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THESIS

WIRELESS CLOUD COMPUTING ON GUIDED MISSILE DESTROYERS: A BUSINESS CASE ANALYSIS

by

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June 2013

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WIRELESS CLOUD COMPUTING ON GUIDED MISSILE DESTROYERS: A BUSINESS CASE ANALYSIS

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This is a Business Case Analysis of the cost and benefits of implementing a Wireless Cloud Computing Network (WCCN) onboard Guided Missile Destroyers (DDGs) utilizing tablet computers. It compares the life cycle costs of WCCNs utilizing tablet computers over a mixed network of thin clients and desktop computers. Currently, the Consolidated Afloat Networks and Enterprise Services (CANES) program will install both thin clients and desktops on board new and old DDGs to implement the unclassified portion of its network. The main cost benefits of tablets will be realized through energy savings and an increase in productivity. The net present value of tablets is expected to be considerably better than the current CANES configuration with the initial investment required for tablets breaking-even in five years if each sailor saves 22 seconds a day by having a tablet. Alternatively, the tablet configuration also breaks even in less than 6 years just considering operational costs alone. Sensitivity analysis on the cost of deferent types of tablet devices and the range of different productivity gains shows very limited downside from investing in tablets compared to considerable upside (depending on the productivity gains achieved in practice).

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LIST OF ACRONYMS AND ABBREVIATIONS

CANES	Consolidated Afloat Network Enterprise Services
CAT	Category
CCE	Common Computing Environment
DDG	Guided Missile Destroyer
ISNS	Integrated Shipboard Network System
kWh	Kilowatts per hour
LAN	Local Area Network
NPV	Net Present Value
PV	Present Value
SPAWAR	Space and Naval War Systems Command
U.S.	United States
USS	United States' Ship
WAP	Wireless Access Point
WCC	Wireless Cloud Computing
WCCN	Wireless Cloud Computing Network
WLAN	Wireless Local Area Network

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I. INTRODUCTION

A. OVERVIEW

The Navy along with the rest of the country is at a precipice, also known as the "fiscal cliff." Looming budget cuts threaten to bring the nation's military to its knees (Lopez, 2012). In a time of such financial uncertainty, it is imperative that our military determines what will save money in the long run. Mobile technology has quickly evolved in the civilian sector and is currently part of the Navy's information technology strategy (Takai, 2012). More and more businesses, large and small, in the U.S. are adopting tablet devices to raise productivity (Dimensional Research, 2011). The myriad of uses for wireless technology has created an inflection point for potential in our society; wireless cloud computing will allow us to minimize our installation and operation costs in the long run creating a more lean and productive force for the future.

The Navy is currently installing the CANES on its DDGs, which builds a network centric infrastructure utilizing approximately 25 wired thin clients, 91 desktop computers and 116 monitors (Carman, 2013). For ease of annotation I will refer to the current CANES approach as a hybrid network. CANES currently has a wireless capability but it will only be installed in a few common areas (Arbulu & Vosberg, 2007). By utilizing tablet devices in a completely wireless cloud computing (WCC) environment the Navy could significantly increase the versatility and productivity of its sailors and minimize its technology energy costs.

This thesis will show that cloud computing with tablet devices can be implemented at low cost, offers a fast pay back on the Navy's investment, and will only require modest assumptions about the productivity benefits of wireless use. Wireless computing removes the tethers from our technology devices and allows us a greater range of freedom to perform our duties. This thesis proposes that every sailor be provided a tablet device to alleviate the wait for limited computers. Onboard a Navy warship: time, space and computers are quite limited and wireless tablet devices will help us maximize all three of the constraints stated. Cloud computing with tablet devices will change the way we execute applications and minimize the amount of time it takes to update our networks. Cloud computing networks will help us to utilize the assets of our network more efficiently and broaden the use of bespoke Navy applications that could be created by the very people who use and operate the network, United States Sailors.

B. SUBJECT OF THE BUSINESS CASE

This is a Business Case Analysis of the costs and benefits of WCC on Guided Missile Destroyers. WCC will minimize the installation and operation costs on board DDGs as well as the refreshment costs of technology devices. A significant initial investment is required to create a purely wireless network and provide devices for every sailor. However, by utilizing tablets in a cloud computing network the Navy could experience significant productivity gains. The cost savings, due to productivity increase, could be transferred into long-term dividends in the form of innovation and effectiveness.

C. RESEARCH QUESTIONS

The research questions analyze both, the long-term monetary benefits and the intangible results of utilizing apps and tablet devices.

1. What are the costs and benefits of wireless cloud computing utilizing tablet devices over thin and thick clients on DDGs?
2. What are the productivity gains associated with a completely tablet driven wireless infrastructure that utilizes apps?

D. ORGANIZATION OF THE STUDY

Chapter II provides a detailed description of all the components necessary to build a WCC infrastructure and discusses a few of the poignant advantages and disadvantages of WCC. Chapter III details the business case for WCC onboard DDGs. Chapter IV discusses the difficulties of quantifying productivity and its effect on this thesis. Chapter V outlines the conclusion and recommendations of the thesis. Appendices A through C go into greater detail about how some of the calculations were executed for the business case analysis.

II. BACKGROUND

A. WIRELESS COMPUTING

1. Advantages

Wireless computing allows the user of the 21st century true mobility and freedom in computing. Wireless users are no longer tethered to their desks and chairs. The importance of wireless operation is even more apparent in a shipboard environment where flexibility and mobility are the epitomes of this military culture. The following advantages can be obtained from a wireless network onboard a ship:

a. Efficiency

Access to the network is provided to a greater number of workers at one time. With a wireless signal being broadcasted to a workspace of wireless users, everyone has the ability to access the work in their daily queue without having to wait for a wired desktop station to open.

b. Space

On board a DDG space is a limited commodity. Space requirements for a desktop will have to include the size of the keyboard, monitor and a sizable tower. Even with the use of a thin client, which only consists of a screen and a keyboard, space is still a concern. A tablet can be operated in one's lap or held by hand (see Figure 1) and utilizes an on screen keyboard or small portable Bluetooth keyboard that can be easily stored to conserve space (see Figure 2).

Figure 1. iPad Mini Physical Measurements (From Apple, 2013)

Figure 2. The Logitech Ultrathin Keyboard Cover (From Stein, 2012)

c. Survivability

Desktops have the potential to breakdown from time to time, which can halt work if one workspace depends on a few computers connected to the network in order to get work done. With a wireless connection, if the desktop connected to the network should break down there are still several wireless devices that are capable of accessing the network via wireless connection.

d. Mobility

Being able to start a wireless session in one space on a particular WAP and then continue that session in a completely different space on another WAP is called roaming. Roaming is the ability of a wireless device to determine the various strengths of the surrounding WAPs and choose the one with the strongest signal and then switch to that access point without an interruption in service (Wheat, Hiser, Tucker, & Neely, 2001).

e. Innovation

With the advent of tablet computers, such as the iPad, came the invention of apps. The word apps is short for applications but has come to describe the applications that are created specifically for mobile phones and tablet computers. Currently, the app store, which works solely with Apples mobile operating systems, contains over 900,000 apps. Most apps do different things and some of them do the exact same thing, just in a different way. Innovation has been a hallmark at the app store, spurring the creation of a myriad of apps that have the potential to make life easier.

The U.S. Army hosts a website aimed at highlighting the different apps they have created and made available through Apple's app store (see Figure 3). The apps that appear on the Army's website range from basic Army news to an app that helps soldiers find Army publications and messages specific to their jobs. The U.S Navy, Air force and Marine Corp all have a service app as well but they are only aimed at recruitment and generally provide no useable professional information to those already in uniform. Using these apps soldiers can tap into a lifeline of information that is pertinent to their careers and the best possible execution of their jobs.

Figure 3. Apps Made By The Army (From U.S. Army, 2013)

During the Iraq/Afghanistan wars a Marine helicopter pilot by the name of Captain Jim Carlson acted on an idea to make use of tablet technology. Capt. Carlson combined all the topographical maps he had, as a cobra attack helicopter pilot, and put them on his iPad. Capt. Carlson seamlessly connected the maps together and integrating his global positioning system signal on top of the maps allowing him to more quickly ascertain the relative location of requests for close air support. By utilizing his computer science degree and the capabilities provided by tablets he constructed an application that allowed him to do his job more efficiently and provide support to his fellow Marines on the ground (Kohlmann, 2012).

2. Disadvantages

a. Signal Shielding

One of the biggest disadvantages in wireless computing on ships is poor signal quality. The metal compartments of a ship can act like shielding causing the wireless signals to essentially remain in the compartment they originated from or haphazardly bounce out when there is an open corridor (Wheat et al., 2001). In order to overcome metal compartment penetration, more access points must be placed throughout a ship to ensure signal reliability, which can lead to high investment costs.

b. Security

Having a wireless system could increase incidents of cyber attack. The wireless spectrum is inherently susceptible to attack even with precautions being taken, such as network traffic encryption (Brenton & Hunt, 2002).

A DDG at sea, in certain situations, relies upon its stealth and the ability to hide its electronic emissions from certain parties. Creating an entirely wireless network will require WAPs to be placed outside the skin of the ship, which could be picked up by other vessels. However, detection by other vessels could be mitigated by the ability to hastily secure only the WAPs located outside the skin of the ship.

3. Wireless Computing Anatomy

a. Wireless Local Area Network (WLAN)

A wireless local area network is comprised of two or more wirelessly connected computer systems or printers that can share and transfer data with each other (LaBerta, 2011) (see Figure 4). Wireless LANs can replace wired LANs or be used as an extension of wired LANs (Zyren & Petrick, 1998). A simple LAN emphasizes a small geographic area over which computers and or peripherals are connected (LaBerta, 2011).

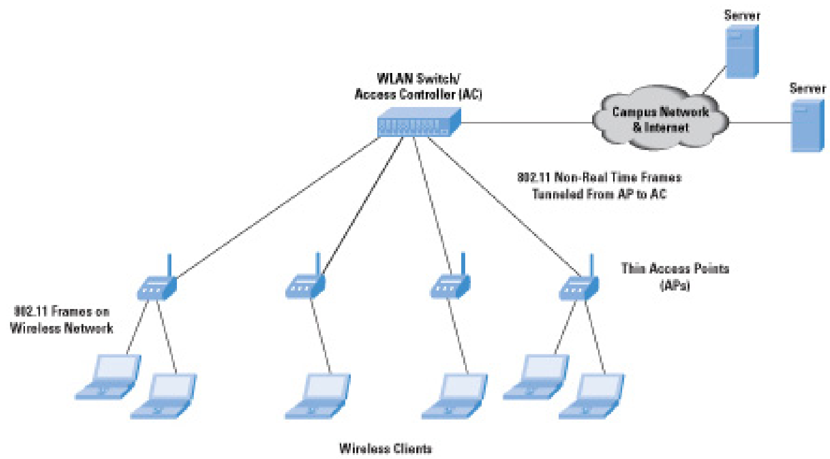

Figure 4. Simple WLAN Architecture (From Sridhar, 2006)

b. Router

A wireless router is a transfer station of information to and from the Internet (Feldman & Feldman, 2003). In a wireless network, wireless access routers, facilitate the transfer of information from computer to computer (Zyren & Petrick, 1998).

Wireless routers of today can transmit and receive data up to 1200 feet without wireless range extenders, also referred to as WAPs. Access points are much like wireless access routers however; they can only service devices on a single network. Access points can also be used to repeat the wireless signal it receives from the wireless router and extend the operational range of a Wireless Local Area Network (WLAN) (Needleman, 2012). Many wireless routers can function as either a wireless router or an access point.

B. CLOUD COMPUTING

Cloud computing works to deliver; applications, infrastructure and data, to the end user, like a service.

1. Cloud Computing Anatomy

Cloud computing behaves like a web server. A web server stores applications and files of importance on its hard drive allowing the client to access those applications by request. The web server allows access via an Internet or an intranet.

a. Thick Client

Thick clients are the traditional desktop computers that consist of a monitor, keyboard, and a central processing unit tower. Thick clients maintain and execute all applications and databases onboard the local central processing unit utilizing a traditional client server relationship (see Figure 5). Thick clients are normally associated exclusively with non-cloud server networks (Gillette, 2012).

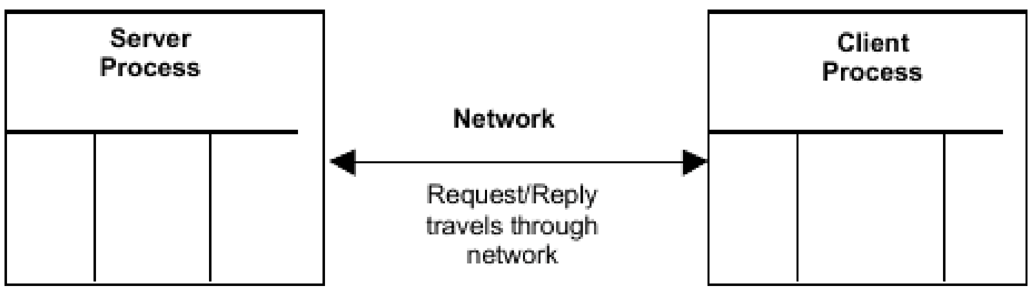

Figure 5. Client Server Relationship (From Yadav & Singh, 2009a)

b. Thin Client

Unlike thick clients, thin clients are completely dependent on the centralized server in the network, which provides them applications and data via a virtualized desktop (Boothe, 2012). A virtualized desktop looks and behaves just like a real one except; it is being executed by a local thin client on the network's centralized server. The thin client will utilize all the resources of the centralized server to perform all tasks. Figure 6 shows a virtual desktop being displayed on an iPad using Oracle's cloud computing software and servers.

