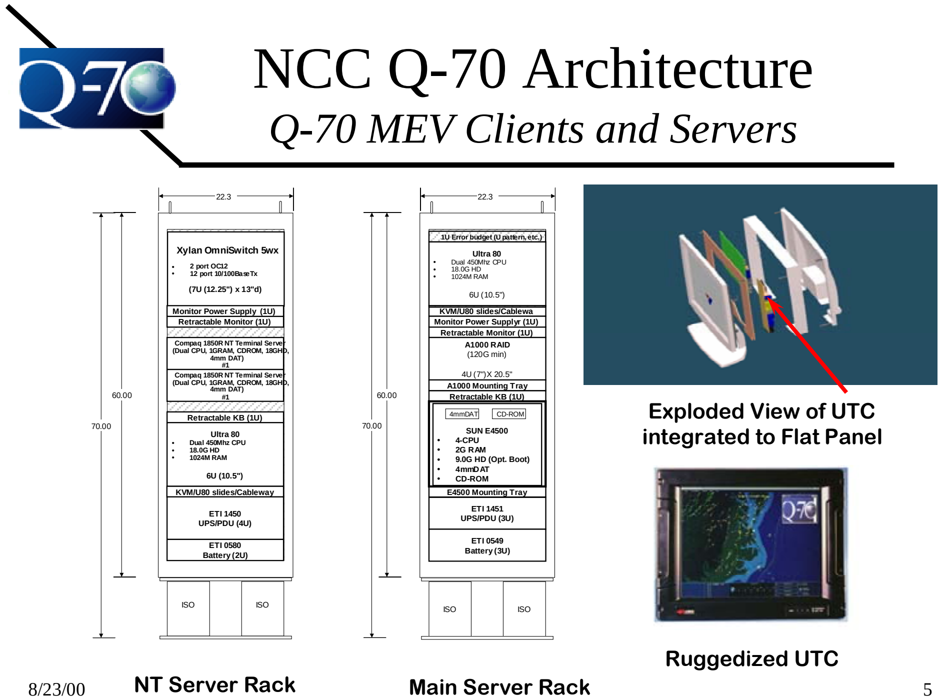

Figure 12. Breakdown of Windows NT and Main Server Racks in Q-70 Architecture [63]

The Q-70 servers used the "hotel concept" in their design which gave them the ability to be upgraded easily with minimal downtime for the system. The *Coronado* network used Sun Microsystems enterprise and application servers for the Sea Based Battle Lab. The hard drives in the main session servers were installed in a Redundant Array of Independent Disks 5 (RAID 5) configuration to increase fault tolerance using striping with parity. The Windows NT servers ran the routine network operations for the system. Both types of servers possessed an uninterruptible power supply with a battery backup in case of a power spike in the ship's electrical system. Each had its own retractable keyboard and monitor. The cabinets that housed the servers were padded with "gray matter" for shock absorption that met MIL-STD-901D Grade A&B requirements.[64]

SPAWAR cited some of the benefits associated with this architecture to include lower costs, consolidation of servers, flexibility in support of both thin/ultra-thin or fat-

[63] SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, (2000, August 23). *Network-centric computing: The network centric Q-70*, p. 5.

[64] Ibid, p. 12.

clients and very low administrative costs due to its centralized nature of design. SPAWAR also noted the simplification of technical refresh by making the changes or patches solely at the server rather than at each PC workstation or end user. Furthermore, SPAWAR noted that additional attributes of this configuration were the smaller footprint of thin-clients as compared to PCs, their reduced energy consumption and heat dissipation, its operating system independence which increase its office needs flexibility and its mobility feature which allows the user to move from one client to the next while maintaining the contents of his or her session.[65] Figure 13 summarizes these attributes.

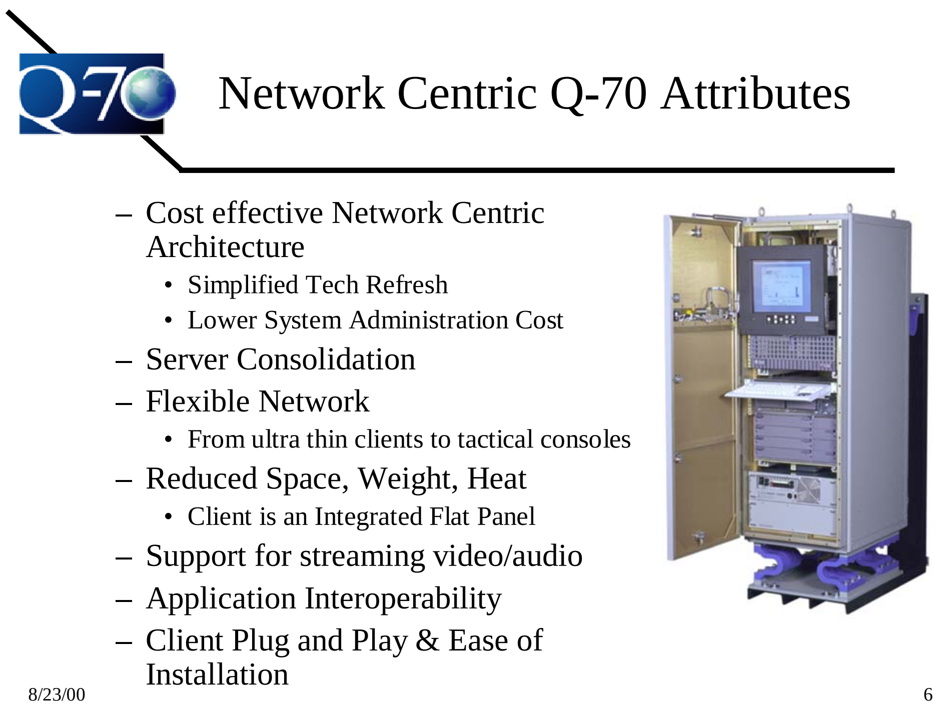

Figure 13. Benefits Associated with the AN/UYQ-70 NCC Architecture [66]

Initial reports indicated that the network ran quite well and was on track for its scheduled phased upgrades that included adding more clients to the network, SIPRNET

---

[65] SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, *(2000, August 23). Network-centric computing: The network centric Q-70*, p. 13.

[66] Ibid, p. 6.

connectivity, and consolidation of the servers to one Mission Essential rack vice two through the development and incorporation of ultra thin, flat panel client products in a cabinet that meets Grade A shock requirements. The goal of the Q-70 program was to lower costs as much as possible by using as many COTS products as feasible. There does not appear to be any indication that the *Coronado*'s network did not achieve these goals. In conversations with the staff personnel at PMW 160, who were instrumental in the installation of the *Coronado*'s network, there were some minor issues noted with the system following operational testing. One issue identified was that some of the applications used were not designed for multiple users and the system ran slow as a result. Another issue that was noted was that, at times, temporary files from one user were overwritten by subsequent users and the work from the original user was lost. SAIC recommended JAVA as the language to be used on the network since it could run on multiple platforms and minimize the multiple user interference issue from bogging down the network. SAIC also stated that the CENTRIXS suites that were later installed on USS *Blue Ridge* (LCC-19) and USS *Mt. Whitney* (LCC-20) were built based on lessons learned as a result of the operational testing on USS *Coronado*.

However, due to the relatively large amount of time between the development and installation of the network and the *Coronado*'s decommissioning in 2005, very little information is available regarding post-installation assessments of the system. Consequently, the authors were not able to determine the end result of the Sea-Based Battle Lab's thin-client network in any official capacity. However, it is known that the use of thin-clients in shipboard computer networks did not end with the *Coronado* since to this date, UTCs are being used for the user interface as a part of the Block II CITRIXS-M multi-level thin-client (MLTC) networks aboard the USS *Abraham Lincoln* (CVN 72), USS *Harry S. Truman* (CVN 75) and the high speed transport vessel.[67]

[67] Tom Hepner (2007, May 9). *CENTRIXS-M DIG background* Power Point presentation. SPAWAR Program Executive Office for Command, Control, Communications, Computers and Intelligence (PEO 41), p. 6.

D. CONCLUSION AND CHAPTER SUMMARY

From all initial indications, the use of CENTRIXS and thin-client networks aboard the test platform ships on which they were installed was quite successful. It is clear that interest in implementing UTC technology still exists and remains an important option as the U.S. Navy continues to move forward with the IT21 initiative and optimizing the use and effectiveness of shipboard computer networks. NCC architecture is capable of handling the many different types of data applications associated with shipboard computer operations, be they Windows-based, Unix-based, and web-based programs, while minimizing user delay time and equipment footprint and maximizing server utilization and efficiency. The mobility and security characteristics associated with UTCs in terms of common access card (CAC) use reinforce the usefulness and practicality of thin-client networks aboard ships. However, because shipboard environments tend to be rough on electronics, the necessity for reliable cabinets that offer near-perfect protection of the servers in a network is absolutely critical. Any catastrophic damage to the server(s) could result in a total shut down of the ship's local area network.

This chapter focused on current and proposed shipboard computer networks. The authors described the function and application of current shipboard networks including the Integrated Shipboard Network System (ISNS), the Special Compartmented Information Automated Digital Network System (SCI ADNS), and the Combined Enterprise Regional Information Exchange System (CENTRIXS). The proposed shipboard network described in this chapter was the Consolidated Afloat Networks and Enterprise Services (CANES). The chapter concluded with a discussion of thin-client networks that have previously been fielded on U.S. Navy ships. In this section, Network Centric Computing and the USS *Coronado*'s Sea Based Battle Lab and associated thin-client network were described and assessed.

The next chapter will focus on the different types of software currently used on ships as well as their compatibility with thin-client network systems and the testing of the software in a thin-client as compared to a thick-client network environment.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. SHIPBOARD SOFTWARE

Numerous software applications are used onboard U.S. Navy ships. This chapter will address several of the major software systems used. These systems contain both commercial off the shelf (COTS) software products, government off the shelf (GOTS) products, and specialized software written for a specific Navy or military application. Known compatibility or incompatibility of these software applications with thin-client networks will also be presented, as well as the results of application testing completed by the authors.

A. COMMON SHIPBOARD NETWORK SOFTWARE

1. Common PC Operating System Environment (COMPOSE)

Common PC Operating System Environment (COMPOSE) is a package of software that is common throughout the fleet and provides a “standardized Windows 2003 network environment.”[68] The package of software includes Windows operating systems for the server (Windows 2003 Standard Server) and the clients (Windows XP Professional) and the necessary software required to carry out standard Navy business office type functions in the form COTS and GOTS software. “In addition, Windows 2000 Professional clients are supported in order to provide compatibility for legacy applications that have not yet transitioned to Windows XP. Other COTS and GOTS products not included as part of the baseline software can be incorporated into COMPOSE 3.0.0.1 as ‘Value Added Products’ in a modular form.”[69]

The primary software applications that are included in COMPOSE for servers and clients are listed in Tables 2 and 3:

[68] SPAWAR System Center Charleston (2006, September 20). Software version description for COMPOSE version 3.0.0.1 revision 12, p. 1.