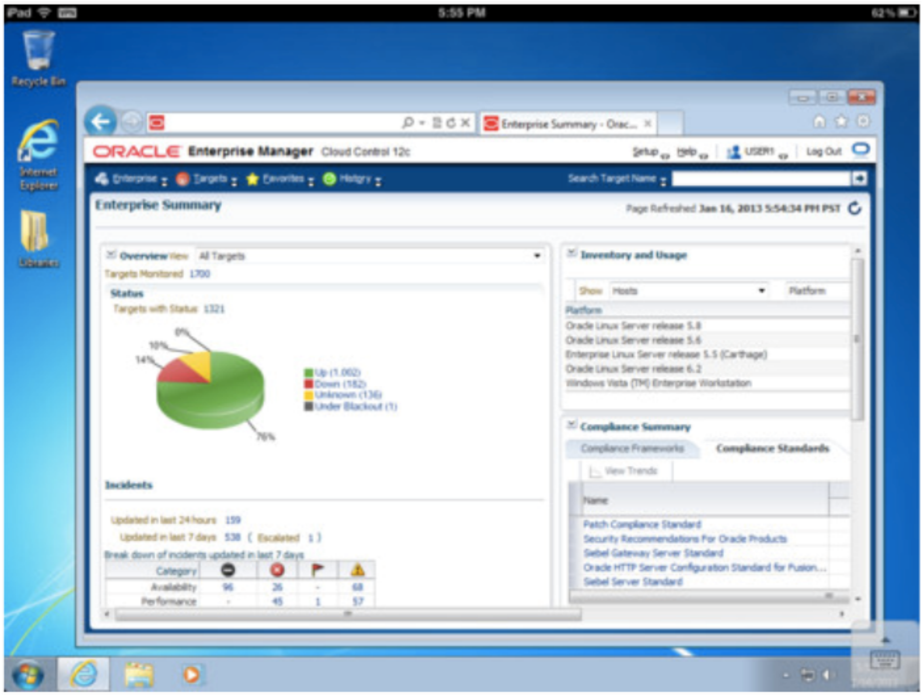

Figure 6. Oracle Cloud Server App Showing Virtual Desktop (From Oracle virtual desktop client app, 2013)

2. Advantages

a. Maintenance

Since all the applications and documents are maintained on the centralized server, whenever there are updates to be made, the server will undergo only one upgrade that will suffice for all the clients connected to that server (Yadav & Singh, 2009b). Due to the centralized software update process cloud computing is significantly more cost effective than the current network configuration onboard Navy vessels (Staehle, Binzenhoefer, Schlosser, & Boder, 2008). A Burton Group study referenced a Gartner benchmark figure of a 19% decrease in maintenance costs associated with thin client networks (Haddad & Simmons, 2004). The current configuration relies on the central storage and processing power of each individual thick client on the network, which retains all the necessary programs on the actual desktop computer.

b. Efficiency

The centralized server of a cloud computing environment will be the most powerful computer of the network, we will refer to the cloud computing server as a centralized server. As certain services are requested by the client all available resources of the server will be utilized, in the most efficient configuration, to supply the client because the server understands what it needs to run the entire network. Often on networks that rely on the computing power of the thick client to run applications, much of the power of the thick client is significantly underutilized. Currently, the network onboard a DDG exists in pieces that often do not talk with each other (Rognlie, 2010).

c. Disadvantages

Due to the network dependent nature of thin clients they require a continuous connection to the network. Depending on the sophistication of the thin client and the signal availability of the network a thin client could lose its connection and the data that it was utilizing on the network (John & Han, 2006).

C. INTEGRATED SHIPBOARD NETWORK SYSTEM

The Integrated Shipboard Network System (ISNS) is the current LAN employed onboard navy vessels that integrates existing pieces of hardware and software from several older systems to provide both unclassified and classified data to the Navy (U.S. Navy, 2005). ISNS utilizes thick clients and an antiquated client-server structure that requires the client to execute all of its applications within its own central processor.

D. CONSOLIDATED AFLOAT NETWORKS AND ENTERPRISE SERVICES

The CANES system will dramatically update the Navy's entire digital suite utilizing a mixture of wired thin client technology and thick clients. CANES consolidates several of the data networks onboard Naval warships however, in this thesis I will only discuss the part of the LAN that deals with everyday office computing tasks such as: email, word processing, power point presentations, excel spreadsheets and other unclassified documents. CANES will partially abandon the ISNS client-server model for a common computing environment that resembles a cloud computing infrastructure utilizing approximately 25 thin clients that will be capable of accessing both classified and unclassified networks (Carman, 2013; Gillette, 2012). The current proposed wireless portion of the CANES system will not ensure complete wireless coverage because most of the access is accomplished with wired thick and thin clients. I am not challenging the installation of the CANES program as a whole but I am challenging the idea that the wireless portion of CANES should be supplementary to wired thin and thick client access. In order to harness the full potential of cloud computing, a complete mobile solution should be utilized with tablet devices.

III. THE BUSINESS CASE FOR WIRELESS CLOUD COMPUTING ON DDGS

A. SCOPE OF THE PROJECT

There are five major data systems onboard a DDG including ISNS. This thesis will only discuss an unclassified ISNS equivalent wireless cloud computing network that handles day to day work tasks such as email and word-processing (Rognlie, 2010).

The DDG is the most prevalent combatant ship in the U.S. Navy, numbering 62 in all; therefore, this thesis will only examine the network infrastructure and requirements in reference to the DDG (NAVSEA Shipbuilding Support Office, 2013).

The current CANES implementation strategy for DDGs installs approximately 91 thick clients to be used purely for the unclassified portion of ISNS, 25 cross-domain thin clients that will be used for both the unclassified and classified portions of ISNS (Carman, 2013). The thick clients examined are HPZ210's, which are made by Hewlett-Packard (see Figure 7). All power specifications and prices for thick clients are obtained for HPZ210 only.

Figure 7. HPZ210 Current Thick Clients in Use (From Hewlett-Packard Development Company, 2013b)

The thin clients being examined are HPt5745's, which are also made by Hewlett-Packard (see Figure 8). All power specifications and prices for thin clients are obtained for HPt5745 only.

Figure 8. HPt5745 Current Thin Clients in Use (From Hewlett-Packard Development Company, 2013a)

The 116 displays being examined are LA1751G TAA 17" monitors (see Figure 9). All power specifications and prices for monitors are obtained for LA1751G only.

Figure 9. LA1751G TAA 17" Monitors in Use (From Hewlett-Packard Development Company, 2011)

For tablets, the iPad 2 is examined for power consumption however; different tablet prices are accounted for to determine an average tablet price. In the subsequent sensitivity analysis, effect on net present value (NPV) and payback period is examined for different tablet prices.

This thesis examined common WAP prices and power specifications to determine an acceptable value (Brown, 2012). All power specifications are listed in greater detail in Appendix C.

Cost savings relative to operations and productivity are the main costs and benefits discussed with WLAN and tablet devices.

B. METHEDOLOGY

Based on the calculation in Appendix A, the installation of the WCC network for 1 DDG will take nearly 20 days with no interruptions and one worker performing the installation. A phased implementation period of 5 years is assumed to completely install the WCC network on all DDGs. According to the Naval Vessel Registry there are a total of 62 DDGs in service of the U.S. Navy, which requires an install rate of 13 DDGs per year. To capture the savings related to bulk procurement and installation, learning curves are applied to both the hybrid and WCC network purchases and installations. NPV calculations were made on a single ship basis assuming a 5-year payback period. A 5-year payback is assumed in order to determine an appropriate productivity requirement to be discussed in more detail. Sensitivity analysis was conducted on the purchase price of tablet devices and the cost of installation to determine the range of possible NPVs affecting the overall productivity gains required to achieve a 5-year payback.

Appendix A discusses the process used to determine a baseline of how many WAPs to install and where to install them. Appendix B covers the calculations made for the productivity savings and Appendix C lists the various specification sheets used to calculate cost of operation.

C. ASSUMPTIONS

1. Net Present Value Assumptions

The cost of investment and operation is summed to obtain the total life cycle costs. The life cycle cost is converted into a present value using the 30 year nominal interest rate of 3.0% for the benefit cost analysis of federal programs (Zients, 2013). All dollars are stated in nominal terms. In order to obtain a present value for crew salary, the average salary of a crewmember is first inflated using the current inflation rate of 1.10%, to adjust for the cost of living, then discounted to the present year using a nominal interest rate of 3.0% (Bureau of Labor and Statistics, 2013).

To obtain the future inflated salary the following formula (Brealey, Myers, & Franklin, 2011) will be utilized:

$$FV=S_{0}*(1+\prod)^{t},$$

where,

FV= nominal salary at date (t)

S_0= the initial real average salary of 1 sailor in the current year,

$\prod$=Inflation Rate

t=time in years

To obtain the appropriate NPV the following formula (Brealey, Myers, & Allen, 2008) will be utilized:

$$NPV=C_0 +\sum(C_t/(1+r_t)^{t}),$$

where,

C_0 = the initial investment costs of year zero,

t = time in years,

C_t = cost in later years (t), and

r = nominal discount rate

The program with the highest NPV is determined to be the best alternative. After examining the programs using the NPV alone, cost saving, germane to productivity and operations, will be determined within the specified payback period.

2. Investment Assumptions

- According to Evan Stump, of the Society of Cost Estimation and Analysis Association, shipbuilding learning curves generally range from 80% to

85% (Stump, 2002). For the purpose of this analysis, we will assume the most conservative learning curve of 85% relating to the installation of the WCC network to allow savings from ship to ship.

- A learning curve of 95% will be applied to the lot procurement of all electronic devices over a 62 ship install, which is common for the learning involved in manufacturing electronics (NASA, 2008).
- The cost per each electronic device is outline in Table 1 and it is assumed that each of these costs will decrease along the established learning curve rate discussed above for electronic devices. The nominal cost for each device was obtained through newegg.com, google.com hp.com and samsung.com.

Electronic Device Costs					
	WAPs	Tablets	Thin Clients	Thick Clients	Monitors
Cost Per Device	$ 88.33	$ 432.25	$ 341.00	$ 800.00	$ 143.00

Table 1. Electronic Device Costs

- The material cost of CAT 5e cable used is $0.36 per foot obtained from showmecables.com. The type of CAT 5e cable used must adhere to the following standards according to the Integrated Shipboard Network System FY 2000 Afloat Installation Guide (SPAWAR, 2000):
  - Must be a shielded twisted pair for installation on Aegis DDGs due to the high electromagnetic and radio frequency interferences from high-powered antenna.
  - Must be plenum grade cable, which will not give off hazardous fumes in the event of a fire.
  - According to current shipbuilding practices in the Pascagoula, MS shipyard the standard Ethernet cable being used is CAT 5e.
- According to ship construction coordinators in Pascagoula, MS and Bath, ME, the average hourly wage rate of a shipyard worker is approximately $87.50.
- Based on my assumption the time it takes to mount a WAP on the wall is approximately 30 minutes.
- According to SPAWAR, the Navy has fully adopted the CANES program and will install the CCE of CANES on all new DDGs and convert the older DDGs (Carman, 2013). Because of the CANES adoption, the cost of obtaining cloud computing servers can be ignored as a sunk cost.

- Based on pilot programs, onboard the USS HOWARD (DDG 83) and the USS MASON (DDG 87), as well as schematics and server locations of a typical DDG, the existing ISNS Ethernet cable infrastructure will be used to install 72 WAPs and additional Ethernet cable will be installed for an additional 23 WAP locations to provide adequate wireless coverage in and outside the skin of the ship. Further details about the determination of WAP locations and distances from server locations are covered in Appendix A.
- Based on my assumptions and the calculations in Appendix A, the total amount of CAT 5e cable used to install the WCC network is 7,053 feet.
- In order to fulfill a 5-year payback for the WCCN I will assume the system can be installed on at least 13 DDGs within one years' time to achieve a complete 62 DDG installation by 5 years.
- According to Apple, the iPad is designed to hold 80% of its full charge after a thousand charge and discharge cycles (Apple, 2012b). If we assume the iPad is charged once a day and divide 1,000 by 365 days we can say that at 2.75 years the battery will only hold 80% of its charge. If we assume a linear decrease in the iPad's battery capacity then by approximately 6 years the battery will only hold 60% of its charge at which point it will be time to replace the tablet device. Based on the calculations above I will assume a refresh rate of every 6 years for tablet devices.
- I will assume a refresh rate of 4 years for the thin and thick clients, based on a research study conducted by the Gartner Group (Kitagawa, Margevicius, & Silver, 2004).
- Based on the current manning requirement of a DDG being 30 Officers and 282 Enlisted, this thesis will allocate 330 iPads for each DDG crew with extra allocated in case of damage, theft, or malfunction.
- The initial installation and procurement costs occur in the beginning of the year.

3. Operation Assumptions

- All gasoline usage will be based upon fuel consumption of an Alison AG 9140 Gas Turbine Generator, which is currently being used on all destroyers in service (Rolls-Royce, 2013).
- All power consumption calculations were based on the specification sheets of each device being analyzed. Power consumption specifications are listed in greater detail in Appendix C.
- According to the status of the Navy, DDGs on average are at sea approximately 6 months out of the year and next to the pier the other half of the year (U.S. Navy, 2013).

- According to the Defense Logistics Agency for Energy, the average price per gallon of diesel marine fuel for the year of 2013 is $3.72 (Defense Logistics Agency Energy, 2013).
- When a DDG is next to the pier the price of electricity will be governed by its shore power connection.
- According to the U.S. Energy Information Administration the average cost of electricity at the commercial rate is $0.099 per kilowatt-hour (kWh) (U.S. Energy Information Administration, 2013).
- Operation costs occur every year including the program installation year.

4. Maintenance Assumption

Cost of maintenance will be recouped in the estimates for productivity gains brought on by the WCC tablet infrastructure but will not be specifically measured within the cost model of this thesis.

5. Productivity Assumptions

- The average yearly salary onboard a DDG is approximately $81,610.05. The specifics of this calculation are covered in Appendix B.
- The total working days in a year are approximately 303 based on the calculations in Appendix B.
- The time savings required to recoup the initial investment of a WCC tablet network is approximately 22 seconds.
- The range of possible productivity savings goes from the required calculated rate of 0.052% to a possible rate of 9%. Chapter IV will capture the reasons behind the broad range of variability in productivity analysis.

D. COST CALCULATIONS

1. Cost of Investment

Cost of investment includes the initial procurement cost of WAPs, tablets, CAT-5e cable, thin clients, thick clients, and monitors as well as the installation costs of the WCCN (see Table 2).

The WCCN requires the installation of 95 WAPs in all. Twenty-five of the WAPs require the pre-installation of CAT 5e cable and the subsequent mounting of the WAP itself on the wall of its respective space. The remaining 72 WAPs use the existing

Ethernet cable of the network to connect to the server but also require mounting. All Prices were obtained from various Internet sources outlined in the investment assumptions and references section.

Initial Procurement Costs			
WCCN			
	Cost Per Device	Qty	Total Cost
WAPs	$ 88.33	95	$ 8,391.35
Tablets	$ 432.25	330	$ 142,642.50
		Total=	$ 151,033.85
Hybrid Network			
Thin Clients	$ 341.00	25	$ 8,525.00
Thick Clients	$ 800.00	91	$ 72,800.00
Monitors	$ 143.00	116	$ 16,588.00
		Total=	$ 97,913.00

Table 2. Initial Procurement Costs

The installation time of WAPs is driven by the process of mounting a metal box over the major portion of the WAP, not including its antenna. The calculations involved in determining the average time to mount and run CAT 5e cable is covered in Appendix A. All assumptions about installation time are based on the author's experience of working in shipyards as a quality control agent. There is no installation cost associated with the hybrid network since all the cables and drops required for the network are previously installed with the ISNS installation during the DDG's construction.

Tablet/WAP Installation Time			
Item	Time Per Item (hours)	Quantity	Total Time (hours)
WAP Mount	0.5	72	36
WAP Mount and Cable Run	5.08	23	116.76
		Total Time=	152.76

Table 3. Tablet/WAP Installation Time

The average amount of CAT 5e cable used to install the 23 additional WAPs is calculated in Appendix A. The largely negligible cost per foot of CAT 5e cable was obtained from showmecables.com.

Material Costs				
Item	Length (Feet)	Cost Per Foot	Number of Installs	Total
CAT 5e Cable Per WAP Install	52.24	$ 0.36	23	$ 432.58

Table 4. Total Material Costs

Sunk costs are recognized as drops already in place from the existing ISNS and CCE servers installed in accordance with the CANES program and as such will not be considered in this thesis.

With the assumption that it takes 30 minutes to mount a WAP on the wall, the total time it will take to mount 95 WAPs is approximately, 95*0.5 hours= 47.5 hours. Based on the calculations performed in Appendix A, the time it takes to install the Ethernet cable for 23 additional WAPs is approximately 117 hours. At a wage rate of $87.50 per hour it will cost $13,366 to install Ethernet cable and mount 95 WAPs.

Installation Cost			
Item	Cost/hour	Total Time Worked (Hours)	Total Cost
Shipyard worker Rate	$ 87.50	152.76	$ 13,366.54

Table 5. Installation Cost

The initial investment cost of the WCC tablet network for the first ship is $164,833 (see Table 6), compared to the investment cost of the hybrid network at $97,913 (see Table 2). Compared to the cost of purchasing the electronic devices for the WCC network the labor and material is fairly negligible.

Summary of Investment		
CAT 5e Cable Costs	$	432.58
Tablet & WAP Procurement	$	151,033.85
Installation Costs	$	13,366.54
Total Cost=	$	164,832.97

Table 6. Summary of 1 DDG WCCN Initial Investment

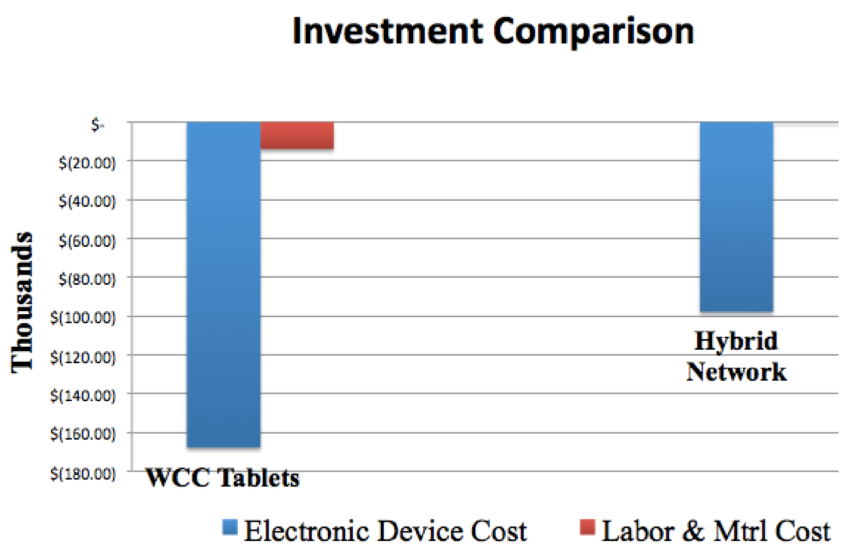

Figure 10. Investment Comparison

2. Cost of Operation

Cost of operations is considered to be energy used to power tablets and WAPs vs. thin/thick clients and monitors.

The following assumptions are made to determine the power consumption schedule of all electronic devices for 1 DDG per year.

- With 365 days in a year the total possible hours a device can be used is 365 days*24 hours= 8,760 hours.
- According to calculations in Appendix B, There are a total of 303 working days available in a year. If we assume most work is accomplished for 12 hours of the day the total active hours for a device will be 303 days*12 hours= 3,636 hours.
- Based on the assumption that a ship is at sea for half the year and next to the pier for half the year, 3,636 hours is divided by 2 to obtain 1,818 active hours at sea and 1,818 active hours pier side.

- Based on 303 possible working days with 12 hours of work, conversely, there are also 12 hours of idle time associated with a day. To find the amount of idle time we use 303 days*12 hours= 3,636 hours.
- Based on the calculation above there are still, 365 days-303days= 62 days of time left that do not involve active work. Therefore, the remaining 62 days will be counted as purely idle time, 62 days*24 hours= 1,488 hours.
- Once again, using the assumption that half the time the ship will be at sea and the other half pier side, 1,488 hours+3,636 hours= 5,124 days divided by 2 which equals 2,562 idle hours at sea and 2,562 idle hours pier side. Figure 11 is provided to aid the reader in understanding these calculations.

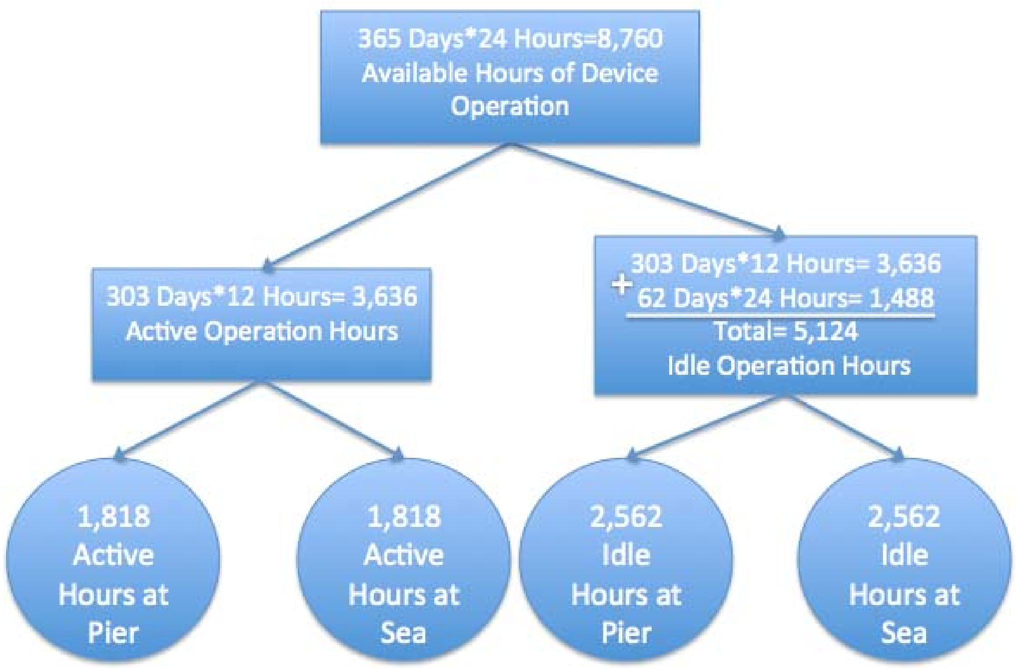

Figure 11. Active and Idle Hours at Sea and Pier

- According to the Rolls-Royce AG9140 specification sheet 1 kWh will consume approximately 0.1114 gallons of diesel marine fuel.
- While at sea the amount of fuel consumed by 1 kWh is multiplied by the power consumption of the respective device to determine how much gasoline the electronic device uses.
- While the ship is pier side, the amount of kilowatt-hours the device consumes can be directly multiplied by the cost of electricity per kWh.

- For the sake of analysis we will assume the iPad 2 is connected to a power source continuously, as the other devices are.

- Active and idle power consumption for WAPs are the same, assuming devices are always connected to the network and WAPs are always executing the task of providing a wireless signal to its surroundings.

a. *Tablet/WAP Operation Computation*

Based on the assumptions discussed, the total cost per year for tablet operations while pier side is calculated by using the following formulas corresponding to the bold letters in Table 7:

- C*B+D*A=E
- E*F=G
- G*H= Total cost per year of WCCN operation while pier side

Tablet/WAP Pier Side Operation Computation									
Electronic Device	Active Power Consumption (kWh) **A**	Idle Power Consumption Per Hour (kWh) **B**	Idle Time At Pier (Hours) **C**	Active Time At Pier **D**	Power Cosumed (kWh) **E**	Cost Per Hour At Pier ($/kWh) **F**	Cost At Pier **G**	Device Quantity **H**	Total Cost Per Year
Tablets	0.00308	0.00007	2562	1818	5.77878	$ 0.0991	$ 0.57	330	$ 188.98
WAPs	0.00800	0.00800	2562	1818	35.04	$ 0.0991	$ 3.47	95	$ 329.88
								TOTAL=	$ 518.87

Table 7. Operation Costs Per Device

The total operation cost per year at sea is calculated using the following series of formulas that correspond to the bold letters in Table 8:

- C*B+D*A=E
- E*F=G
- G*H=I
- I*J=Total cost per year of WCCN operation at sea.

Tablet/WAP At Sea Operation Computation											
Electronic Device	Active Power Consumption (kWh) **A**	Idle Power Consumption Per Hour (kWh) **B**	Idle Time At Sea (Hours) **C**	Active Time At Sea (Hours) **D**	Power Cosumed (kWh) **E**	Gallons of Fuel consumed by 1 kWh (gal of fuel/kWh) **F**	Gallons of Fuel Consumed At Sea (Gal) **G**	Cost Per Gallon At Sea **H**	Cost At Sea **I**	Device Quantity **J**	Total Cost Per Year
Tablets	0.00308	0.00007	2562	1818	5.77878	0.111413	0.64383	$ 3.72	$ 2.40	330	$ 790.37
WAPs	0.00800	0.00800	2562	1818	35.04	0.111413	3.90391	$ 3.72	$ 14.52	95	$ 1,379.64
										TOTAL=	$ 2,170.01

Table 8. Tablet/WAP At Sea Operation Computation

Based on calculations in Table 8 and 9, $518.87 and $2,170.01, the total cost of operation of the tablet/WAP network will be $2,688.88 per year.

b. Hybrid Network Operation Computation

The following equations are used to calculate the hybrid pier side operation:

- C*B+D*A=E
- E*F=G
- G*H= Total cost per year of hybrid network operation while pier side.

Hybrid Pier Side Operation Computation									
Electronic Device	Active Power Consumption (kWh) **A**	Idle Power Consumption Per Hour (kWh) **B**	Idle Time At Pier (Hours) **C**	Active Time At Pier **D**	Power Cosumed (kWh) **E**	Cost Per Hour At Pier ($/kWh) **F**	Cost At Pier **G**	Device Quantity **H**	Total Cost Per Year
Thick Clients	0.14900	0.00327	2562	1818	279.25974	$ 0.0991	$ 27.67	91	$ 2,518.39
Monitors	0.01605	0.00052	2562	1818	30.51114	$ 0.0991	$ 3.02	116	$ 350.74
Thin Clients	0.01210	0.00043	2562	1818	23.09946	$ 0.0991	$ 2.29	25	$ 57.23
								TOTAL=	$ 2,926.37

Table 9. Hybrid Pier Side Operation Computation

And finally the following equations are used to calculate the hybrid operation at sea:

- C*B+D*A=E
- E*F=G
- G*H=I
- I*J= Total cost per year of hybrid network operation at sea.

Hybrid At Sea Operation Computation											
Electronic Device	Active Power Consumption (kWh) **A**	Idle Power Consumption Per Hour (kWh) **B**	Idle Time At Sea (Hours) **C**	Active Time At Sea (Hours) **D**	Power Cosumed (kWh) **E**	Gallons of Fuel consumed by 1 kWh (gal of fuel/kWh) **F**	Gallons of Fuel Consumed At Sea (Gal) **G**	Cost Per Gallon At Sea **H**	Cost At Sea **I**	Device Quantity **J**	Total Cost Per Year
Thick Clients	0.14900	0.00327	2562	1818	279.25974	0.111413	31.1132	$ 3.72	$ 115.74	91	$10,532.43
Monitors	0.01605	0.00052	2562	1818	30.51114	0.111413	3.39934	$ 3.72	$ 12.65	116	$ 1,466.88
Thin Clients	0.01210	0.00043	2562	1818	23.09946	0.111413	2.57358	$ 3.72	$ 9.57	25	$ 239.34
										TOTAL=	$12,238.66

Table 10. Hybrid At Sea Operation Computation

Based on the calculations in Tables 9 and 10, the total operation of the hybrid network will be, $12,238.66 + $2,926.37= $15,165.02 per year.

c. 1 DDG WCCN Installation Operation Cost Savings Summary

The power consumption of thick clients clearly drives the cost of operation for the hybrid network configuration while tablets and WAPs use only 17% of what the hybrid network uses in total power consumption.

Summary of Operation Calculation			
Network	Total Electricity Consumed Pier Side Per Year (kWh)	Total Fuel Consumed At Sea Per Year (Gal)	Total Cost
WCCN	5235.8	4.55	$ (2,688.88)
HYBRID	29529.4	3289.96	$ (15,165.02)

Table 11. Summary of Operation Calculation

The initial investment required to install the WCC network on the first ship is $164,833.29 and the cost of the current hybrid network is $97,913.00. If we subtract the status quo cost from the WCCN we get a difference of $66,920.29. With operation cost savings of $12,746.14 every year, payback for the program will be reached in 5.4 years, which ignores any productivity calculations.