[69] Ibid, p. 1.

SERVER SOFTWARE	VERSION
Microsoft Windows 2003 Standard Server	SP1
Microsoft Internet Explorer	6.0 SP1
Symantec AntiVirus Corporate Edition	10.0.0.359
Symantec AntiVirus System Center Console	10.0.0.359
Symantec Mail Security	4.6.1 b107
Microsoft .NET Framework	1.1 SP1
Microsoft Exchange Server 2003 Enterprise Edition	2003 SP3
Microsoft ISA Server 2004 Standard Edition	2004 SP1
Veritas Backup Exec	10.0
SQL Server 2000 Standard Edition	2000 SP4
NicoMak WinZip	9.0 SR1
Ipswitch WS-FTP Pro	8.01
Adobe Acrobat Reader	7.0
Microsoft Netmeeting	3.01
Microsoft Windows Media Player	10
ActivCard Gold	2.2 SP2
Netscape	7.2

Table 2. COMPOSE COTS software that is available for installation on servers.[70]

CLIENT SOFTWARE	VERSION
Microsoft Windows XP Professional	XP SP2
Microsoft Internet Explorer	6.0 SP1
Microsoft Office Professional	2003 SP1
Microsoft Office Professional	XP SP3
Symantec AntiVirus Corporate Edition	10.0.0.359
NicoMak WinZip	9.0 SR1
Ipswitch WS-FTP Pro	8.01
Adobe Acrobat Reader	7.0
RealOne Player	10.5.B6.0.12.1056
Macromedia Shockwave	10.1.0
Flash Player	7.0.19.0
Apple QuickTime Movie and Audio Viewer	6.5.2
Microsoft Netmeeting	3.01
Microsoft Windows Media Player	10
Microsoft ISA Client	2004 SP1
ActivCard Gold	2.2 SP2
Java Runtime Environment	1.5.0.02
Netscape	7.2
Microsoft .NET Framework	1.1 SP1
Microsoft Chat	2.5

Table 3. COMPOSE default workstation software load.[71]

[70] SPAWAR System Center Charleston (2006, September 20). Software version description for COMPOSE version 3.0.0.1 revision 12, p. 4.

[71] Ibid, pp. 4-5.

2. Naval Tactical Command Support System (NTCSS)

The Naval Tactical Command Support System (NTCSS) is a suite of government software forming an information system "used to complete the tactical readiness picture for operational commanders by supporting the Global Command Support System (GCSS) and the Common Operational Picture (COP)." "NTCSS supports network-centric warfare by integrating logistics information for the warfighter."[72] NTCSS is a Mission Essential, Acquisition Category (ACAT) IAC, Major Automated Information System (MAIS). It is used by ships and shore based fleet support facilities to perform management of logistics information, personnel, material management, equipment management, maintenance, medical operations, and finances. These functions support ships and submarines as well as Navy and Marine Corps aircraft. NTCSS was developed to merge the functions of the Shipboard Non-Tactical Automated Data Processing Program (SNAP), the Naval Aviation Logistics Command Management Information System (NALCOMIS), and Maintenance Resource Management System (MRMS). The functions of these systems are now conducted by the components that make up NTCSS: The Relational Administrative Data Management application (R-ADM), Relational Supply (RSupply), Organizational Maintenance Management System-Next Generation (OMMS-NG), and the Naval Aviation Logistics Command Management Information System (NALCOMIS).

a. Relational Administrative Data Management Application (R-ADM)

Relational Administrative Data Management application (R-ADM) is an application designed to provide shipboard access to personnel information. The application goes far beyond simply maintaining personnel records, its features are used to conduct the majority of shipboard personnel management requirements. The main functions of R-ADM include: recording and managing absences; advancements; berthing

[72] Requirements to capabilities. (2002) Retrieved April 25, 2007, from Vision Presence Power: A Program Guide to the U.S. Navy - 2002 Edition Web site: http://www.navy.mil/navydata/policy/vision/vis02/vpp02-ch3y.html.

assignments; career information; training; division officer's notebook; lifeboat assignments; manpower management; personnel management; personnel qualification standards (PQS); property management; quarterdeck management (on ships with quarterdeck smart card swiping capability for tracking the arrival and departure of personnel); school assignments; watch bills; and tickler management. R-ADM is also interfaced with the Navy Training Management and Planning System.

b. Relational Supply (RSupply)

Relational Supply (RSupply) is another NTCSS application that provides a wide range of support services to the fleet and supporting shore activities. The application is used to order, track, receive and issue supplies. Additionally it maintains supply inventory records as well as financial management records. It "provides on-line, real time interactive capability for automated supply and financial management functions for submarines, surface ships, and aviation sites."[73]

c. Organizational Maintenance Management System-Next Generation (OMMS-NG)

Organizational Maintenance Management System-Next Generation (OMMS-NG) provides shipboard maintenance personnel the information tools they need to support shipboard readiness. The application is used to plan, schedule, report and track maintenance actions. It contains the Consolidated Shipboard Allowance List (COSAL) which lists the parts required to complete maintenance on shipboard equipment. OMMS-NG interfaces with RSupply for seamless requisitioning of parts and supplies required to conduct maintenance. It also interfaces with shore activities to provide them the configuration, maintenance and logistics information they require to support the fleet.

73 RSupply: Relational supply. Retrieved April 25, 2007, from Space and Naval Warfare Systems Center Norfolk -- Naval Tactical Command Support System (NTCSS) Web site: http://www.scn.spawar.navy.mil/products/NTCSS/RSupply/RSupplybrochureNorfolk.pdf.

d. Naval Aviation Logistics Command Management Information System (NALCOMIS)

Naval Aviation Logistics Command Management Information System (NALCOMIS) is an information system used to manage aviation maintenance and material. It has three configurations based on the type of maintenance facility it is supporting: Organizational Maintenance Activity (OMA), Intermediate Maintenance Activity (IMA), and Organizational at the Intermediate Maintenance Activity (OIMA). At the operational level OMA is used. The key features of OMA include: configuration management, data integration with logistics support systems, pilot and aircrew tracking, squadron detachment processing, total asset visibility, and printed reports.[74]

3. Sensitive Compartmented Information (SCI)

The Sensitive Compartmented Information (SCI) system is utilized by units to send and receive intelligence information. SCI software provides real-time receipt and transmission of Special Intelligence (SI) and Sensitive Compartmented Information (SCI) data through secure and reliable IP communications for cryptologic and intelligence systems. Several functions of the software include direction finding (DF) data transfer, record messaging, e-mail, chat, file transfer and web browsing as well as voice and data transfer among SCI-capable ships and submarines, with gateways to shore nodes.[75]

B. COMPATIBILITY OF EXISTING SOFTWARE WITH THIN-CLIENT NETWORKS

1. Common PC Operating System Environment (COMPOSE)

COMPOSE software applications have been tested successfully on thin-client networks. Many of the components of COMPOSE have been tested individually, and

[74] Naval Aviation Logistics Command information system for organizational maintenance activities (NALCOMIS OMA). Retrieved April 29, 2007, from Space and Naval Warfare Systems Center Norfolk -- Naval Tactical Command Support System (NTCSS) Web site: http://www.scn.spawar.navy.mil/products/NTCSS/nalcomis/brochures/nalcomisOMA.pdf

[75] Requirements to capabilities. (2002) Retrieved April 25, 2007, from Vision Presence Power: A Program Guide to the U.S. Navy - 2002 Edition Web site: http://www.navy.mil/navydata/policy/vision/vis02/vpp02-ch3y.html

found to be compatible in the thin-client environment. The COMPOSE 3.0 Baseline was also successfully tested for use with Combined Enterprise Regional Information Exchange Systems – Maritime (CENTRIXS-M) Block II with Multilevel Thin-Client version 3.0.

Many of the software components contained in COMPOSE were tested individually by Lieutenant Kenneth J. Landry, during research for his Naval Postgraduate School Thesis in 2006. During his testing, Lieutenant Landry found the individual COMPOSE applications listed in Table 4 to function on a thin-client network. The network used in the testing was composed of Wyse Winterm V90 clients utilizing Windows Terminal Server as a remote desktop protocol with a server running Microsoft Windows Server 2003 Standard Edition.[76]

COMPOSE Software Tested Successfully
Microsoft Windows 2003 Standard Server
Microsoft Internet Explorer
WinZip
Adobe Acrobat
Microsoft Windows Media Player 10
Microsoft Office Professional 2003/XP
Microsoft Word
Microsoft Excel
Microsoft PowerPoint
Microsoft Access
Microsoft FrontPage
Microsoft Publisher
Apple QuickTime
Macromedia Shockwave
Flash Player
Real Player

Table 4. COMPOSE Software Applications Tested Successfully on a Thin-Client Network

[76] Kenneth J. Landry (2006, June). The performance and compatibility of thin-client computing with fleet operations. Naval Postgraduate School thesis, pp. 33 & 45.

In the case of CENTRIXS-M, the COMPOSE 3.0 Baseline was successfully tested on the CENTRIXS-M Block II system "with no adverse affects."[77] The system tested utilized Sun Ray 1g workstations and Sun Fire V120 and V240 servers. The main system components of CENTRIXS-M are listed in Table 5 below.

Name	*Qty*	*Description*
Primary Domain Controller	1 per enclave	Hosted on Windows 2003 Standard. Server functions include (W2K3, Primary AD Controller, Distribution Console, C2PC Gateway)
Exchange Server	1 per enclave	Hosted on Windows 2003 Standard. Server functions include (W2K3 AD Controller, Exchange Server, File Server, Symantec Antivirus Server, Backup Location)
CAS Server	1 per enclave	Hosted on Windows 2003 Standard. Server functions include (W2K3, Domino Server, SameTime Server)
MLTC Citrix Server	1 per enclave	Hosted on Windows 2003 Standard and Enterprise. Server functions include terminal services and office applications as well as interface clients (C2PC).
MLTC Clients	5	Ultra Thin Clients (UTCs) hosted on SUN Sunray platforms with integrated smart card readers.
MLTC Master Server	1	Hosted on Trusted Solaris 8 07/03
MLTC Session Server	2	Hosted on Trusted Solaris 8 07/03
ISNS Citrix Server	1	Hosted on Windows 2003 Standard and Enterprise. Is a member server to ship's ISNS network running COMPOSE 2.0.3
VIC ICA Thin Client	1	Troubleshooting and configuration of servers remotely to aid in physical access restrictions.

Table 5. CENTRIXS-M Block II Main System Components[78]

2. Naval Tactical Command Support System (NTCSS) and Sensitive Compartmented Information (SCI)

The existing compatibility of Naval Tactical Command Support Systems (NTCSS) and Sensitive Compartmented Information (SCI) software with thin-client networks is not known. NTCSS is made up of a suite of government software that requires access to remote NTCSS servers in order to test operability. SCI networks by

[77] Central Design Authority Team and Integration Test Facility SPAWAR System Center (2006, June). System integration testing (SIT) for combined enterprise regional information exchange systems-maritime (CENTRIXS-M): Block II with MLTC v3.0, p. 1-1.