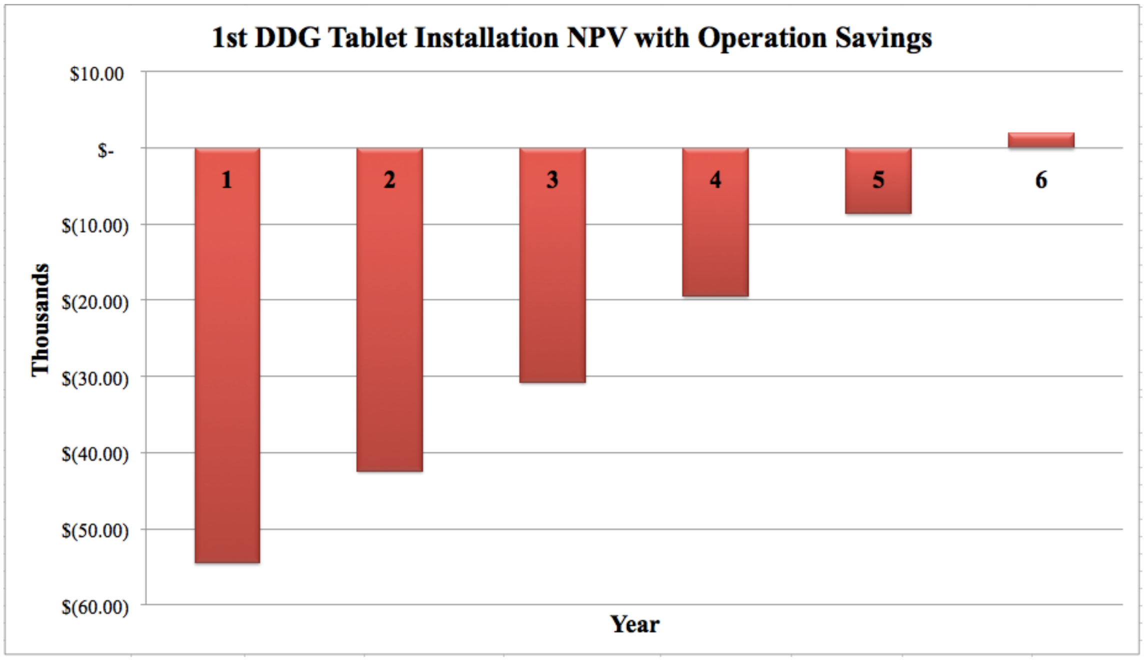

Figure 12. 1st DDG WCCN Installation NPV With Operation Savings

1 Ship Installation Payback Calculations					
Year	WCCN PV	Discounted Hybrid Network Operation Costs	Discounted WCCN Operation Cost	Opeartion Savings	NPV WCCN & Operation Savings
1	$ (66,920.29)	$ (15,165.02)	$ (2,688.88)	$ 12,476.15	$ (54,444.15)
2		$ (14,910.06)	$ (2,643.67)	$ 12,310.84	$ (42,133.31)
3		$ (14,659.39)	$ (2,599.22)	$ 12,146.83	$ (29,986.48)
4		$ (14,412.93)	$ (2,555.52)	$ 11,984.14	$ (18,002.35)
5		$ (14,170.61)	$ (2,512.56)	$ 11,822.80	$ (6,179.54)
6		$ (13,932.36)	$ (2,470.32)	$ 11,662.84	$ 5,483.30

Table 12. 1st DDG WCCN Payback Cash Flow Calculations

d. 62 DDG WCCN Installation Operation Cost Savings Summary

Based on an installation rate of 13 ships per year and tablet refreshes occurring every 6 years, the present value of the WCCN will be $9,723,654.65 (see Table 13). Based on a hybrid network installation of 13 ships per year and a refresh rate of 4 years the present value will be $5,484,021.08. By subtracting the hybrid present value from that of the WCCN we obtain a WCCN present value of $4,239,633.57 (see Table 13).

62 Ship WCCN Installation and Refreshment Schedule			
Years	Ship Installs Purchased	WCCN Discounted Investment/Refresh	Hybrid Discounted Investment/Refresh
1	1 to 13	$ (2,142,832.82)	$ (1,272,869.00)
2	14 to 26	$ (1,301,288.02)	$ (876,109.57)
3	27 to 39	$ (1,225,117.27)	$ (477,138.79)
4	40 to 52	$ (1,171,342.92)	$ (457,459.47)
5	53 to 62	$ (781,050.47)	$ (789,332.72)
6		$ -	$ (394,166.11)
7		$ (1,072,724.46)	$ (415,224.43)
8		$ (1,028,399.09)	$ (408,243.47)
9		$ (1,000,899.60)	$ (393,477.53)
	Present Value=	$ (9,723,654.65)	$ (5,484,021.08)
WCCN Net Present Value=		$ (4,239,633.57)	

Table 13. 62 Ship Installation And Refreshment Schedule With No Operation Savings

By applying an average operation cost savings of $540,159.70 every year we obtain a payback occurring in year 8 (see Table 14 and Figure 13); and this is once again with no consideration of productivity savings.

5 Year 62 Ship Install With Operation Savings					
Year	WCCN PV	Discounted Hybrid Operation Costs	Discounted WCCN Operation Costs	Opeartion Savings	NPV WCCN With Operation Savings
1	$(4,239,633.57)	$ (197,145.31)	$ (34,955.41)	$ 162,189.90	$ (4,077,443.67)
2		$ (387,661.60)	$ (68,735.45)	$ 313,564.21	$ (3,763,879.47)
3		$ (571,716.06)	$ (101,369.75)	$ 454,663.86	$ (3,309,215.61)
4		$ (749,472.11)	$ (132,887.30)	$ 586,005.73	$ (2,723,209.89)
5		$ (921,089.50)	$ (155,778.73)	$ 715,127.06	$ (2,008,082.83)
6		$ (905,603.68)	$ (153,159.70)	$ 691,283.04	$ (1,316,799.79)
7		$ (890,378.21)	$ (150,584.70)	$ 668,234.04	$ (648,565.75)
8		$ (875,408.72)	$ (148,052.99)	$ 645,953.54	$ (2,612.21)
9		$ (860,690.91)	$ (145,563.85)	$ 624,415.93	$ 621,803.72

Table 14. NPV Of 5 Year 62 Ship WCCN Installation With Operation Cost Savings

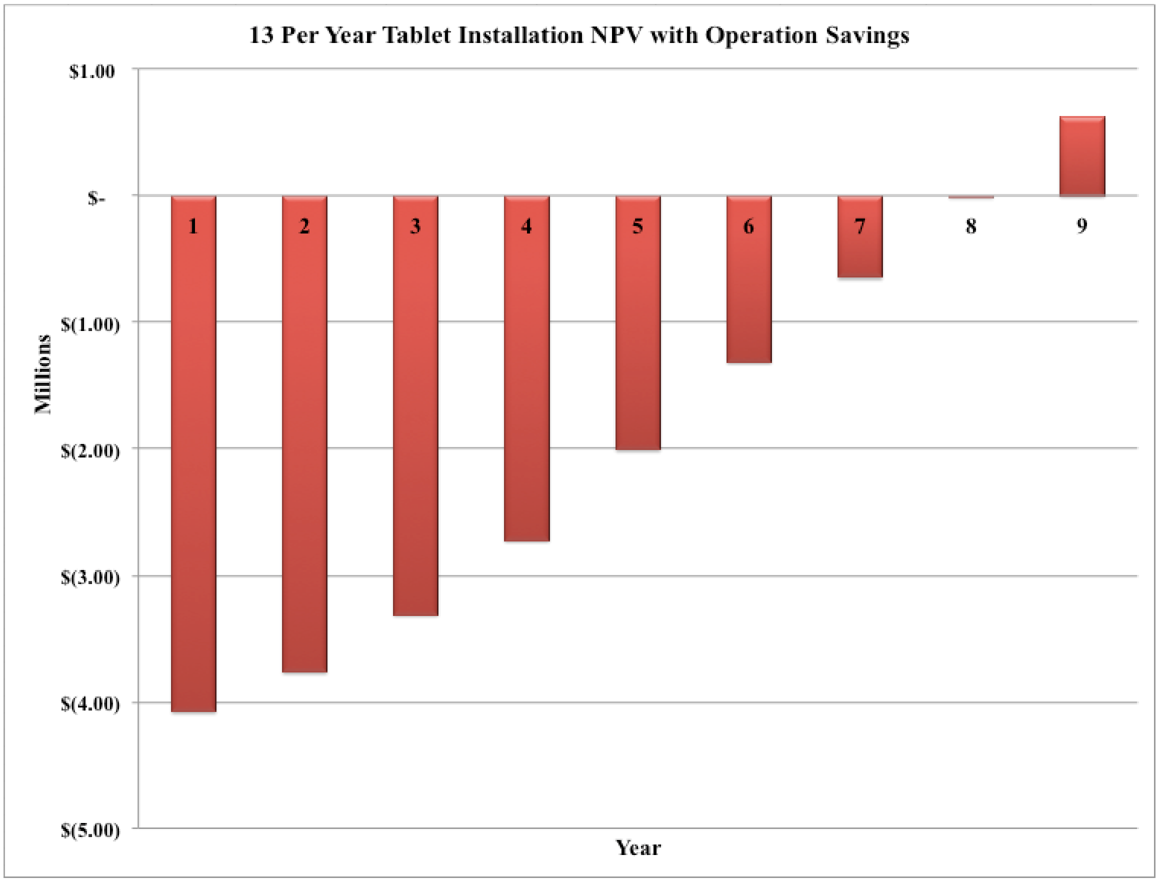

Figure 13. NPV Of 62 Ship Installation With 5 Year Payback and Operation Savings

e. Accelerated 31 Ship WCCN Installation Operation Cost Savings Summary

As seen in Figure 13, due to the technology refresh schedule, the benefit of accumulated operation cost savings is slightly degraded; therefore, we will consider an accelerated installation schedule of 31 ships in year 1 and 31 ships in year 2. By subtracting the PV of the WCCN at $10,133,755.14 and the hybrid network at $6,019,574.95 we have a total NPV of the WCCN at $4,114,180.19 (see Table 15).

Accelerated 31 WCCN Installation Per Year Schedule			
Years	Ship Installs Purchased	Discounted WCCN Investment	Discounted Hybrid Investment
1	1 to 31	$ (5,109,832.11)	$ (3,035,303.00)
2	32 to 62	$ (5,023,923.03)	$ (2,984,271.95)
	Present Values=	$ (10,133,755.14)	$ (6,019,574.95)
	WCCN NPV=	$ (4,114,180.19)	

Table 15. Accelerated Ship Installation With No Operation Cost Savings

By applying an average cost savings of $645,055.64 the accelerated WCCN initial investment will be completely paid off in approximately 6.4 years (see Table 16 and Figure 14). The accelerated purchase rate allows us to take advantage of the accumulated cost savings due to operation.

Accelerated Installation with Operation Cost Savings					
Year	WCCN PV	Discounted Hybrid Operation Costs	Discounted WCCN Operation Costs	Oceartions Savings	NPV WCCN Operation Savings
1	$ (4,114,180.19)	$ (470,115.73)	$ (83,355.21)	$ 386,760.52	$ (3,727,419.67)
2		$ (924,423.82)	$ (163,907.61)	$ 747,730.03	$ (2,979,689.64)
3		$ (908,881.94)	$ (161,151.91)	$ 722,798.95	$ (2,256,890.69)
4		$ (893,601.36)	$ (158,442.54)	$ 698,699.13	$ (1,558,191.55)
5		$ (878,577.68)	$ (155,778.73)	$ 675,402.86	$ (882,788.69)
6		$ (863,806.59)	$ (153,159.70)	$ 652,883.34	$ (229,905.35)
7		$ (849,283.83)	$ (150,584.70)	$ 631,114.68	$ 401,209.32

Table 16. Accelerated Installation With Operation Cost Savings

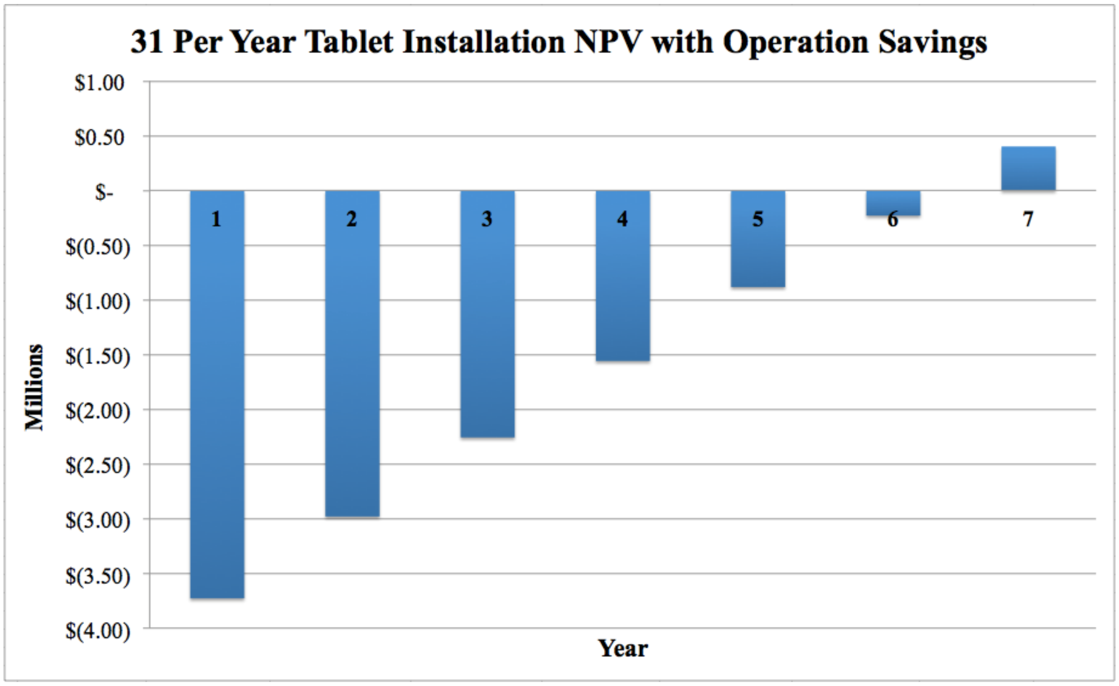

Figure 14. NPV Of Accelerated Operation Savings

E. PRODUCTIVITY CALCULATIONS

As discussed in the previous section, moderate payoff times are available with the consideration of accumulated operation savings alone (see Table 17). However, this thesis will also examine productivity savings as an added effect. Before discussing the savings from productivity this thesis will outline how productivity savings is calculated with crew pay assumptions.

WCCN Payoffs With Operation Savings	
Investment Options	Payoff Time (Years)
1 Ship Installation	5.4
5 Year Installation	8
2 Year Installation	6.37

Table 17. Payoff Time With Operation Savings

1. Average Pay Determination

In order to calculate the average pay determinations in Table 18 the following assumptions are made:

- The possible ranks onboard a DDG range from E-2 to O-5. According to my experience as a Surface Warfare Officer on DDGs, there are generally no E-1s onboard since junior sailors tend to pick up the next rank while they attend their respective schools after boot camp.
- Yearly salaries are based on the Department of Defense's military personnel composite standard pay and reimbursement rates. Reimbursement rates capture basic allowance for subsistence, basic allowance for housing, incentive pay, special pay, medical benefits, permanent change of station expenses and miscellaneous pay. The rates are used in order to determine the cost of military personnel for the means of budgeting and management studies (Roth, 2012).
- Column 4 of Table 18 indicates how many of each rank is typically on a DDG. Column 4 is multiplied to the values in column 3 and acts as a weighting factor.
- Column 5 is summed to obtain the total cash flow achieved by an average crew of a DDG per year.
- The total number of crewmembers, being 330, divides $26,931,316.00 to give an average weighted yearly salary per person of $81,610.05.

Average Pay Determination				
Ranks	Monthly Salary	Total Pay Per Rank	Strength	Total Pay by Strength
O-5	$ 16,285.25	$ 195,423.00	1	$ 195,423.00
O-4	$ 14,528.58	$ 174,343.00	2	$ 348,686.00
O-3	$ 12,475.17	$ 149,702.00	5	$ 748,510.00
O-2	$ 9,836.42	$ 118,037.00	2	$ 236,074.00
O-1	$ 7,943.58	$ 95,323.00	18	$ 1,715,814.00
WO-2	$ 10,835.25	$ 130,023.00	2	$ 260,046.00
E-9	$ 12,017.75	$ 144,213.00	1	$ 144,213.00
E-8	$ 10,241.50	$ 122,898.00	2	$ 245,796.00
E-7	$ 9,151.17	$ 109,814.00	24	$ 2,635,536.00
E-6	$ 8,011.33	$ 96,136.00	30	$ 2,884,080.00
E-5	$ 6,823.33	$ 81,880.00	96	$ 7,860,480.00
E-4	$ 5,533.50	$ 66,402.00	138	$ 9,163,476.00
E-3	$ 4,624.08	$ 55,489.00	8	$ 443,912.00
E-2	$ 4,105.83	$ 49,270.00	1	$ 49,270.00
			330	$ 26,931,316.00
Weighted Average Yearly Salary				$ 81,610.05

Table 18. Average Pay Determination For DDG

As shown in Table 19, the initial investment of the WCCN for 1 DDG is approximately $66,920.29, after taking the $113,078.02 into account for the status quo program and 1 year of operation cost savings.

SINGLE DDG NPV OF WCCN	
Year	Investment
1	$ (164,833.29)
SINGLE DDG NPV OF HYBRID NETWORK	
Year	Investment
1	$ (97,913.00)
NPV WCCN=	$ (66,920.29)

Table 19. NPV Of 1 DDG Installation

In order to calculate the productivity required to pay off the remaining $66,920.29, the average discounted crew salary is summed for years 1 through 5 obtaining $129,779,466.33 (see Table 20). $66,920.29 is then divided by $129,779,466.33 providing a productivity requirement percentage of 0.052%. To obtain the hours requirement per sailor .052% is multiplied by 3,636 possible working hours in a year providing 1.87 hours of required savings per person per year. By dividing 1.87 hours by 303 possible working days in a year and multiplying it by 3600, to convert to seconds, we obtain 22.28 seconds. Therefore, if each sailor saves over 22 seconds a day the initial investment of $164,833.29 is recouped in 5 years' time factoring the difference between the WCCN investment and the hybrid network.

Discounted Crew Salary				
Year	Inflation Factors (1+∏)^t	Weighted Sailor Avg Yearly Salary Inflated to Nominal Flows	Discount Factors to PV (1+r)^t	Weighted Crew Avg Yrl Salary Discounted to PV Using Nominal Intrest Rate and Multiplied by 330
1	1.00	$ 81,610.05	1.00	$ 26,931,316.00
2	1.01	$ 82,507.76	1.03	$ 26,434,524.73
3	1.02	$ 83,415.34	1.06	$ 25,946,897.58
4	1.03	$ 84,332.91	1.09	$ 25,468,265.49
5	1.04	$ 85,260.58	1.13	$ 24,998,462.53
6	1.06	$ 86,198.44	1.16	$ 24,537,325.84
7	1.07	$ 87,146.62	1.19	$ 24,084,695.56

Table 20. Discounted Crew Salary

Figure 15 shows the NPV of one DDG Tablet/WAP installation and its subsequent payback period of 5.4 years. As discussed in the productivity assumptions, a base productivity requirement of 0.052% is required resulting in 22 seconds of required savings. Figure 15 accounts for possible productivity savings ranging from 0.076% to 9%. When transitioning from 90 seconds to 4 minutes of possible savings the program shows positive cash flows. Table 21 shows the calculations that make Figure 15; all the numbers highlighted in yellow show when the cash flows become positive due to productivity savings accumulation.

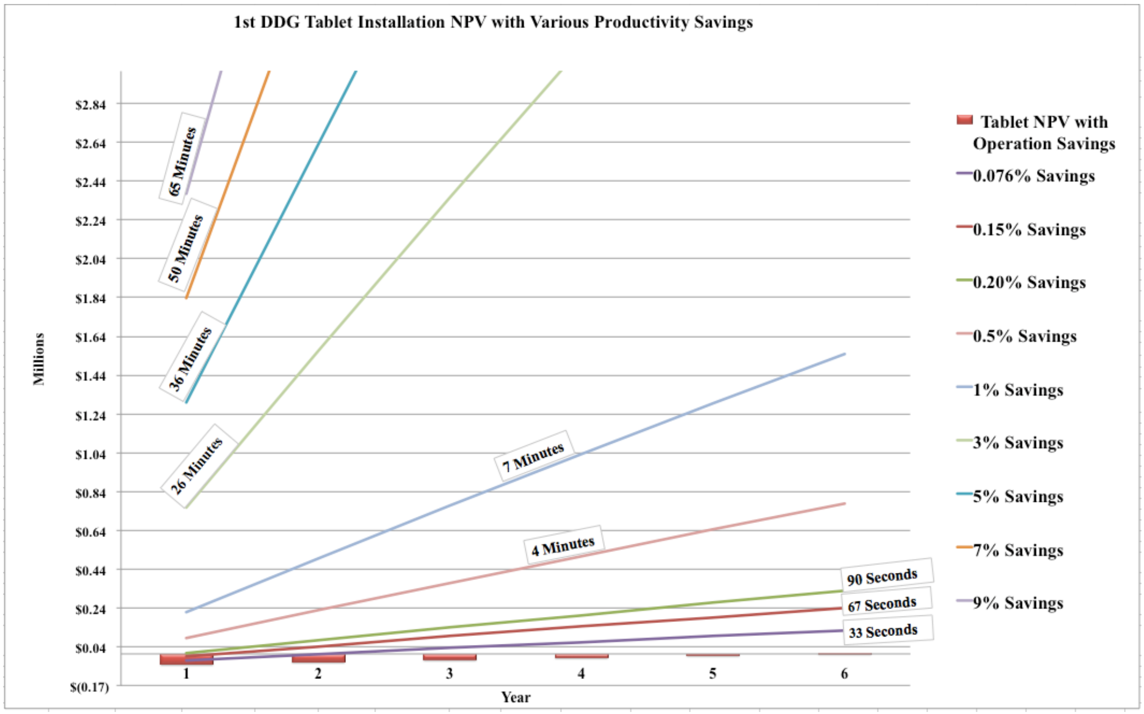

Figure 15. 1st DDG WCCN Installation NPV With Various Productivity Savings

1 DDG Installation NPV with Productivity Savings Calculations

Year	Tablet PV	Hybrid Operations	WCCN Operations	Opeartion Savings	NPV WCCN W/ Ops Savings	0.0762% Productivity	NPV WCCN @ .076% Productivity
1	$ (66,920.29)	$ (15,165.02)	$ (2,688.88)	$ 12,476.15	$ (54,444.15)	$ 20,521.66	$ (33,922.49)
2		$ (14,910.06)	$ (2,643.67)	$ 12,060.16	$ (42,383.99)	$ 20,143.11	$ (1,719.22)
3		$ (14,659.39)	$ (2,599.22)	$ 11,658.05	$ (30,725.94)	$ 19,771.54	$ 29,710.37
4		$ (14,412.93)	$ (2,555.52)	$ 11,269.34	$ (19,456.60)	$ 19,406.82	$ 60,386.53
5		$ (14,170.61)	$ (2,512.56)	$ 10,893.59	$ (8,563.00)	$ 19,048.83	$ 90,328.95
6		$ (13,932.36)	$ (2,470.32)	$ 10,530.38	$ 1,967.37	$ 18,697.44	$ 119,556.77

Year	0.15% Productivity Savings	NPV WCCN @ .15% Productivity	0.209% Productivity Savings	NPV WCCN @ 0.209% Productivity	0.5% Productivity Savings	NPV WCCN @ 0.5% Productivity	1% Productivity Savings	NPV WCCN @ 1% Productivity
1	$ 41,043.33	$ (13,400.82)	$ 56,286.45	$ 1,842.30	$ 134,656.58	$ 80,212.43	$ 269,313.16	$ 214,869.01
2	$ 40,286.22	$ 38,945.55	$ 55,248.16	$ 69,150.62	$ 132,172.62	$ 224,445.22	$ 264,345.25	$ 491,274.42
3	$ 39,543.07	$ 90,146.67	$ 54,229.02	$ 135,037.68	$ 129,734.49	$ 365,837.75	$ 259,468.98	$ 762,401.44
4	$ 38,813.64	$ 140,229.65	$ 53,228.67	$ 199,535.70	$ 127,341.33	$ 504,448.42	$ 254,682.65	$ 1,028,353.44
5	$ 38,097.66	$ 189,220.90	$ 52,246.79	$ 262,676.08	$ 124,992.31	$ 640,334.33	$ 249,984.63	$ 1,289,231.66
6	$ 37,394.88	$ 237,146.16	$ 51,283.01	$ 324,489.47	$ 122,686.63	$ 773,551.33	$ 245,373.26	$ 1,545,135.29

Year	3% Productivity Savings	NPV WCCN @ 3% Productivity	5% Productivity Savings	NPV WCCN @ 5% Productivity	7% Productivity Savings	NPV WCCN @ 7% Productivity	9% Productivity Savings	NPV Tablet @ 9% Productivity
1	$ 807,939.48	$ 753,495.33	$ 1,346,565.80	$ 1,292,121.65	$ 1,885,192.12	$ 1,830,747.97	$ 2,423,818.44	$ 2,369,374.29
2	$ 793,035.74	$ 1,558,591.24	$ 1,321,726.24	$ 2,625,908.05	$ 1,850,416.73	$ 3,693,224.87	$ 2,379,107.23	$ 4,760,541.68
3	$ 778,406.93	$ 2,348,656.21	$ 1,297,344.88	$ 3,934,910.98	$ 1,816,282.83	$ 5,521,165.74	$ 2,335,220.78	$ 7,107,420.51
4	$ 764,047.96	$ 3,123,973.52	$ 1,273,413.27	$ 5,219,593.59	$ 1,782,778.58	$ 7,315,213.67	$ 2,292,143.89	$ 9,410,833.74
5	$ 749,953.88	$ 3,884,820.99	$ 1,249,923.13	$ 6,480,410.31	$ 1,749,892.38	$ 9,075,999.64	$ 2,249,861.63	$ 11,671,588.97
6	$ 736,119.78	$ 4,631,471.14	$ 1,226,866.29	$ 7,717,806.98	$ 1,717,612.81	$ 10,804,142.83	$ 2,208,359.33	$ 13,890,478.67

Table 21. 1st DDG Installation NPV With Productivity Savings Calculation

Figure 16 shows the NPV of 13 Tablet/WAP installations taking place every year for 5 years resulting in a complete installation of 62 DDGs. As discussed earlier, the required productivity savings per person for a 62-ship installation over 5 years is approximately 22 seconds. Transitioning from 7 minutes of savings to 22 minutes yields a positive cash flow in year 1.