[78] Ibid, p. 2-1.

their nature are sensitive and contain classified information. To keep this Project unclassified, only SCI networks and associated software, not their actual functionality, are addressed.

C. SOFTWARE TESTING

One area of weakness in past thin-client network configurations has been the use of rich streaming media. Past thin-client networks experienced difficulties with delivering the full range of multimedia applications, particularly web based streaming media. This issue is of particular importance when considering thin-client networks for shipboard use because the U.S. Navy utilizes web based media rich training courses to fulfill many of its individual training requirements. In order to address this issue the authors conducted some simple tests on two separate thin-client networks that involved the use of the U.S. Navy's Sea Warrior web based training.

1. Rich Streaming Media (NPS Classroom)

The Wyse S90 workstation was used in a Naval Postgraduate School (NPS) classroom to conduct online Sea Warrior training through the Navy Knowledge Online (NKO) website on 9 April 2007. The test was conducted to assess the performance of the NPS thin-client workstation's performance in regards to media rich online applications. In order to enroll in Sea Warrior training, on-line training profiles must be able to be accessed and managed within the E-Learning section of NKO. The authors found no issues with managing their on-line NKO profiles through the Wyse terminals and enrolling in training courses. Two on-line courses were chosen in order to test a wide range of streaming media applications and to represent the diverse training topics that are conducted on-board ships. "Level B Code of Conduct Training" was chosen for its rich streaming audio and video and "Cost Management and IT Project Trade-Offs" was chosen because of its use of the Skillsoft courseware.

The first training event involved the "Level B Code of Conduct Training" course. The course was successfully launched and throughout the course it was noted that the streaming audio and text worked normally with no noted discrepancies. However, the streaming video applications contained within the training would not load the video for viewing. An error symbol was displayed on the screen where the video should have beendisplayed. During the "Cost Management and IT Project Trade-Offs" course there were no discrepancies noted. The Skillsoft courseware application worked flawlessly through the Wyse S90 terminals and the NPS network.

2. Rich Streaming Media (Sun Microsystems Lab)

In order to test the abilities of more than one configuration of thin-client network, the authors were invited to visit the Sun Microsystems facility in San Diego on 13 April 2007. The authors were allowed to use the Sun Microsystems San Diego thin-client lab to further test the rich media streaming abilities of thin-client networks. The components of the thin-client network used included a Sun Ray 1 Virtual Display Client and a Sun Fire X4200 server, both of which have been superseded in the Sun product line by newer models. The server was utilizing the Sun Solaris 10 operating system as well as Sun Ray Software and a prototype version of Win4Solaris from Virtual Bridges, which allows Solaris users to run Microsoft Windows applications.

During the test, the authors accessed the NKO website, accessed and managed the same on-line training profile, and enrolled in and completed the same "Level B Code of Conduct Training." The authors found that the presentation ran smoothly with seamless streaming audio and video using the Sun Microsystems thin-client network and their Appliance Link Protocol (ALP). The ALP is designed to send only those bits of information that change between the server and the workstation in order to greatly reduce the bandwidth requirements. To be fair, it should be noted that the authors were the only two users on the network and occupying the Sun server at the time.

3. Rich Streaming Media (Fat Client)

In order to compare the abilities of thin-client networks to networks containing standard personal computers (PC), in regards to their ability to display rich streaming media, the same NKO Sea Warrior based "Level B Code of Conduct Training" course was utilized. A Hewlett-Packard Pavilion dv2120us Notebook PC was used on a typical wireless network. The same training profile was able to be accessed and managed, enrollment was made in the "Level B Code of Conduct Training," and the training was conducted. There were no issues with the rich media streams. Both streaming audio and video worked flawlessly.

D. CONCLUSION

It is widely known that DOS based software applications will not function on thin-client networks and in many cases do not function well in Windows environments on PCs. However, there seems to be no such problems running Windows based software on thin-client networks. The usability of Windows based software on thin-client networks has been illustrated through independent testing, use of thin-clients on USS *Coronado*, and through the testing of COMPOSE 3.0 Baseline on CENTRIXS-M networks that incorporate ultra-thin-clients. Although the functionality of NTCSS and SCI software applications on thin-client networks is not yet known by the authors, it does not mean any compatibility issues that may exist with the software used on the systems cannot be rectified in order to use the networks onboard ships.

V. COST-BENEFIT ANALYSIS OF SHIPBOARD THIN-CLIENT NETWORKS

This chapter will analyze the benefits, costs, flexibility and risks associated with installing thin-client networks on U.S. Navy ships compared to the CANES Lite blade server networks currently being prepared for shipboard installation. In particular, the analysis will provide a framework to evaluate the impact of installing a Sun Ray virtual display solution on a guided missile destroyer (DDG). The Sun Ray thin-client technology was chosen for this analysis because it has previously been certified for use with CENTRIXS networks onboard U.S. Navy ships. The DDG platform was chosen because it makes up a significant portion of unit level ships in the U.S. Navy. The entire CANES Lite model is listed in Appendix A. The major assumption in the analysis is that both models are being considered prior to the CANES Lite network being fielded, and therefore there is no existing shipboard equipment that will be utilized.

A. DESCRIPTION OF CANES LITE BLADE SERVER NETWORK MODEL

1. Workstations

The CANES Lite blade server network model utilizes Dell Optiplex GX520 PC workstations and Dell 17" flat panel monitors. The costs associated with the CANES Lite network model are broken down and listed in Table 6. Each workstation (including KVM) costs $875.12. In our comparison we will focus on the 65 workstations currently supplied by PMW-160 to a DDG class ship as part of ISNS. This number does not take into account the workstations provided by GCCS-M or NTCSS because they are provided separately by those programs. The total cost of 65 workstations (including KVM) is $56,882.80. The cost breakdown and configuration for a PC workstation is listed in Table 6. For the purpose of our cost comparison, a three-year refresh rate will be utilized for PC work stations. This refresh rate was selected because it is the standard refresh rate used by Navy/Marine Corps Intranet (NMCI) for its workstations. It is one year less than the four-year refresh rate used by Gartner in its 2004 thin-client TCO research study.[79]

WORKSTATIONS	Manufacturer	Model #	Unit	Unit Price	QTY	Total Price
Dell Optiplex GX520					**65**	
Dell Optiplex GX520 P4 2.4GHz, 512MB SDRAM, 40GB HDD, Scroll Mouse, 40X CDRW, Win2000, Speakers, Keyboard, 3 Year on site CONUS/OCONUS Warranty.	Dell	GX520	1	$519.00	**65**	$33,735.00
RAM Upgrade to 512 MB NON-ECC 133 MHZ SDRAM (one chip)	Dell		1	$65.00	**65**	$4,225.00
RAM Upgrade to 1GB NON-ECC 533MHz SDRAM (Two Chips) Total of 1GB	Dell		1	$103.00	**65**	$6,695.00
Standard Keyboard	Dell		1	$5.00	**65**	$325.00
17" Viewable Flat Panel Monitor (1024x1024)	Dell		1	$183.12	**65**	$11,902.80
TOTAL Dell Optiplex GX270				**$875.12**		**$56,882.80**

Table 6. CANES Lite Workstations

2. Servers

The CANES Lite network model utilizes 32 IBM Telco Blade Servers housed in four IBM Blade Center chassis on a DDG. The cost of each Blade Center chassis is $19,244.20 and each Telco Blade Server is $4,722.00. The total of four Blade Center chassis and 32 Telco Blade Servers is $225,808.40. The Blade Center solution uses eight blade servers in each Blade Center chassis on unit level ships, such as the DDG class.

[79] Mikako Kitagawa, Mark A. Margevicius, & Michael A. Silver (2004, August 17). Gartner, Inc.: *When Thin Clients Can Narrow Your TCO*. p. 9.

The cost breakdown and configuration for the blade servers and chassis is listed in Table 7. A three-year server refresh rate will be utilized in our cost comparison for all servers.

BLADE SERVERS	Model #	Unit	Unit Price	QTY	Total Price
BLADE SERVER CHASSIS (IBM Telco Equipment)				**4**	
IBM eServer BladeCenter™ T Chassis AC Powered Models	87302RU	1	$6,460.00	**4**	$25,840.00
Nortel L2-3 GbE Switch Module (Copper)	32R1860	2	$1,715.00	**8**	$13,720.00
4 Gbps SW SFP Transceiver 4 Pack	22R4897	2	$385.00	**8**	$3,080.00
IBM BladeCenter™ T 1300W AC Power Supply Modules	32R0834	4	$1,259.00	**16**	$20,144.00
Hardware integration - BladeCenter	58P8676	1	$200.00	**4**	$800.00
Low Profile Handle for LS20 IBM eServer BladeCenter	25R7748	4	$40.00	**16**	$640.00
Qlogic iSCSI Expansion Card	32R1923	4	$513.00	**16**	$8,208.00
DPI 30AMP/250V FRONT-END PDU WITH NEMA L6-30P	39Y8939	2	$284.05	**8**	$2,272.40
TOTAL BLADE SERVER CHASSIS (IBM Telco Equipment)			**$19,244.20**		**$74,704.40**
ISNS GigE LAN SERVERS - IBM Telco Blade Servers - Model:LS20 Processor: AMD Opteron 2.6 GHz - RAM: 4GB Per Blade Server				**32**	
LS20, AMD Opteron Dual Core 275 2.6 GHz/1GHz, 1MB L2, 2x512MB, O/Bay U320	885066U	1	$2,099.00	**32**	$67,168.00
AMD Opteron Dual Core 2.6 GHZ /1GHz 1MB L2, Processor Model 275	25R8895	1	$769.00	**32**	$24,608.00
2 GB (2x1GB Kit) PC3200 CL3 ECC DDR VLP SDRAM RDIMM	39M5849	2	$701.00	**64**	$44,864.00
IBM 36.4 GB SFF Non Hot-Swap U320 10K SCSI Drive	40K1037	2	$226.00	**64**	$14,464.00
TOTAL ISNS GigE LAN SERVERS - IBM Blade Servers			**$4,722.00**		**$151,104.00**

Table 7. CANES Lite Blade Servers and Chassis

3. Software

The CANES Lite blade server network model utilizes the COMPOSE server software suite as well as the COMPOSE workstation software suite previously described in Chapter IV. The software and associated costs are listed in Tables 8 through 11.