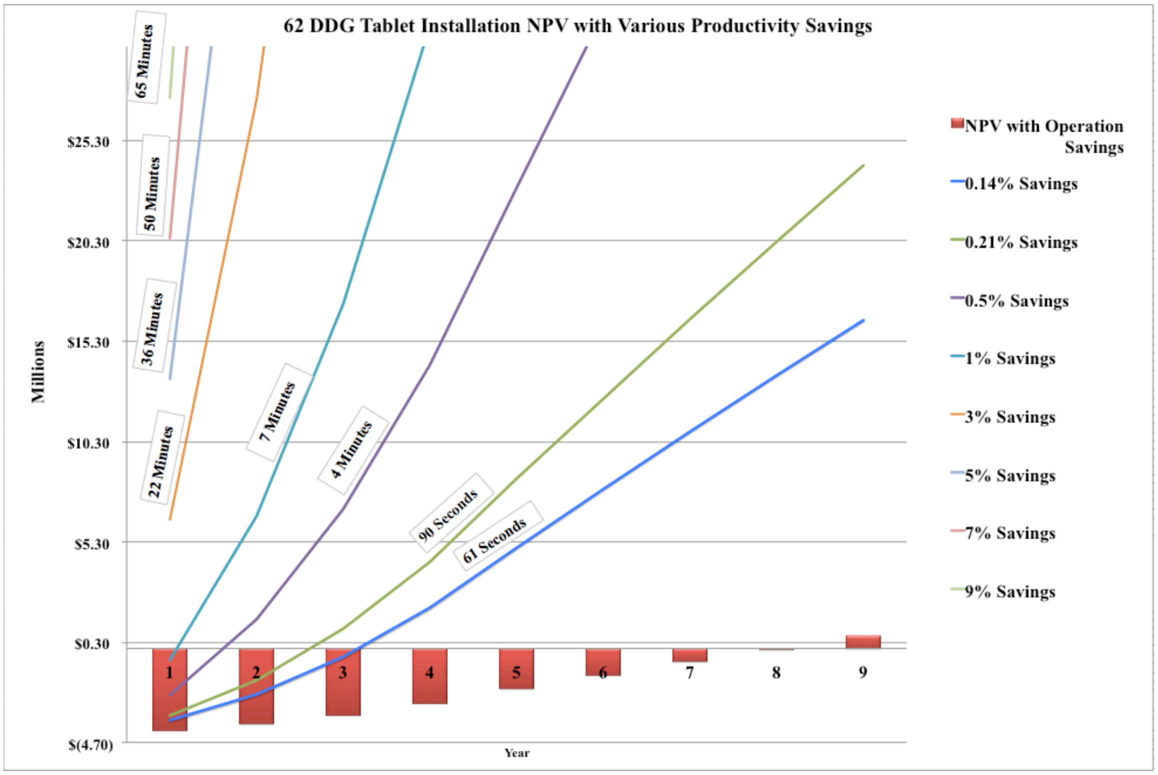

Figure 16. 62 DDG Tablet Installation NPV With Various Productivity Savings

62 DDG INSTALLATION 13 PER YEAR PRODUCTIVITY SAVINGS GRAPH DATA

Year	Tablet PV	Hybrid Operations	WCCN Operations	Opeartion Savings	NPV WCCN W/ Ops Savings	0.14% Productivity Savings	NPV WCCN @ 0.14% Productivity
1	$ (4,239,633.57)	$ (197,145.31)	$ (34,955.41)	$ 162,189.90	$ (4,077,443.67)	$ 491,816.46	$ (3,585,627.21)
2		$ (387,661.60)	$ (68,735.45)	$ 313,564.21	$ (3,763,879.47)	$ 965,488.24	$ (2,306,574.77)
3		$ (571,716.06)	$ (101,369.75)	$ 454,663.86	$ (3,309,215.61)	$ 1,421,517.39	$ (430,393.52)
4		$ (749,472.11)	$ (132,887.30)	$ 586,005.73	$ (2,723,209.89)	$ 1,860,393.63	$ 2,016,005.83
5		$ (921,089.50)	$ (155,778.73)	$ 715,127.06	$ (2,008,082.83)	$ 2,282,594.61	$ 5,013,727.51
6		$ (905,603.68)	$ (153,159.70)	$ 691,283.04	$ (1,316,799.79)	$ 2,240,488.50	$ 7,945,499.05
7		$ (890,378.21)	$ (150,584.70)	$ 668,234.04	$ (648,565.75)	$ 2,199,159.10	$ 10,812,892.18
8		$ (875,408.72)	$ (148,052.99)	$ 645,953.54	$ (2,612.21)	$ 2,158,592.09	$ 13,617,437.81
9		$ (860,690.91)	$ (145,563.85)	$ 624,415.93	$ 621,803.72	$ 2,118,773.40	$ 16,360,627.15

Year	0.21% Productivity Savings	NPV WCCN @ 0.21% Productivity	0.5% Productivity Savings	NPV WCCN @ 0.5% Productivity	1% Productivity Savings	NPV WCCN @ 1% Productivity
1	$ 731,723.86	$ (3,345,719.82)	$ 1,750,535.54	$ (2,326,908.13)	$ 3,501,071.08	$ (576,372.59)
2	$ 1,436,452.07	$ (1,595,703.54)	$ 3,436,488.22	$ 1,423,144.29	$ 6,872,976.43	$ 6,610,168.04
3	$ 2,114,931.62	$ 973,891.94	$ 5,059,645.03	$ 6,937,453.17	$ 10,119,290.06	$ 17,184,121.95
4	$ 2,767,891.09	$ 4,327,788.76	$ 6,621,749.03	$ 14,145,207.92	$ 13,243,498.05	$ 31,013,625.73
5	$ 3,396,041.13	$ 8,438,956.95	$ 8,124,500.32	$ 22,984,835.30	$ 16,249,000.65	$ 47,977,753.44
6	$ 3,333,395.72	$ 12,463,635.71	$ 7,974,630.90	$ 31,650,749.24	$ 15,949,261.80	$ 64,618,298.27
7	$ 3,271,905.89	$ 16,403,775.63	$ 7,827,526.06	$ 40,146,509.34	$ 15,655,052.12	$ 80,941,584.43
8	$ 3,211,550.35	$ 20,261,279.52	$ 7,683,134.80	$ 48,475,597.68	$ 15,366,269.60	$ 96,953,807.57
9	$ 3,152,308.16	$ 24,038,003.61	$ 7,541,407.07	$ 56,641,420.68	$ 15,082,814.14	$ 112,661,037.64

Year	3% Productivity Savings	NPV WCCN @ 3% Productivity	5% Productivity Savings	NPV WCCN @ 5% Productivity	7% Productivity Savings	NPV WCCN @ 7% Productivity	9% Productivity Savings	NPV Tablet @ 9% Productivity
1	$ 10,503,213.24	$ 6,425,769.57	$ 17,505,355.40	$ 13,427,911.73	$ 24,507,497.56	$ 20,430,053.89	$ 31,509,639.72	$ 27,432,196.05
2	$ 20,618,929.29	$ 27,358,263.06	$ 34,364,882.15	$ 48,106,358.09	$ 48,110,835.02	$ 68,854,453.11	$ 61,856,787.88	$ 89,602,548.13
3	$ 30,357,870.17	$ 58,170,797.09	$ 50,596,450.28	$ 99,157,472.22	$ 70,835,030.39	$ 140,144,147.35	$ 91,073,610.50	$ 181,130,822.49
4	$ 39,730,494.16	$ 98,487,296.97	$ 66,217,490.27	$ 165,960,968.21	$ 92,704,486.37	$ 233,434,639.45	$ 119,191,482.48	$ 300,908,310.69
5	$ 48,747,001.94	$ 147,949,425.97	$ 81,245,003.23	$ 247,921,098.50	$ 113,743,004.52	$ 347,892,771.03	$ 146,241,005.81	$ 447,864,443.56
6	$ 47,847,785.40	$ 196,488,494.40	$ 79,746,308.99	$ 328,358,690.53	$ 111,644,832.59	$ 460,228,886.66	$ 143,543,356.19	$ 592,099,082.79
7	$ 46,965,156.35	$ 244,121,884.79	$ 78,275,260.58	$ 407,302,185.15	$ 109,585,364.81	$ 570,482,485.50	$ 140,895,469.04	$ 733,662,785.86
8	$ 46,098,808.80	$ 290,866,647.13	$ 76,831,348.00	$ 484,779,486.69	$ 107,563,887.20	$ 678,692,326.25	$ 138,296,426.40	$ 872,605,165.81
9	$ 45,248,442.43	$ 336,739,505.49	$ 75,414,070.71	$ 560,817,973.33	$ 105,579,698.99	$ 784,896,441.17	$ 135,745,327.28	$1,008,974,909.02

Table 22. 62 DDG 13 Per Year Installation NPV With Productivity Calculations

With a 5-year installation plan, the cumulative cost and productivity savings completely pay for the program well before the requirement. By saving at least 90 seconds the program is paid off in 20 months. Figure 17 shows the effects on NPV with an accelerated implementation schedule of 31 ships per year resulting in a complete installation in 2 years. With cost savings alone, the program is paid off in 6 years. When transitioning from 90 seconds to 4 minutes of productivity savings, the accelerated program obtains a positive cash flow in year 1.

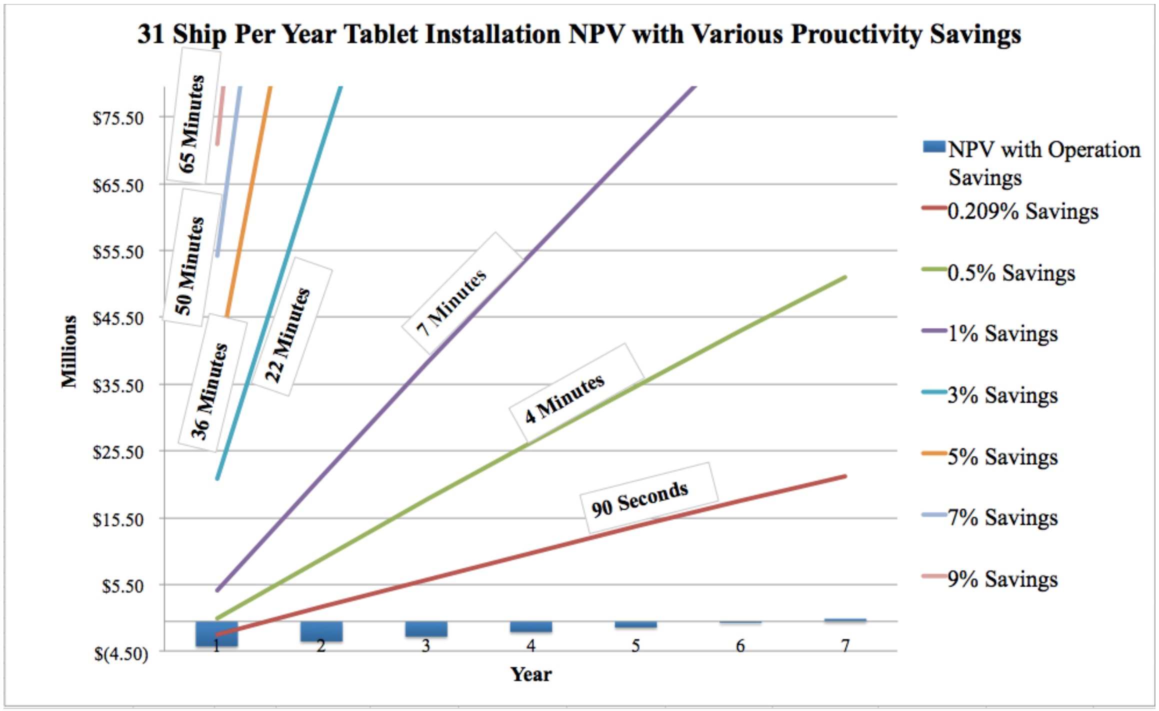

Figure 17. NPV Of Accelerated Installation With Various Productivity Savings

F. RISK/BENEFIT ANALYSIS

1. Risks of Adopting Wireless Cloud Computing

Security Risks: As discussed in the background information, there are some inherent security risks associated with wireless devices. By ensuring the WAPs on the outside of the ship can be readily secured at a moment's notice will help mitigate the emission of electronic signals.

Theft of Tablets: By introducing a device that is small enough to fit in a purse or a backpack, the possibility of theft is pronounced. Due to tablet devices utilizing solid-state memory they do not require to be shut down like a laptop or desktop would. Since tablets are always energized, the network can always detect them. By conducting a ping of each tablet device each day, the crew can verify that all devices are still present aboard the ship.

Survivability of Tablets: With a more portable device that can travel with the user comes the concern of the devices ability to withstand the harsh environment of shipboard life. Tablet devices can easily be broken if handled with enough disdain or aloofness however, there are cases that can be wrapped around the device that significantly mitigate the risk of destruction and still allow considerable ease of use. A tablet case is generally available for a small fraction of what the tablet device is worth, offering protection at small cost. All electronic devices have a threshold of brutality they can withstand but through regular handling of the technology device the average person comes to understand how it should be handled to reduce the possibility of destruction.

Adoption of Change: The wireless LAN standard of 802.11 has been in use since 1997 (IEEE, 2012). The armed forces have not readily adopted wireless use in tactical environment not only due to the risk but also due to the underlying desire to resist change. It is unnatural to believe that a wireless connection can be as secure and reliable as a wired network. Until the diffusion of wireless technology permeates the crevices of our daily lives it may prove quite difficult to overcome the resistance to wireless technology in the military.

2. Qualitative Benefits

Qualitative benefits are covered at length in Chapter IV.

G. SENSITIVITY ANALYSIS CONCERNING TABLET DEVICE COSTS

1. Tablet Device Costs

As it stands the largest monetary burden of adopting a WCC tablet infrastructure is the initial investment in the actual tablet devices, which is significant. For the purposes of this thesis an average tablet price was developed using a range of tablet prices in the market. A learning curve of 95% took into account the savings associated with the continued bulk manufacturing of electronic devices over time. There are a significant amount of tablet devices currently in the market. An exhaustive review of possible tablets would need to be conducted to understand the best fit for the Department of Defense and more specifically for the different services. To understand the variability of tablet device procurement I will examine the effect that two price extremes has on the present value of the WCC tablet network.

The sensitivity analysis presented in Table 23 outlines a break-even time that does not factor in productivity savings however, the productivity requirement column indicates how much time is required to be saved by each sailor every day in order to recoup the investment costs of the program within 5 years' time.

The Google Nexus is one of the smallest and least expensive tablets on the market. At a price point of $200, the present value of the program drops considerably and positive net present value is seen in year 1; meaning that the program becomes immediately less to acquire than the status quo hybrid network.

At a price point of $900 the Surface Pro offers the functionality of a laptop, with its windows operating system, minus the hard drive and compact disk drive. With the price of the Surface Pro the break-even point of the program shifts to 18 years into the life of the ship however, with at least 74 seconds a day of productivity savings the initial investment can be recovered in 5 years.

Even with the broad range of prices to choose from with tablet purchases the productivity savings of the WCC tablet network remains the same. With all three price points listed in Table 23 all the productivity requirements are well within the reach of each and every sailor onboard a DDG.

Device Cost Sensitivity Analysis With 1 DDG Installation				
Device	Price	Initial Investment	Payback Achieved (years)	Productivity Req (seconds)
Google Nexus	$ 200.00	$ 9,722.21	N/A	N/A
Average Device Price	$ 432.25	$ (66,920.29)	5	22
Surface Pro	$ 900.00	$ (221,277.79)	18	74

Table 23. Device Cost Sensitivity Analysis

2. Installation Costs

This thesis concludes that installation, for the WCCN, will cost approximately $13,799.13. However, in the event that installation is in fact 10 times its current estimate at $137,991.27 the payback required would be 22 years, with only operation savings (see Table 24). However, the productivity requirement would only be 64 seconds per day to pay off the initial investment in less than 5 years' time. Therefore, the break-even point concerning operations savings is sensitive to installation fluctuations however; the productivity savings are still quite obtainable based on these calculations

1st DDG Payback with Operation Savings			
Initial Investment Costs	Year 1 Installation	Productivity Required (seconds)	Payback Years with Operation Savings Alone (Years)
$ (191,112.44)	$ (137,991.27)	64	22

Table 24. Program Payback With High Installation Costs

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IV. ACCOUNTING FOR PRODUCTIVITY

A. PRODUCTIVITY PARADOX

From the early 1980s to the late 1990s, the United States experienced a boom in technology investment that did not have an observable impact on productivity. Some economists argue that the paradox between the 1980s and 1990s mirrors the rapid adoption of electricity between 1890 and 1913 in that there was an obvious slowdown in productivity (Spithoven, 2003). The economist that recognized the mirror between now and the late 1800s assert that the expected effect of electricity on productivity was measured far too early and that there should be a longer incubation period to adequately assess technology's effect on productivity. In the minds of some, technology actually had an unintended negative effect on the productivity of the United States. There are three guiding principles on why the productivity paradox relating to information technology occurred (Lee & Perry, 2002).