COMPOSE SERVER SOFTWARE	Manufacturer	Model #	Unit	Unit Price	QTY	Total Price
7 Server CFG (per Server Rack) for A(V)9 & (V)8 ~ COMPOSE 3.5 [DRAFT]					4	
Exchange 2003 Server Enterprise	GTSI / ASAP	395-02873	1	$2,640.55	4	$10,562.20
Backup Exec 10.1 (D) Server	GTSI / ASAP	A180498-0LE000	7	$383.04	30	$11,491.20
Backup Exec 10.1 (D) Server Open File Option Agent w/ CAL	GTSI / ASAP	A180528-0LE000	7	$431.19	30	$12,935.70
Backup Exec 10.1 (D) Exchange Agent W/ CAL	GTSI / ASAP	A180618-0LE000	1	$479.34	4	$1,917.36
ISA 2004 STD (per processor)	GTSI / ASAP	E84-00537	2	$1,710.22	8	$13,681.76
Windows 2003 Enterprise Server	GTSI / ASAP	P72-00122	7	$1,576.21	30	$47,286.30
WINZIP 10.0	GTSI / ASAP	WINZIP10	7	$26.00	30	$780.00
WS-FTP Pro Ver 2006	GTSI / ASAP	WS-8003	7	$12.50	30	$375.00
SMS - SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART / Microsoft	271-02374	7	$857.40	30	$25,722.00
MICROSOFT OPERATIONS MANAGER (MOM) Ops Mgr Serv Enterprise 2005 w/SQL Tech	SOFTMART / Microsoft	A8L-00007	1	$858.13	4	$3,432.52
SQL Svr Enterprise Ed 2005	SOFTMART / Microsoft	810-04745	1	$5,570.18	4	$22,280.72
MOM Ops Mgr Serv Enterprise 2005 w/SQL Tech	SOFTMART / Microsoft		1	$279.83	32	$8,954.56
TOTAL 7 Server Configuration for A(V)9 & (V)8				**$35,973.02**		**$159,419.32**

Table 8. CANES Lite COMPOSE Server Software

	Manufacturer	Model #	Unit	Unit Price	QTY	Total Price
SOA (Service Oriented Architecture) SW Procurement ~ SWAG	GTSI / HP	Q2426A-3YRHP	1	**$190,000.00**	1	**$190,000.00**

Table 9. CANES Lite SOA Estimate

	Manufacturer	Model#	Unit	Unit Price	QTY	Total Price
Other COMPOSE Server Software					1	
Technet Subscription Rev A	GTSI / ASAP	323-04487	1	$380.00	1	$380.00
Windows 2K/2K3 Server ResKit	GTSI / ASAP	1-57231-805-8	2	$460.00	2	$920.00
Windows 2K/2K3 Pro ResKit	GTSI / ASAP	0-7356-2167-5	2	$80.00	2	$160.00
TOTAL Other COMPOSE Server Software				**$1,460.00**		**$1,460.00**

Table 10. CANES Lite Other COMPOSE Server Software

COMPOSE Workstation Software	Manufacturer	Model#	Unit	Unit Price	QTY	Total Price
User Workstation (COMPOSE 3.5)					2	
WINDOWS 2003 CAL (DEVICE)	GTSI / ASAP	R18-00041	1	$18.99	2	$37.98
EXCHANGE 2003 CAL	GTSI / ASAP	381-01836	1	$43.00	2	$86.00
OFFICE 2003 PRO	GTSI / ASAP	269-06826	1	$309.43	2	$618.86
WINZIP 10.0	GTSI / ASAP	WINZIP10	1	$13.00	2	$26.00
WS-FTP PRO VER 2006	GTSI / ASAP	WS-8003	1	$12.50	2	$25.00
SQL CAL	GTSI / ASAP	359-00608	1	$96.17	2	$192.34
SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART / Microsoft		1	$26.82	2	$53.64
SQL Svr Enterprise Ed 2005	SOFTMART / Microsoft	359-00608	1	$96.17	2	$192.34
TOTAL User Workstation				**$616.08**		**$1,232.16**
Web Workstation (COMPOSE 3.5)					65	
WINDOWS 2003 CAL (DEVICE)	GTSI / ASAP	R18-00041	1	$18.99	65	$1,234.35
EXCHANGE 2003 CAL	GTSI / ASAP	381-01836	1	$43.00	65	$2,795.00
OFFICE 2003 PRO	GTSI / ASAP	269-06826	1	$309.43	65	$20,112.95
WINZIP 8.1	GTSI / ASAP	WINZIP10	1	$13.00	65	$845.00
WS-FTP PRO VER 2006	GTSI / ASAP	WS-8003	1	$12.50	65	$812.50
SQL CAL	GTSI / ASAP	359-00608	1	$96.17	65	$6,251.05
SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART / Microsoft		1	$26.82	65	$1,743.30
SQL Svr Enterprise Ed 2005	SOFTMART / Microsoft	359-00608	1	$96.17	65	$6,251.05
TOTAL Web Workstation				**$693.50**		**$40,045.20**

Table 11. CANES Lite COMPOSE Workstation Software

4. Miscellaneous Network Equipment

In addition to the servers, workstations and associated software, there are various other pieces of equipment integral to any network. This equipment is shared by both network models being compared and therefore is not relevant to the cost comparison. The list of this equipment along with the associated costs can be found in Appendix A.

B. DESCRIPTION OF ULTRA-THIN-CLIENT CANES LITE NETWORK MODEL

1. Workstations

In the UTC version of the CANES Lite model, the 65 PC workstations are replaced with 65 Sun Ray 2 UTC workstations. Each Sun Ray 2 workstation (including KVM) has a cost of $589.75, totaling $38,333.75 for the 65 total workstations considered in this model. The hardware, software and cost breakdown for the Sun Ray UTC workstations is listed in Table 12. According to the manufacturer, the Sun Ray 2 clients have a six- to ten-year product life. The costs models that are presented will include both six- and nine-year refresh rates.

WORKSTATIONS	Manufacturer	Model #	Unit	Unit Price	QTY	Total Price
Sun Ray 2					**65**	
Sun Ray 2 Client, 1600 x 1200 max resolution, 2 USB ports, 1 serial port, RoHS-6 compliant.	Sun	NTC-10Z-00	1	$249.00	**65**	$16,185.00
Electronic Software Distribution Sun Ray Software 4 10/06	Sun	CECI9-410C99HS	1	$89.00	**65**	$5,785.00
Localized Power Cord Kit North America	Sun	X311L	2	N/A	**N/C**	N/A
Type 7 UNIX Country Kit.	Sun	X3738A	1	$35.00	**65**	$2,275.00
17-inch TFT LCD Monitor	Sun	X7204A	1	$216.75	**65**	$14,088.75
TOTAL Sun Ray 2 Client				**$589.75**	**65**	**$38,333.75**

Table 12. Ultra-Thin-Client Network Model Workstations [80]

[80] Based on information provided by Sun Microsystems on May 17, 2007.

2. Servers

The UTC version of CANES Lite utilizes the 32 IBM Telco Blade Servers and adds four Sun Fire X4200 M2 X64 servers. The Sun Fire X4200 M2 X64 servers allow the Sun Ray 2 clients to interact with the network of blade servers. Each Sun Fire X4200 M2 X64 server package costs $10,427.40, totaling $41,709.60 for the four servers required in the model. This $41,709.60 is in addition to the $225,808.40 cost of the blade servers and blade server chassis. The breakdown of hardware and software costs for the Sun Fire X4200 M2 X64 servers is listed in Table 13.

SESSION SERVERS	Model #	Unit	Unit Price	QTY	Total Price
Sun Fire X4200 M2 X64 Server				**4**	
Sun Fire X4200 M2 X64 Server: 2X AMD Opteron Model 2220 (2.8GHz/1MB) processor, 4x 2 GB PC2-5300 DDR2-667 memory, 2x 146GB HDD, DVD-ROM/CD-RW, 2x High Efficiency PSU, Service Processor, 4x 10/100/1000 Ethernet Ports, 4x USB 2.0 ports, 4x 8-Lane PCI-E Slots, 1x 64-bit/ 133 MHz PCI-X Slot, no power cord.	A87-FPZ2BH8GKBA	1	$7,493.40	**4**	$29,973.60
X-Option Cable Management Arm for Sun Fire X4200 M2 x64 Servers	X8028A-Z	1	$88.00	**4**	$352.00
Localized Power Cord Kit North America	X311L	2	N/C	**N/A**	N/C
4 GB Memory Kit DDR2-667 Registered ECC DIMMs (2x2GB)	X4226A-Z	2	$871.00	**8**	$6,968.00
146GB 10k RPM 2.5" SAS Disk Drive	XRA-SS2CD-146G10KZ	2	$483.00	**8**	$3,864.00
X-Option slide rail kit for Sun Fire X4200 M2 x64 servers.	X8029A-Z	1	$138.00	**4**	552.00
TOTAL Sun Fire X4200 M2 X64 Session Servers			**$10,427.40**		**$41,709.60**

Table 13. Ultra-Thin-Client Network Model Session Servers [81]

[81] Based on information provided by Sun Microsystems on May 17, 2007.

3. Software

In addition to the software requirements for the CANES Lite network model, Sun Ray Software, Sun Solaris and Sun Secure Global Desktop are also required for the UTC model. Sun Ray Software, listed in Table 12, delivers the operating system to the Sun Ray 2 client. Sun Solaris is the operating system for the Sun Fire servers and is no cost, as it is free open source software. The Sun Secure Global Desktop software:

> uncouples applications from their underlying infrastructure and delivers the applications through a virtualized desktop environment to existing desktop systems, laptops, Sun Ray clients, other thin clients and mobile devices.[82]

Sun Server Global Desktop costs $35.00 per workstation, for a total of $2,275.00 for the 65 workstations in the model. The details of and costs for the Sun Server Global Desktop software are listed in Table 14.

	Manufacturer	Model #	Unit	Unit Price	QTY	Total Price
Sun Secure Global Desktop Software Media Kit for Solaris and Linux. Version 4.31	Sun	TTA99-431C99M9	1	**$35.00**	**65**	**$2,275.00**

Table 14. Ultra-Thin-Client Network Model Virtual Desktop Software [83]

4. Miscellaneous Network Equipment

The UTC network model utilizes the same network equipment as the CANES Lite model listed in Appendix A. The CANES model utilizes four server racks with 33 total standard rack units (RU). Each 33 RU server rack in this model has 3 RU of blank space, enough to fit a 2 RU Sun Fire X4200 M2 X64 server. An RU is equal to 1.75 inches of rack space.

[82] Sun Software (2007). Retrieved May 18, 2007, from Sun Microsystems Web site: http://www.sun.com/software/index.jsp?cat=Desktop&tab=3&subcat=Sun%20Ray%20Clients.

[83] Based on information provided by Sun Microsystems on May 17, 2007.

C. IDENTIFICATION OF RELEVANT COSTS

1. Work Stations

Strictly relevant costs involving the workstations are considered in this cost comparison. This is the only hardware and software area where one model is completely different than the other model. The relevant costs for workstations includes the total cost of purchasing PC workstations ($56,882.80) and the total cost of purchasing UTC workstations ($38,333.75). However, the workstations will be compared using different refresh rates. PC workstations will be costed with a three year refresh rate and UTC workstations at six and nine year refresh rates to give a conservative and optimistic comparison. It is important to point out that although sixteen PCs are provided by NCTSS and seven PCs are provided for GCCS-M, they are not included in the hardware cost calculations as they are designated as PC-only systems due to software restrictions and the classified nature of their operations.

2. Servers

The only relevant costs involving the servers are the total costs associated with acquiring and installing the Sun Fire servers ($41,709.60). Since the installation costs are unknown, they are not quantified but noted as an additional expense that must be added in the case that the UTC model is adopted. The refresh rate for the blade servers as well as the Sun Fire servers will be calculated at three years.

3. Software

Software costs involving the addition of the Sun Ray 2 UTC workstation and the Sun Fire servers to the CANES Lite blade server network are the only relevant software costs when comparing the two models. The COMPOSE costs will remain virtually the same. The only difference being that the COMPOSE Workstation software bundle switches to a server based software bundle with per seat user licenses being purchased rather than a copy of the software being installed on each workstation. The costs of the

Sun software include Sun Secure Global Desktop which costs $2,275.00 for the 65 workstations in the model and Sun Ray Software which costs $5,785.00 for 65 workstations.

D. COSTS COMPARISON

1. Hardware and Software Costs

When comparing the costs of hardware for a PC workstation to a UTC workstation, the difference came to $374.37 per workstation in favor of the UTC workstation ($875.12 per PC - $500.75 per UTC). Since the DDG platform used in this analysis is to be equipped with sixty-five workstations, the hardware cost for PC workstations totals $56,882.80 per install or refresh. Likewise, the cost for 65 UTC workstations totals $32,548.75. This thin-client hardware cost does not include the price of the four Sun Fire servers ($10,427.40 each) which increases the total initial installation hardware cost for a UTC network to $74,258.35 [$32,548.75 + (4 servers * $10,427.40 each)].

For software, the relevant costs include those required to run the UTC workstations and thin-client servers. These programs include Sun Ray Software and Sun Secure Global Desktop. The Sun Microsystems operating system, Solaris, is free open-source software and it is provided with the Sun Fire servers. The costs for Sun Ray Software and Sun Secure Global Desktop software are $89 and $35 per client, respectively. For 65 clients, the total thin-client software cost totals $8,060 [($89 * 65) + ($35 * 65)]. Thus, the $8,060 is the additional software cost incurred when implementing a UTC network. This brings the total initial hardware costs to $56,882 for PC workstations in the CANES Lite network model and $82,318.35 for the additional hardware and software required by the UTC network model.

2. Refresh Costs

The relevant annual cash outlays for hardware and software in each network model and their refresh requirements (PC 3-year lifespan, UTC 6-year lifespan, and UTC

9-year lifespan) are illustrated in Table 15. The total expenditures for hardware over a ten-year period totals $227,531.20 (2007 dollars) for PC workstations and $248,055.90 (2007 dollars) for thin-clients. The thin-client amounts include all hardware and software costs associated with both the UTC workstations and their servers. The only relevant CANES Lite network cash outlays listed in Table 15 are those associated with the PC workstations, which are replaced (refreshed) on a three-year cycle.

Total Relevant Cost Cash Outlays			
Year	**CANES Lite (PC) Network**	**UTC Network (6-year)**	**UTC Network (9-year)**
1	$ 56,882.80	$ 82,318.35	$ 82,318.35
2			
3			
4	$ 56,882.80	$ 41,709.60	$ 41,709.60
5			
6			
7	$ 56,882.80	$ 82,318.35	$ 41,709.60
8			
9			
10	$ 56,882.80	$ 41,709.60	$ 82,318.35
Total	**$227,531.20**	**$248,055.90**	**$248,055.90**

Table 15. Relevant Hardware and Software Cash Outlays (First Ten Years)

3. Energy Costs

The UTC network model offers a distinct energy cost savings over the blade server network model. Even with the addition of the four Sun Fire servers, the UTC network model saves an estimated 53,227 kilowatt hours annually over the PC blade server model. Those 53,227 kilowatt hours equate to an estimated $8,833 (2007 dollars) in annual savings per DDG based on a $0.16595 electrical rate.[84] This savings only represents the difference between powering a blade server model network and a UTC model network. It does not consider other possible energy savings such as from the

[84] Electric Rate Comparison Information (2007, January). Retrieved May 18, 2007, from JEA - Quarterly Electric Rates Web site: http://www.jea.com/services/electric/rates_quarterly.asp.

reduced use of air conditioning due to the smaller amount of heat generated by the Sun Ray client compared to the Dell Optiplex workstation. The energy cost savings calculations are listed in Table 15.

Ultra-Thin-Client Annual Energy Savings							
Component	**Number of Units**	**Kilowatts**	**Weekly Hours of Use (1)**	**Weeks in Year**	**Kilowatt Hours per Year**	**Electric Rate per Kilowatt Hour (2)**	**Cost of Electricity Annually**
Dell Optiplex PC Workstation	65	0.22	100	52	74,360	$0.16595	$12,340.04
Dell 17" Flat Panel Monitor	65	0.04	100	52	13,520	$0.16595	$2,243.64
Total	130	0.26	200	104	87880	$0.16595	**$14,583.69**
Sun Ray 2 Client	65	0.004	100	52	1,352	$0.16595	$224.36
Sun 17" Flat Panel Monitor	65	0.042	100	52	14,196	$0.16595	$2,355.83
Sun Fire X4200 M2 Server	4	0.55	167	52	19,105	$0.16595	$3,170.44
Total	134	0.596	367	156	34652.8	$0.16595	**$5,750.63**
Cost Savings Using Thin-Client Model							
PC Model	$14,583.69						
TC Model	$5,750.63						
Annual Savings	**$8,833.05**						
(1) The hours that workstations and monitors are powered on onboard a ship is estimated at 100 hours per week. The weekly hours of server operation are estimated at 167, with one hour of downtime for maintenance.							
(2) The electric rate used is $0.16595 per kilowatt hour. This rate used is the average rate for San Diego Gas and Electric in a quarterly survey conducted in January 2007 by Jacksonville Energy Authority (JEA).[85]							

Table 16. Ultra-Thin-Client Energy Cost Savings

[85] Electric Rate Comparison Information (2007, January). Retrieved May 18, 2007, from JEA - Quarterly Electric Rates Web site: http://www.jea.com/services/electric/rates_quarterly.asp.

4. Administration/Manpower Costs

The largest benefit due to overall cost savings with a UTC network is reduced administration costs. The number of network administrators can normally be greatly reduced because of the very low maintenance involved with the UTC workstations. As addressed in Chapter II, the UTC workstations, unlike the PC workstations, are plug-and-play and can be maintained by the work center rather than by network administrators. It is very unlikely that network administrators on U.S. Navy ships could realize reductions to the extent that Sun Microsystems was able to attain with the implementation of their Sun Ray UTC network. However, it is likely that a 19% reduction in network administrators could be achieved as benchmarked by Gartner Group and utilized by Burton Group in their thin-client studies.[86]

5. Intangible Benefits

There are many cost differences between adopting a standard blade server network model and a UTC network model that are extremely hard to quantify, particularly in a shipboard environment. One intangible benefit that is of particular importance on a ship is the reduced footprint/space and weight savings. In the case of both space and weight, the UTC client network model is the clear winner. Although the monitor size and weight does not vary much between the two models the size and weight of the workstations does. The Sun Ray 2 client takes up only about 13.4% of the space of a Dell Optiplex mini-tower. The Sun Ray 2 client with stand is 3.76” (W), 8.46” (D), 8.58” (H), and weighs 2.21 lbs. The Dell Optiplex mini-tower PC is 16.2” (H), 7.4” (W), and 17” (D). The weight of the mini-tower, at approximately 30.5 lbs, varies depending on options installed, but is clearly much heavier than the Sun Ray 2 clients regardless of its configuration. The Sun Fire servers do not take up any addition shipboard space because they are housed in common server racks with the blade servers. Each Sun Fire server adds 56.2 lbs., including the rack kit.

[86] Chris Haddad & Doug Simmons (2004, December 22). Thin Client Architecture Study, p. 73.

A second benefit that is very difficult to quantify is security. The added layers of security UTC networks provide in preventing both data corruption and data theft is significant. In addition to data security, the relative uselessness of a UTC not connected to a UTC network makes the workstation itself of no real value for property theft.

6. Risks

Along with all the benefits comes one significant possible risk of implementing a UTC network – network failure or downtime. Since UTC workstations are only display devices and all actual computing and storage of data takes place at the server, any time a server is down all workstations connected to that server are also down and data is inaccessible. The risk involved with a server failure must be carefully considered, as it may be too much to bear in a shipboard environment.

Software compatibility is also an area of risk for thin-client networks in a shipboard environment. The U.S. Navy may have software versions currently used on ships not a part of COMPOSE that may not function, or not function well, on a thin-client network. Until all software used on ships is written to operate in a server-based computing environment it must be an area of concern that is considered prior to UTC network implementation.

7. Final Cost Comparison

After individual analysis, each of the components in the cost models was placed into one of two categories: costs or benefits. The costs listed in Table 17 reflect those relevant cash outlays that are used to pay for the additional hardware and software required for a UTC network with a six-year lifespan. The benefits include what would have been the cost of installing or replacing 65 PC workstations plus the additional savings associated with the reduced annual energy consumption of a UTC network ($8,833). These annual costs and benefits were discounted using a beginning-of-the-year discount factor of 7% (as directed by the Office of Management and Budget in Circular

Number A-94) to determine the Present Value (PV) of each. To determine the present value of an amount with payments being made at the beginning of each period, the following formula is used:

$$\text{PV} = \frac{\text{FV}}{(1+i)^{n-1}}$$

Where: FV = future value of a given amount

i = the interest rate; and

n = the number of periods

A beginning-of-the-year format for calculating the PVs of the costs and benefits was chosen because the model assumes that the expenditures for the purchase of the network materiel will occur at the beginning of the fiscal year as is customary in defense contract financing.

Then PVs were summed to get the annual Net Present Value (NPV) of the additional costs or benefits/savings.[87] The annual figures were calculated for ten years and then totaled to give the total NPV of implementing a UTC network with a 6-year lifespan.

[87] Office of management and budget circular no. A-94 (1992, October 29). Retrieved May 20, 2007, from Office of Management and Budget Web site: http://www.whitehouse.gov/omb/circulars/a094/a094.html#8.