The first theory is that a large investment in technology will only offer an advantage or boost in productivity that is momentary, relative to the competition. The idea is that as soon as something new comes along the first establishment that adopts the new technology will have an edge that last for as long as it takes the competition to catch up.

The second theory says that the metrics that are in place inadequately measure the effects of productivity relating to information technology and that a change in the quality of output is therefore not captured. Economist Paul David argues in his widely known paper that even though electricity was such a huge advancement in the United States and England the industries that would eventually benefit from its use were not necessarily being measured as inputs to productivity (David, 1990).

The third theory postulates two principles that contribute to the productivity paradox. Number one is that even though information technology investment was pronounced in the aforementioned time period people did not initially understand how to apply the boom of information technology. Some feel that proper training did not accompany the technology boost, which led to poor adoption of the new technology. This theory is supported by William King and Jun He's paper on the Meta-analysis of the Technology Acceptance Model; where they assert that if a new technology is not easy enough to use or does not have a useful purpose then people are less likely to use it.

The second principal claims that industry did not have the appropriate infrastructure to appropriately accept technology innovations. According to economists, during the period of the productivity paradox, more time may have been required for the business industry to catch up to new innovations and that time was not captured with the introduction of the technology. The same is not true for the introduction of tablet devices.

Before 2005, the market relied mainly upon computers (see Figure 17). With the release of the iPhone in 2007 and the iPad in 2010 the landscape of the computing world completely changed direction (CNET News Staff, 2010).

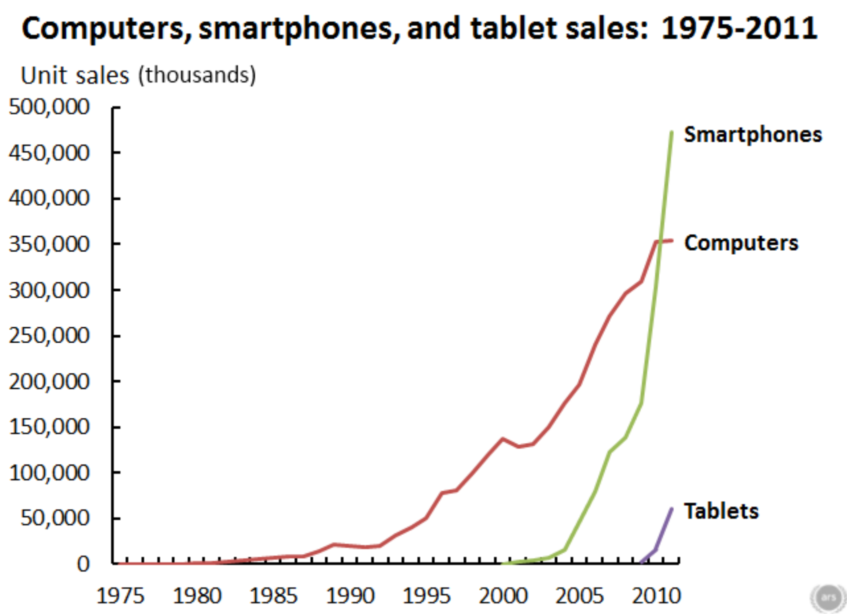

Figure 18. Market Share Of Tablets, Smartphones And Computers (From Reimer, 2012)

The introduction of the iPad has literally changed the way people do business and it shows in the rate of tablet adoption compared to other mobile technologies that have been released throughout the years (see Figure 19). According to the Morgan Stanley Research Group, tablets have caused a decrease of 20% in personal computer use since 2008. The general population is relying more upon tablets to perform daily tasks such as Internet, communication and education (Morgan Stanley Research Team, 2011). During the fourth quarter of 2012 personal computer sells were down by nearly 10% worldwide (Bajarin, 2013).

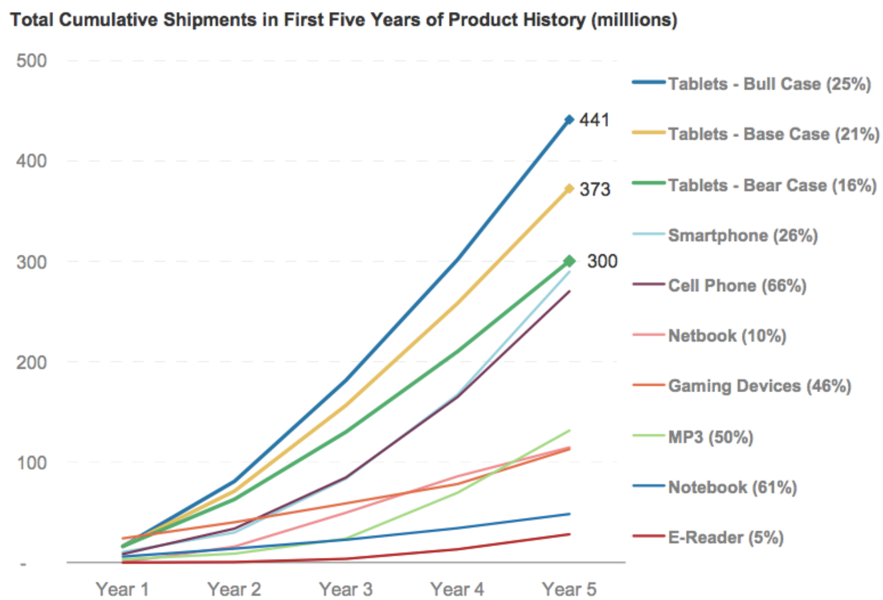

Figure 19. Mobile Technology Demand Following Release (From Morgan Stanley Research Team, 2011)

The world is adopting tablet use at a very fast rate. The Technology Acceptance Model says that if technology is easy to use and people understand the utility of it then they will harness it (King & He, 2006). If people are adopting the use of tablet devices at such an increasing rate then we can draw, based on the technology acceptance model paper, that people really see the practical use in tablet devices and they are largely easy to use.

One of the most telling research cases on technology introduction and productivity comes from a case study on the introduction of wireless personal digital assistants at Sears (Violino, 1998). Sears armed its 14,000 service technicians with wireless personal computers that linked to their databases via a WLAN connection. Sears' Chief Information Officer (CIO) projected a productivity gain of up to 8% because the devices would allow technicians to: request price estimates, check for parts availability, place orders, receive software updates and obtain job schedule updates all while on the go. The CIO calculated cost savings and NPVs over a 5-year period using estimates of the best and worst case scenarios. As a result of the NPV analysis completed by the Sears CIO the company adopted the program and even sought an upgrade of the program to the Windows operating system.

Recently, according to an article in Forbes magazine, a hospital CIO conducted a return on investment analysis of iPads using a "time-motion analysis around clinical workflow tied roughly to various labor costs" (Munro, 2013). The CIO found that it took only 9 days to achieve return. The study conducted by the hospital's CIO showed that even if projections were off by 300% or more the return would still be dramatically compelling in favor of continued iPad adoption. The case is the same for this thesis concerning the range of productivity required to ensure payback. According to calculations in the productivity section, even if sailors saved only 33 seconds a day it would be enough to ensure the program pays for itself in well under 5 years.

The productivity studies outlined in this thesis are less than substantive evidence of the benefits of tablet and WCCN adoption due to the newness of this technology. The iPad has only been around for approximately 3 years and has yet to undergo significant scientific research as to its impact on productivity. Currently the proof of the tablet concept lies in the rate of its adoption.

B. QUALITATIVE BENEFITS

The life of a ship of war is one of constant flux, in order to keep pace with the changing missions, briefings and flow of information the crew must be truly mobile and able to respond to a dynamic environment. Mobility must not only take root in the sole mission of the ship but in the daily seemingly trivial activities of the crew.

With the status quo network onboard Navy ships the basic needs of every sailor are not being met concerning simple access to email and word processing. By placing a tablet device in every sailor's hand the path to efficiency truly begins. After the question of availability has been answered the door for innovation is open to Sailors using the technology in the way of apps.

As stated earlier, an app store is fueled by the needs of the technology users. If there is an area that can be improved, tablet devices empower the user to make an application that can meet their own need. There are several processes in the Navy that are repetitious in nature and could stand to be streamlined by leveraging information technology. Doing things faster, wherever we are, and with more precision is a hallmark of military culture and can be more effectively achieved by a host of apps.

Log Taking App: In the engineering department on board a DDG there are several watch standers that are required to monitor levels on certain pieces of equipment at regular intervals. These watch standers must also be able to notify higher authority in the event that one or several of the readings they have taken departs from a controllable limit. With an app for log taking the minute a log begins to trend in an undesirable way, key people within a department can be notified therefor decreasing the response time to a developing casualty.

Foreign Port Lessons Learned App: When a ship travels to different ports there are a series of reports that must be filed to request for supplies, disposal of trash and assistance with navigation into foreign waters. With a lessons learned app that provides information dependent upon GPS location, as soon a ship gets to a certain port a list of lessons learned can become visible in the app informing the user about the quickest way to deal with certain aspects of a particular port or what navigational aids can be readily used to help navigate into port safely.

Anonymous Opinion Submission App: Often times the Captain of a ship has an opinion box that Sailors use to give anonymous opinions to the Captain that would not normally feel comfortable saying to his face. Normally there are some personnel higher up in the chain of command that vet the opinions prior to them reaching the Captain so that ones that seem a little more dicey can be taken out. With an anonymous submission app the Captain can get a truly honest look at what is on the minds of his crew.

Damage Control Reporting App: When a ship takes on damage it requires that numerous reports be given to repair lockers that organized the efforts of combating the damage. By utilizing an app that allows all apps to see the same picture an schematic of certain parts of the ship can be annotated in real time by Sailors on scene providing instantaneous information to the repair lockers. This app can greatly reduce the time it takes to combat damage onboard a Navy ship.

Preventive Maintenance App: In order to ensure the many pieces of equipment onboard ship remain in good working order, Sailors perform regular maintenance on those pieces of equipment to prevent their subsequent failure in time of need. Normally a sailor is required to bring at least 2 or 3 large binders to the location of the preventive maintenance to adequately perform the maintenance. It would be much more time efficient if the sailor could simply take the tablet with them to the piece of equipment of interest and look up the procedure on their tablet device. This would not only save the trouble of thumbing through different publications to find the write one but also the hassle of lugging several binders up and down narrow hallways and stairs to perform 5 minutes of maintenance.

The required time to be saved in order to recoup an investment in WCC is 22 seconds per sailor per year. Surely 22 seconds can be obtained by utilizing any of the apps mentioned.

V. CONCLUSION AND RECOMMENDATIONS

Due to the high upfront costs of purchasing tablet devices for every person in the crew the initial investment is a third larger than the hybrid option. However, based on the operation cost savings alone the tablet alternative costs less over its life cycle. With the compounding costs of both productivity and operation cost savings, the recommendation of this thesis is to adopt a WCCN using tablet devices with a 2-year installation approach. The accelerated installation approach helps quickly capture the cost savings in operation and productivity therefore providing a high NPV earlier in the programs life cycle and it also has a slightly lower initial investment requirement.

The procurement of tablets should be made based on the functionality and overall reliability of the tablet platform being considered. Whether the tablet cost is $200 or $900 the program will pay for itself several times over based on productivity improvements for United States Sailors.

WCCN Payoffs With Productivity Savings								
Investment Options	Initial Investment	Productivity Payoff Times (Months)				Productivity Payoff Times (Days)		
		0.209% (90 sec)	0.5% (4 min)	1% (7 min)	3% (26 min)	5% (36 min)	7% (50 min)	9% (65 min)
1 Ship Installation	$ (66,920.29)	5	6	3	1	19	13	10
5 Year Installation	$ (4,239,633.57)	20	8	4	1	25	18	14
2 Year Accelerated Installation	$ (4,114,180.19)	16	7	3	1	20	14	11

Table 25. Productivity Payoff Times With Different Investment Options

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APPENDIX A. WAP LOCATION, QUANTITY, AND INSTALLATION TIME DETERMINATION

In 2001, 3e Technologies International undertook the process of installing a completely WLAN on the USS HOWARD (DDG 83) (see Figure 20). The WLAN undertaking sought to achieve a smart ship design that would allow the remote monitoring of the ship and reduce the costs of drop installation allowing wireless devices to join the network with little effort (3e Technologies, 2001).

Figure 20. USS HOWARD WLAN Presentation Introduction (From 3e Technologies, 2001)

The program would achieve its goal by installing WAPs all over the ship and measuring the signal strength at several pre-determined points throughout the ship to determine adequacy. Ultimately the program determined that by installing the WAPs where they did, they achieved a 95% coverage rate throughout the ship.