Beginning of Year Discounted Costs vs. Benefits of UTC (Six-Year) Plan						
Year	Costs	Benefits	Discount Rate	Discounted Costs (Present Value)	Discounted Benefits (Present Value)	Discounted Net (Present Value)
	C	B	R	C*R	B*R	B*R-C*R
1	$82,318	$65,716	1.0000	$82,318	$65,716	$(16,603)
2	-	$8,833	0.9346	-	$8,255	$8,255
3	-	$8,833	0.8734	-	$7,715	$7,715
4	$41,710	$65,716	0.8163	$34,047	$53,644	$19,596
5	-	$8,833	0.7629	-	$6,739	$6,739
6	-	$8,833	0.7130	-	$6,298	$6,298
7	$82,318	$65,716	0.6663	$54,852	$43,789	$(11,063)
8	-	$8,833	0.6227	-	$5,501	$5,501
9	-	$8,833	0.5820	-	$5,141	$5,141
10	$41,710	$65,716	0.5439	$22,687	$35,745	$13,058
Total	$248,056	$315,861		$193,905	$238,542	$44,637

Table 17. Ultra-Thin-Client Network Net Present Value (Six-Year Refresh)

The comparison of the costs and benefits associated with implementing a UTC network instead of the proposed PC based CANES Lite network show that, while more expensive at the onset, it is a cost-effective and beneficial plan to pursue. The calculations show that, despite having a negative NPV in years one and seven, the sum of the discounted annual costs and benefits results in a positive total NPV of $44,637 in the first ten years alone. This figure does not take into account the additional savings that would result from the estimated 19% reduction in administration and maintenance costs as benchmarked in the Gartner thin-client network study.[88]

The same cost components and discount rates utilized in the cost and benefit analysis of the UTC network 6-year refresh rate model were also used in the UTC network 9-year refresh rate model, with the exception of the UTC workstation refresh costs occurring at the beginning of year ten instead year seven. The results, displayed in Table 18, show negative NPVs associated with the initial investment in year one and the UTC workstation refresh at the beginning of year ten. Overall, implementing a UTC network with a nine-year workstation refresh rate achieves a positive NPV of $49,608 during the first ten years, without considering the estimated 19% reduction in

[88] Chris Haddad & Doug Simmons (2004, December 22). Thin Client Architecture Study, p. 73.

administration and maintenance costs. Once again, based purely on long-term savings, implementing a UTC network proves to be more cost effective than implementing the proposed CANES Lite blade server network model.

Beginning of Year Discounted Costs vs. Benefits of UTC (Nine-Year) Plan						
Year	Costs	Benefits	Discount Rate	Discounted Costs (Present Value)	Discounted Benefits (Present Value)	Discounted Net (Present Value)
	C	B	R	C*R	B*R	B*R-C*R
1	$82,318	$65,716	1.0000	$82,318	$65,716	$(16,603)
2	-	$8,833	0.9346	-	$8,255	$8,255
3	-	$8,833	0.8734	-	$7,715	$7,715
4	$41,710	$65,716	0.8163	$34,047	$53,644	$19,596
5	-	$8,833	0.7629	-	$6,739	$6,739
6	-	$8,833	0.7130	-	$6,298	$6,298
7	$41,710	$65,716	0.6663	$27,793	$43,789	$15,996
8	-	$8,833	0.6227	-	$5,501	$5,501
9	-	$8,833	0.5820	-	$5,141	$5,141
10	$82,318	$65,716	0.5439	$44,776	$35,745	$(9,031)
Total	$248,056	$315,861		$188,934	$238,542	$49,608

Table 18. Ultra-Thin-Client Network Net Present Value (Nine-Year Refresh)

8. Recommendation

Based on the cost-benefit analysis, implementing a UTC version of the CANES Lite network is the better option of the two networks, however, the risks must be weighed against the benefits. The risk involving possible incompatible software or software systems appears to be an easy risk to overcome. To accommodate those few workstations that require running incompatible software or access to an incompatible software system, PC workstations can be used in place of UTC workstations. Although overall hardware, software and administration costs would increase slightly, a UTC network can operate with PCs as workstations. For instance, if 20% of network users require access to software that requires the use of a PC, an 80% UTC / 20% PC solution can be utilized on the UTC network. In the case of the UTC workstations not being functional if the network is down, an 80% UTC / 20% PC solution may alleviate that risk as well. If the network is down, neither PC workstations nor UTC workstations would be able to utilize any intranet or internet resources, however, 20% of workstations would still be able to provide non-network PC functions.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSION

A. PROJECT SUMMARY

This project considered whether or not thin-client network computing is a feasible and cost-effective alternative to the standard PC-based networks found onboard Navy surface ships. The findings from the literature review indicate that although thin-client computing was nearly obsolete in the 1980s, its strong resurgence since the mid-1990s was largely due to its attributes of having a low total cost of ownership, a small footprint, and low maintenance requirements. The report went on to describe the general characteristics of a thin-client network in terms of hardware, software, and design.

Thin-client networks operate in much the same way that the "dumb terminals" did during the start of network computing in the late 1970s and 1980s. The network of thin-client users is governed by a central server or group of servers that carry out the routing calculations and processing that is normally processed by a standard personal computer's central processing unit. The server(s) then pass the output from the performed operation back to the client to be displayed on the monitor to which the client is attached. The thin-client along with the KVM set serve as the conduit for the end-user's input and output as he or she conducts business via the server's built-in applications. Data streams can also be sent directly to the network's centralized printer(s) from the server rather than back across the intranet, saving time and network bandwidth.

This report presented background information on thin-client network computing with a description of the most common advantages and disadvantages associated with thin-clients. Among the advantages discussed were fewer network administrative costs and ease of maintenance, enhanced security, minimal hardware costs in terms of the clients themselves, decreased energy costs, smaller footprint and lower bandwidth use. Potential disadvantages include the increased server requirements, poor multimedia application performance, and the single point of failure that is inherent in a centralized server-based network as the major problems associated with thin-client networks.

This study also discussed the different types of networks used aboard Navy surface ships today. The shipboard networks discussed included ISNS, SCI ADNS, and CENTRIXS. The proposed shipboard network described in this report was CANES Lite. A modified version of this network, the CANES Lite suite, was used as the frame upon which the alternative UTC network could be established. It was used to determine costs for both the PC- and UTC-based network solutions in this project. Based upon the implied success of the Sea-Based Battle Lab on USS *Coronado*, and from the information gathered during the literature review for this study, it can be shown that thin-clients are compatible with most of the applications used in each network system examined. However, the only way to know for sure is to actually install UTCs and their servers in an afloat network for real-time operational testing with a ship's information systems.

During the course of our research, two main models of thin-clients were examined, the Wyse S90 and the Sun Ray 2. The HP Compaq †5000 series thin-client was also discussed but a unit was not available for operational testing and was not included as hardware in any of the actual estimated pricing of networks in this report. Of the two thin clients that were examined, the Sun Ray 2 is the better option for use in an afloat network. One of the factors that led to this conclusion is that there is more maintenance associated with the Wyse S90 clients than the Sun Rays. The Wyse clients have an embedded operating system that requires periodic updates, whereas the Sun Ray clients have no internal software and therefore do not require updates or maintenance. Furthermore, the Sun Ray clients have previously been certified by the Navy for shipboard use in the CENTRIXS system.

The costs associated with adding Sun Ray 2 clients and their corresponding Sun Fire servers to the CANES Lite blade server network were compared to the price of the same blade server network utilizing Dell Optiplex GX520 PC workstations. When the NPV of both the six- and nine-year UTC lifespan options were evaluated along with the other attributes associated with UTC networks, it became clear that UTCs present a more cost-effective and feasible long-term alternative to PC-based networks and should be viewed as a viable option for shipboard use.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Due to funding and time constraints several shipboard software systems were not tested on a UTC network and UTCs were not tested in a shipboard environment. Consideration should be given to locating a sponsor interested in providing funding and access to test current UTC systems with all software systems utilized through an afloat network. Testing of UTC networks should also be accomplished onboard a U.S. Navy ship to determine with absolute certainty if they are in fact feasible for shipboard use.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A. CANES LITE DDG COST MODEL

COMPONENT	VENDOR/ MANUFACTURER	MODEL #	SUB COMPONENT QTY	UNIT PRICE	DDG	
					GigE Full LAN - A(V)9	
					Qty.	Cost
ROUTERS						
Cisco 2851 Router					2	
Cisco 2851 Router	GTSI / Cisco	CISCO 2691	1	$3,896.87	2	$7,793.74
Module, Four (4) Port Fast Ethernet Switching Module		HWIC-4ESW	1	$254.99	2	$509.98
Serial Card, Two (2) Port Serial Card		WIC-2T	1	$419.99	2	$839.98
Module, 2-Port Serial WAN Interface Card	GTSI / Cisco	WIC-2T	1	$ -	2	$ -
Maintenance, SMARTnet 8x5xNBD High Perf., 10/100 Dual Eth Router, 3-year Warranty	GTSI / Cisco	CON-SNT-269XXR	1	$1,125.00	2	$2,250.00
SUBTOTAL Cisco 2691 Router				**$5,696.85**		**$11,393.70**

<u>SWITCHES</u>						
OMNI-3WX Switch (For ATWCS/ADS)					2	
OMNI-3WX (3 slots) Wide version, built-in 150W power supply and rack-mount brackets.	Onix Networking Corporation	111-32100	1	$1,440.00	2	$2,880.00
Kit, Rugged 3WX/MILAN 9100 Rackmount (For ATWCS/ADS)	Onix Networking Corporation	MPM-1GW-56MD-12MF	1	$4,920.00	2	$9,840.00
Switch Management Module	Onix Networking Corporation	MPM-1GW-56MD-12MF	1	$3,205.00	2	$6,410.00
32 port 10/100 Ethernet Module	Onix Networking Corporation	ESM-100C-32W-2C	1	$3,645.00	2	$7,290.00
SUBTOTAL OMNI-3WX SWITCH				**$13,210.00**		**$26,420.00**
ALCATEL 6850-48 Switch (Edge)					2	
OS6850-48 Chassis	TBD	OS6850-48	3	$4,060.01	6	$24,360.06
OS6850-BPS(3) - Redundant Power Supply			3	$287.35	6	$1,724.10
Power Cord for OS6850-BPS		PWR-CORD-US	3	$ -	6	$ -
OS6850-P48 - Chassis, Power Over Ethernet (POE)			1	$4,662.68	2	$9,325.36
OS6850 P48-BPS - Redundant Power Supply, POE			1	$403.44	2	$806.88
MINIGBIC-SX (16)		MiniGBIC-SX	16	$200.27	32	$6,408.64
SUBTOTAL ALCATEL 6850 SWITCH				**$9,613.75**		**$42,625.04**

ALCATEL 9700 Switch (Backbone)					4	
OS9700-RCB-FED		OS9700-RCB-FED	1	$16,236.58	4	$64,946.32
OS9-GNI-U24		OS9-GNI-U24	2	$8,124.09	8	$64,992.72
OS9-GNI-C24		OS9-GNI-C24	3.5	$4,641.09	14	$64,975.26
MINIGBIC-SX (60)		MiniGBIC-SX	36	$200.27	144	$28,838.88
100FX SFP (36)			12	$229.29	48	$11,005.92
Switch Software (Included in Switch Price)			1	$ -	2	$ -
Omni-Vista 2000 Basic, Single User		OV2520-BSU	1	$2,899.59	4	$11,598.36
SUBTOTAL 9700 Switch (Backbone) SWITCH				**$61,589.37**		**$246,357.46**
ALCATEL 6850-48 Switch (Switch for inside Server Racks)					4	
OS6850-48 Chassis	TBD	OS6850-48	1	$4,060.01	4	$16,240.04
OS6850-BPS(3) - Redundant Power Supply			1	$287.35	4	$1,149.40
Power Cord for OS6850-BPS		PWR-CORD-US	1	$ -	4	$ -
MINIGBIC-SX (16)		MiniGBIC-SX	4	$200.27	16	$3,204.32
SUBTOTAL ALCATEL 6850 SWITCH				**$4,547.63**		**$20,593.76**
POE (Power over Ethernet) Injectors ~ for Unclass Backbone Switch racks on A(V)9 only					2	
24 Port POE Injector from 3COM	NETAPP		1	$900.00	2	$1,800.00
SUBTOTAL Storage				**$900.00**		**$1,800.00**

WIRELESS LAN DROPS EQUIPMENT (HARDWARE + SOFTWARE)					52	
Access Point (3ETI)		OS9700-RCB-FED	varies	$1,938.00	22	$42,636.00
IDS Sensor		OS9-GNI-U24	varies	$1,200.00	6	$7,200.00
IDS Server Software		OS9-GNI-C24	1	$7,000.00	1	$7,000.00
Client Security Software		OS9-GNI-C24	1	$2,000.00	1	$2,000.00
WLAN Card (Per Client)		MiniGBIC-SX	varies	$70.00	52	$3,640.00
RF Manager Security Software			1	$3,281.00	1	$3,281.00
SUBTOTAL Wireless LAN Drops Equip.						**$65,757.00**
<u>**BLADE SERVERS**</u>						
BLADE SERVER CHASSIS (IBM Telco Equipment)					**4**	
IBM eServer BladeCenter™ T Chassis AC Powered Models		87302RU	1	$6,460.00	**4**	$25,840.00
Nortel L2-3 GbE Switch Module (Copper)		32R1860	2	$1,715.00	**8**	$13,720.00
4 Gbps SW SFP Transceiver 4 Pack		22R4897	2	$385.00	**8**	$3,080.00
IBM BladeCenter™ T 1300W AC Power Supply Modules		32R0834	4	$1,259.00	**16**	$20,144.00
Hardware integration - BladeCenter		58P8676	1	$200.00	**4**	$800.00
Low Profile Handle for LS20 IBM eServer BladeCenter		25R7748	4	$40.00	**16**	$640.00
Qlogic iSCSI Expansion Card		32R1923	4	$513.00	**16**	$8,208.00
DPI 30AMP/250V FRONT-END PDU WITH NEMA L6-30P		39Y8939	2	$284.05	**8**	$2,272.40
SUBTOTAL ISNS GigE LAN SERVERS				**$19,244.20**		**$74,704.40**

ISNS GigE LAN SERVERS - IBM Telco Blade Servers - Model: LS20 Processor: AMD Opteron 2.6 GHz - RAM: 4GB Per Blade Server					**32**	
LS20, AMD Opteron Dual Core 275 2.6 GHz/1GHz, 1MB L2, 2x512MB, O/Bay U320		885066U	1	$2,099.00	**32**	$67,168.00
AMD Opteron Dual Core 2.6 GHZ /1GHz 1MB L2, Processor Model 275		25R8895	1	$769.00	**32**	$24,608.00
2 GB (2x1GB Kit) PC3200 CL3 ECC DDR VLP SDRAM RDIMM		39M5849	2	$701.00	**64**	$44,864.00
IBM 36.4 GB SFF Non Hot-Swap U320 10K SCSI Drive		40K1037	2	$226.00	**64**	$14,464.00
SUBTOTAL ISNS GigE LAN SERVERS - IBM Blade Servers				**$4,722.00**		**$151,104.00**
STORAGE					4	
NETAPP Filer (Configured as a concurrent NAS/SAN)	NETAPP		2	$32,000.00	8	$256,000.00
OSSV Software (Open System Snap Vault)			2	$10,000.00	8	$80,000.00
SUBTOTAL Storgae				**$84,000.00**		**$336,000.00**
WORKSTATIONS						
Dell Optiplex GX520					**65**	
Dell Optiplex GX520 P4 2.4GHz, 512MB SDRAM, 40GB HDD, Scroll Mouse, 40X CDRW, Win2000, Speakers, Keyboard, 3 Year on site CONUS/OCONUS Warranty.	Dell	Dell Optiplex GX270	1	$519.00	**65**	$33,735.00
RAM Upgrade to 512 MB NON-ECC 133 MHZ SDRAM (one chip)	Dell		1	$65.00	**65**	$4,225.00
RAM Upgrade to 1GB NON-ECC 533MHz SDRAM (Two Chips) Total of 1GB	Dell		1	$103.00	**65**	$6,695.00
Standard Keyboard	Dell		1	$5.00	**65**	$325.00
17" Viewable Flat Panel Monitor (1024x1024)	Dell		1	$183.12	**65**	$11,902.80
SUBTOTAL Dell Optiplex GX270				**$875.12**		**$56,882.80**

LAPTOPS						
Dell Latitude D610 Laptop					2	
Dell Latitude D610 Pentium M 1.8GHZ, 20GB HDD	Dell	Dell Latitude C640	1	$1,046.00	2	$2,092.00
RAM Upgrade to 1GB Non-ECC 133 MHz SDRAM	Dell		1	$71.00	2	$142.00
SUBTOTAL Dell Latitude C640 Laptops				**$1,554.00**		**$2,234.00**
PRINTERS						
HP4250N, Medium Speed BW Laser printer with 32mb of RAM	GTSI / HP	Q2426A-3YRHP		**$1,290.00**	29	**$37,410.00**
SERVER RACKS						
OJ-685C (V)G5 Server Rack (5 Server Design) - for all ISNS Configurations	FSC	**FS-RTI-17**	**1**	**$62,000.00**	**4**	**$248,000.00**
SWITCH RACKS						
Backbone Switch Rack (for 9700)					4	
Backbone Switch Rack w/ Router & Slices (12-port & 32-port)	FSC	FS-RTI-19	1	$41,000.00	2	$82,000.00
Backbone Switch Rack w/o Router & Slices (12-port & 32-port)	FSC	FS-RTI-18	1	$41,000.00	2	$82,000.00
SUBTOTAL Backbone Switch Rack						**$164,000.00**
Edge Switch Rack (for 6850) - 41" Rack						
Edge Switch Rack for A(V)9 with Transceiver	FSC	0205897-100	1	$34,000.00	2	$68,000.00
SUBTOTAL 41" Edge Switch Rack						**$68,000.00**
LOCKHEED MARTIN - RACK INTEGRATION & FEE						
Rack (COMPONENT) Integration Cost for G5 Server Racks	FSC	FS-RTI-19	1	$12,000.00	4	$48,000.00
Rack (COMPONENT) Integration Cost for Backbone Switch Racks	FSC	FS-RTI-19	1	$10,000.00	4	$40,000.00
Rack (COMPONENT) Integration Cost for Edge Switch Racks	FSC	FS-RTI-19	1	$7,500.00	2	$15,000.00
Lockheed Martin Q70 Material Handling, Program Support, G&A, and Fee	FSC	FS-RTI-18		21.4%		$319,715.65
SUBTOTAL Rack Integration						**$422,715.65**

SOFTWARE						
INM Pro Server Software					2	
Windows 2003 Enterprise Server	GTSI / ASAP	P72-00122	1	$1,576.21	2	$3,152.42
WINZIP 10.0	GTSI / ASAP	WINZIP10	1	$26.00	2	$52.00
WS-FTP Pro Ver 2006	GTSI / ASAP	WS-8003	1	$12.50	2	$25.00
Backup Exec 10.1 (D) Server	GTSI / ASAP	A180498-0LE000	1	$383.04	2	$766.08
Backup Exec 10.1 (D) Server Open File Option Agent w/ CAL	GTSI / ASAP	A180528-0LE000	1	$431.19	2	$862.38
SMS - SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART / Microsoft	271-02374	1	$857.40	2	$1,714.80
HP OpenView Network Node Manager (v7.5/8.0)	GTSI / ASAP	J5322BA	1	$9,300.00	2	$18,600.00
SUBTOTAL INM Pro Server Software				**$12,586.34**		**$25,172.68**
SOA (Service Oriented Architecture) SW Procurement ~ SWAG	GTSI / HP	Q2426A-3YRHP	1	**$190,000.00**	1	**$190,000.00**
Other COMPOSE Server Software					1	
Technet Subscription Rev A	GTSI / ASAP	323-04487	1	$380.00	1	$380.00
Windows 2K/2K3 Server ResKit	GTSI / ASAP	1-57231-805-8	2	$460.00	2	$920.00
Windows 2K/2K3 Pro ResKit	GTSI / ASAP	0-7356-2167-5	2	$80.00	2	$160.00
SUBTOTAL Other COMPOSE Server Software				**$1,460.00**		**$1,460.00**

<u>COMPOSE SERVER SOFTWARE</u>						
7 Server CFG (per Server Rack) ~ COMPOSE 3.5 [DRAFT]					4	
Exchange 2003 Server Enterprise	GTSI/ ASAP	395-02873	1	$2,640.55	4	$10,562.20
Backup Exec 10.1 (D) Server	GTSI/ ASAP	A180498-0LE000	7	$383.04	30	$11,491.20
Backup Exec 10.1 (D) Server Open File Option Agent w/ CAL	GTSI/ ASAP	A180528-0LE000	7	$431.19	30	$12,935.70
Backup Exec 10.1 (D) Exchange Agent W/ CAL	GTSI/ ASAP	A180618-0LE000	1	$479.34	4	$1,917.36
ISA 2004 STD (per processor)	GTSI/ ASAP	E84-00537	2	$1,710.22	8	$13,681.76
Windows 2003 Enterprise Server	GTSI/ ASAP	P72-00122	7	$1,576.21	30	$47,286.30
WINZIP 10.0	GTSI/ ASAP	WINZIP10	7	$26.00	30	$780.00
WS-FTP Pro Ver 2006	GTSI/ ASAP	WS-8003	7	$12.50	30	$375.00
SMS - SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART/ Microsoft	271-02374	7	$857.40	30	$25,722.00
MICROSOFT OPERATIONS MANAGER (MOM) Ops Mgr Serv Enterprise 2005 w/SQL Tech	SOFTMART/ Microsoft	A8L-00007	1	$858.13	4	$3,432.52
SQL Svr Enterprise Ed 2005	SOFTMART/ Microsoft	810-04745	1	$5,570.18	4	$22,280.72
MOM Ops Mgr Serv Enterprise 2005 w/SQL Tech	SOFTMART/ Microsoft		1	$279.83	32	$8,954.56
SUBTOTAL 7 Server Config				**$35,973.02**		**$159,419.32**
<u>COMPOSE Workstation Software</u>						
User Workstation (COMPOSE 3.5)					2	
WINDOWS 2003 CAL (DEVICE)	GTSI/ ASAP	R18-00041	1	$18.99	2	$37.98
EXCHANGE 2003 CAL	GTSI/ ASAP	381-01836	1	$43.00	2	$86.00
OFFICE 2003 PRO	GTSI/ ASAP	269-06826	1	$309.43	2	$618.86
WINZIP 10.0	GTSI/ ASAP	WINZIP10	1	$13.00	2	$26.00
WS-FTP PRO VER 2006	GTSI/ ASAP	WS-8003	1	$12.50	2	$25.00
SQL CAL	GTSI/ ASAP	359-00608	1	$96.17	2	$192.34
SYS Mgmt Svr Ent Ed 2003 R2 w/SQL Tech	SOFTMART/ Microsoft		1	$26.82	2	$53.64
SQL Svr Enterprise Ed 2005	SOFTMART/ Microsoft	359-00608	1	$96.17	2	$192.34
SUBTOTAL User Workstation				**$616.08**		**$1,232.16**

Production Engineering						
SSC Proc Fee				**2.9%**		$13,997.87
Prod Eng General MR				**3.0%**		$68,891.98
SUBTOTAL Production Engineering						**$82,889.84**
SUBTOTAL Procurement Items			HW + Production Engineering			$2,379,289.01
01 Procurement Withholds (2.5% of Install Cost)				**2.5%**		**$59,482.23**
Switch-to-Switch Cabling Material and Labor						
Backbone Links - Qty Fiber - SM 8 Strand						
- Qty Fiber - MM 8 Strand					12	
- Qty Fiber - MM 4 Strand						
- Qty UTP/STP						
Fiber (300 ft per link) - 8 strand Multi Mode			MM 8 Strand Fiber	$6.51	12	$23,436.00
Stainless Connectors			(SM 8 Strand Fiber + MM 8 Strand Fiber + MM 4 Strand Fiber) * 4	$25.00	72	$1,800.00
Cable Labor (per link of 300 ft)			SM 8 Strand Fiber + MM 8 Strand Fiber + MM 4 Strand Fiber + UTP/STP	$1,200.00	12	$14,400.00
Fiber Connector Labor (per connector)			((SM 8 Strand Fiber + MM 8 Strand Fiber + MM 4 Strand Fiber) * 4) + Zinc Connectors Qty.	$60.00	72	$4,320.00
SUBTOTAL (BB Link Cabling)						**$43,956.00**

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Becta ICT Research, (2006, November). Thin client technology in schools: case study analysis. Retrieved March 13, 2007, from Becta Government and Partners Web site: http://partners.becta.org.uk/index.php?section=rh&catcode=_re_rp_ap_03&rid=11414.

Boardman, Jill L. & Shuey, Donald W. (2004, April). *Combined enterprise information exchange system (CENTRIXS); supporting coalition warfare world-wide*. Retrieved May 1, 2007 from Air Force University Web site: http://www.au.af.mil/au/awc/awcgate/ccrp/centrixs.pdf.

Brachfeld, Lawrence J. (2001, August). *Network centric computing: a new paradigm for the military?* STINET. Retrieved on April 25, 2007 from: http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=A434186&Location=U2&doc=GetTRDoc.pdf.

Central Design Authority Team and Integration Test Facility, SPAWAR System Center, San Diego, (2006, June 21). *System integration testing (SIT) for Combined Enterprise Regional Information Systems - Maritime (CENTRIXS – M): Block II with MLTC v3.0*.

Condor High Throughput Computing. Idle Machine Statistics. Retrieved: April 22, 2007 from: http://www.cs.wisc.edu/condor/goodput/idle.html.

David, Barrie (2002, March 27). Thin client benefits. ThinClient.net. Retrieved March 13, 2007, from: http://www.thinclient.net/new_site/pdf/Thin_Client_Benefits_Paper.pdf.

Dell Inc., UltraSharp 1708FP flat panel LCD monitor. Retrieved April 17, 2007, from: http://accessories.us.dell.com/sna/productdetail.aspx?c=us&l=en&s=dhs&cs=19&sku=320-5294.

Ditch that shabby two-year-old PC (2000, February 3). PC World. Retrieved April 18, 2007, from: http://www.pcworld.com/article/id,15122-page,1/article.html.

Dix, John (2006, October 20). The benefits of thin clients. Network World. Retrieved April 5, 2007, from: http://www.networkworld.com/columnists/2006/102306edit.html.

Felisiak, Krysztof K. & Grunt, Pavel S. (2006). Evaluating thin-client computers for use by the Polish Army. Naval Postgraduate School thesis.

Greenberg, Steve Greenberg & Anderson, Christa (2001, September). Desktop energy consumption; A comparison of thin clients and PCs. Wyse Technology. Retrieved April 1, 2007, from: http://www.wyse.com/resources/whitepapers/energy.asp.

Haddad, Chris & Simmons, Doug (2004, December 22). *Thin Client Architecture Study*.

Hancock, David (2006, January 3). Thin client technology enhances security. TechLINKS. Retrieved April 19, 2007, from: http://www.techlinks.net/CommunityPublishing/tabid/92/articleType/ArticleView/articleId/3503/Thin-Client-Technology-Enhances-Security.aspx.

Hepner, Tom (2007, May 9). *CENTRIXS-M DIG background* Power Point presentation. SPAWAR Program Executive Office for Command, Control, Communications, Computers and Intelligence (PEO 41).

Hewlett-Packard Development Company, (2004, January). Thin client server computing: Benefit analysis. Hewlett-Packard. Retrieved March 18, 2007, from: http://h20202.www2.hp.com/Hpsub/downloads/HP%20-%20TC%20TCO%20Jan%2004.pdf.

Hines, Matt (2006, September 25). Vendors plug thin client as security elixir. eWeek Channel Insider. Retrieved April 10, 2007, from: http://www.channelinsider.com/article/Vendors+Plug+Thin+Client+as+Security+Elixir/189624_1.aspx?kc=CZNKT03119TX1K000059.

Kitagawa, Mikako; Margevicius, Mark A. & Silver, Michael A. (2004, August 17). *When Thin Clients Can Narrow Your TCO.*

Lai, Albert M. & Nieh, Jason (2006, May). On the Performance of Wide-Area. *ACM Transactions on Computer Systems.* Retrieved April 5, 2007, from http://portal.acm.org/citation.cfm?doid=1132026.1132029.

Landry, Kenneth J. (2006, June). The performance and compatibility of thin-client computing with fleet operations.

Lawton, Christopher (2007, January 30). 'Dumb terminals' can be a smart move. Wall Street Journal.

Lowber, P. (2001, September 28). Gartner Group: *Thin-Client vs. Fat-Client TCO*.

Naval Aviation Logistics Command information system for organizational maintenance activities (NALCOMIS OMA). Retrieved April 29, 2007, from Space and Naval Warfare Systems Center Norfolk -- Naval Tactical Command Support System (NTCSS) Web site: http://www.scn.spawar.navy.mil/products/NTCSS/nalcomis/brochures/nalcomisOMA.pdf.

Panduit Corporation (2007). Power over ethernet (PoE): Technology primer and deployment considerations. Retrieved May 5, 2007, from Power Over Ethernet (PoE) Web site: http://www.panduit.com/enabling_technologies/098749.asp.

Program Manager, Warfare (PMW) 160 (2006, June 20). Financial management and cost estimating support performance work statement White Paper. Retrieved May 4, 2007, Web site: http://www.anteon.com/seaport/document/879__39_Attachment_(1)_PWS_-_FINAL_-_6-20-06.doc.

Requirements to capabilities (2004). Retrieved April 29, 2007 from Vision Presence Power: A Program Guide to the U.S. Navy – 2004 Edition. Web site: http://www.chinfo.navy.mil/navpalib/policy/vision/vis04/vpp04-ch3.pdf.

Requirements to capabilities. (2002) Retrieved April 25, 2007, from Vision Presence Power: A Program Guide to the U.S. Navy - 2002 Edition Web site: http://www.navy.mil/navydata/policy/vision/vis02/vpp02-ch3y.html.

RSupply: Relational supply. Retrieved April 25, 2007, from Space and Naval Warfare Systems Center Norfolk -- Naval Tactical Command Support System (NTCSS) Web site: http://www.scn.spawar.navy.mil/products/NTCSS/RSupply/RSupplybrochureNorfolk.pdf.

SearchSMB.com (2006, January 3). SearchSMB.com Definitions. Retrieved February 13, 2007, from SearchSMB.com Web site: http://searchsmb.techtarget.com/sDefinition/0,,sid44_gci1155689,00.html.

Program Manager, Warfare (PMW) 160 (2006, September 29). Server Concepts and Integration White Paper.

Shah, Dharmesh (2006, May 28). The thin-client, thick-client cycle. Retrieved February 13, 2007, from http://onstartups.com/home/tabid/3339/bid/161/The-Thin-Client-Thick-Client-Cycle.aspx.

Sheldon, Tom (2001). Thin clients. In Encyclopedia of Networking and Telecommunications [Web]. Mc Graw-Hill. Retrieved March 14, 2007, from http://www.linktionary.com/t/thin_client.html.

SPAWAR Program Executive Office for Expeditionary Warfare Detection, Processing, and Navigation Systems Power Point presentation, (2000, August 23). *Network-centric computing: The network centric Q-70*.

SPAWAR System Center Charleston (2006, September 20). Software version description for COMPOSE version 3.0.0.1 revision 12.

Thinstore. Retrieved April 1, 2007, from: http://www.thinstore.net/.

Why buy thin clients?. Hewlett-Packard. Retrieved April 5, 2007, from: http://h20331.www2.hp.com/hpsub/cache/295747-0-0-225-121.html.

Wyse Technology, Winterm SX0. Wyse Technology. Retrieved April 5, 2007, from: http://www.wyse.com/products/winterm/S30/BackMount.htm.

Wyse Technology, Wyse S10. Retrieved April 5, 2007, from Wyse Technology Products and Services Web site: http://www.wyse.com/products/winterm/S10/index.asp.

Zojwalla, Shaheen & Erickson, Jon (2006, October 3) The Total Economic Impact of Deploying Sun Ray Technology. Retrieved May 14, 2007, from Sun.com Web site: http://www.sun.com/sunray/whitepapers/wp_tei_sun_ray.pdf.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dr. Douglas E. Brinkley, Commander, United States Navy (Retired)
   Graduate School of Business and Public Policy
   Naval Postgraduate School
   Monterey, California

4. John E. Mutty, Captain, United States Navy (Retired)
   Graduate School of Business and Public Policy
   Naval Postgraduate School
   Monterey, California