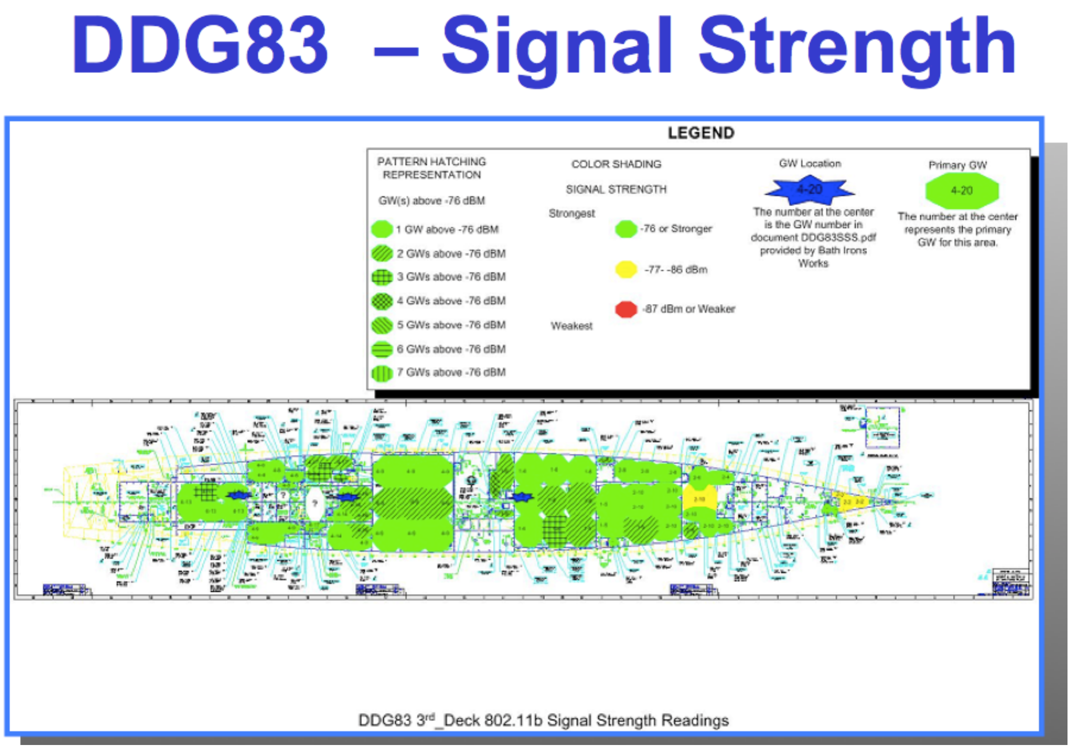

Figure 21. USS HOWARD Signal Strength Readings (From 3e Technologies, 2001)

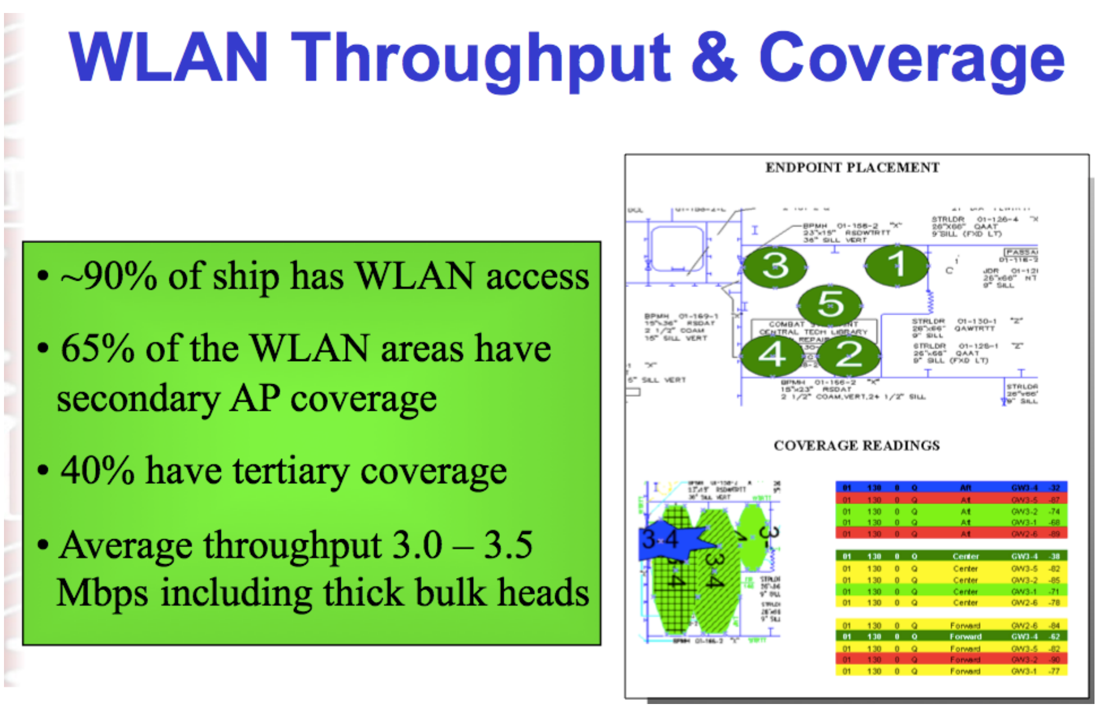

Figure 22. WLAN Coverage on USS HOWARD (DDG 83) (From 3e Technologies, 2001)

I used the various locations indicated in Figure 23 to build a database of WAP locations that would ensure adequate signal coverage throughout a DDG.

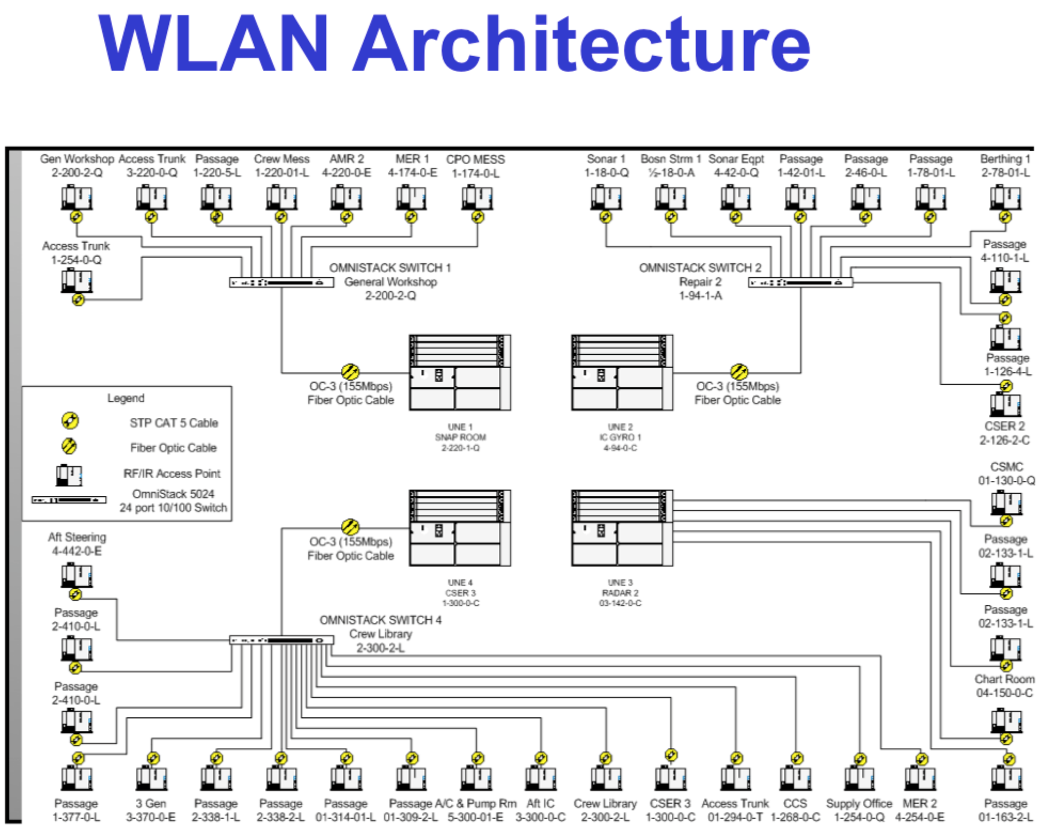

Figure 23. USS HOWARD (DDG 83) WLAN Architecture (From 3e Technologies, 2001)

Shortly after the USS HOWARD WLAN installation, 3e technologies commenced a similar installation program onboard the USS MASON (DDG 87) that is outlined in a presentation obtained from the Internet (SPAWAR, 2013). I added to my database of WAP locations using Figure 24 from the USS MASON installation presentation.

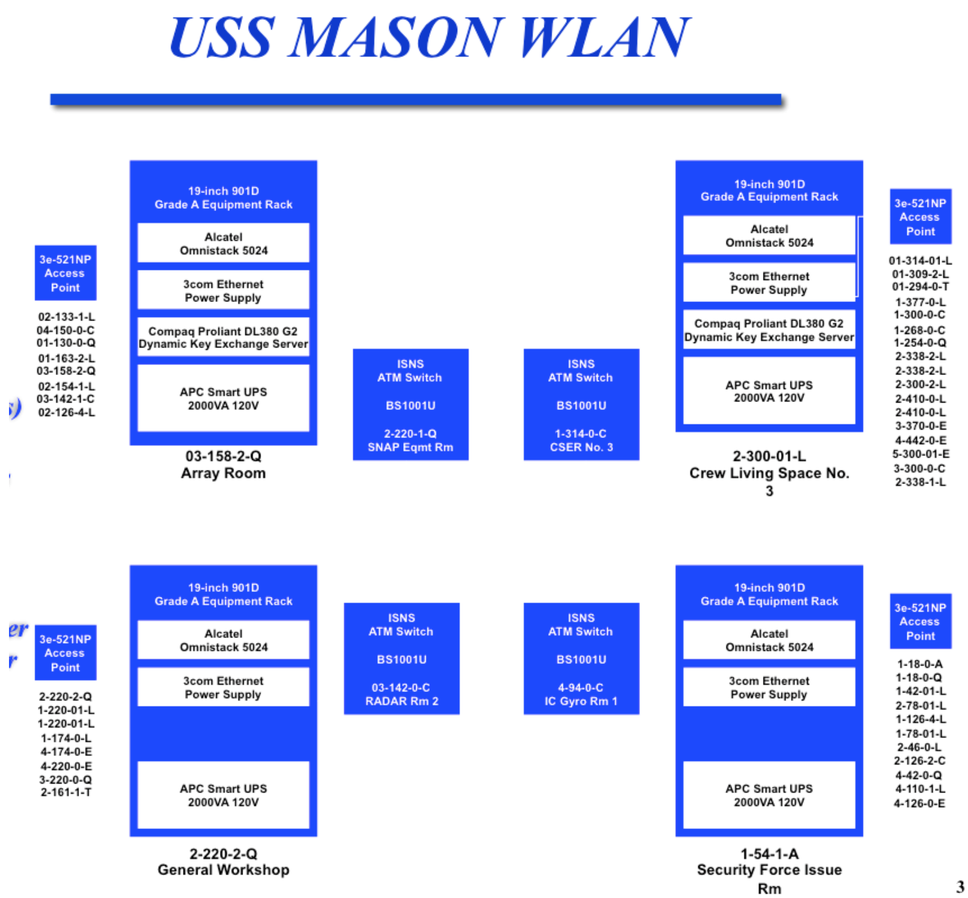

Figure 24. USS MASON (DDG 87) WLAN Architecture (From 3e Technologies, 2001)

Using a generic list of DDG drop locations obtained from the Bath, ME shipyard and SPAWAR, I cross referenced the existing drop locations with the WAP location database that was created using the USS HOWARD and MASON pilot programs. After the cross reference was completed, I had a list of 72 existing drops that could be used to install WAPs with CAT 5e cable already in place and a list of 23 WAP locations that needed CAT 5e wire installation.

Generic DDG Drop List								
Comp B	Compartment	item	Comp B	Compartment	item	Comp B	Compartment	item
Armory	2-370-5-A	1	CSMC	01-130-0-Q	38	Ships Office	1-78-4-Q	75
Array Room No 4 (AFT PORT)	03-158-2-Q	2	CSMC	01-130-0-Q	39	Ships Office	1-78-4-Q	76
Auxilliary Machinary Room 1	4-126-0-E	3	CSMC	01-130-0-Q	40	Ships Office	1-78-4-Q	77
AVIATION FLIGHT GEAR STRM	01-314-4-A	4	DC EQUIP LOCKER	1-330-0-A	41	SNAP COMPUTER ROOM	2-220-1-Q	78
AVIATION OFFICE	01-377-1-Q	5	DEP HEAD STATEROOM	01-314-2-L	42	SNAP COMPUTER ROOM	2-220-1-Q	79
BOSN STOREROOM #1	.5-18-0-A	6	DISBURSING	1-84-1-Q	43	Sonar Control Admin Office	2-42-1-Q	80
CCS & DC CENTRAL	1-268-0-C	7	ELECTRIC SHOP	2-381-1-Q	44	Sonar Control Room	2-50-2-C	81
Chart Room	04-150-0-C	8	ENGINE ROOM #2	4-254-0-E	45	Sonar Equipment Room 1	1-18-0-Q	82
CIC	1-126-0-C	9	Engineering Department Office	1-258-3-Q	46	SSES	01-130-2-C	83
CIC	1-126-0-C	10	Engineering Department Office	1-258-3-Q	47	State Room	01-320-1-L	84
CIC Annex	1-126-0-C	11	Engineering Department Office	1-258-3-Q	48	State Room	2-338-4-L	85
CIC Annex	1-126-0-C	12	Engineering Department Office	1-258-3-Q	49	State Room	2-358-2-L	86
CMAA Office	1-258-1-Q	13	Engineering Department Office	1-258-3-Q	50	State Room	01-314-1-L	87
CMAA/ NC	3-357-2-Q	14	Engineering TECH LIBRARY	0.5-50-1-Q	51	State Room	01-300-4-L	88
CMC Office	1-206-1-Q	15	ET Shop #2	01-174-2-Q	52	State Room	02-126-2-L	89
CO Cabin	02-146-1-L	16	FILTER CLEANING SHOP	01-188-2-Q	53	State Room	02-126-1-L	90
CO SEA CABIN	04-158-2-L	17	GAUGE CAL SHOP	.05-42-1-Q	54	State Room	02-158-7-L	91
Communications Center	2-126-1-C	18	General Workshop	2-200-2-Q	55	State Room	02-145-2-L	92
Communications Center	2-126-1-C	19	HAZMAT ISSUE ROOM	4-410-1-A	56	State Room	02-145-1-L	93
CPO MESS	1-174-0-L	20	IC and Gyro Room 1	4-94-0-C	57	State Room	02-136-2-L	94
CREW LIBRARY	2-300-2-L	21	IC and Gyro Room 2	3-300-Q-C	58	State Room	02-136-1-L	95
CREW LIBRARY	2-300-2-L	22	IC and Gyro Room 2	3-300-Q-C	59	Supply Department Office	1-254-0-Q	96
CREW LIBRARY	2-300-2-L	23	MEDICAL	1-220-3-L	60	Supply Department Office	1-254-0-Q	97
CREW LIBRARY	2-300-2-L	24	OOD Station 1	01-220-1-Q	61	Supply Department Office	1-254-0-Q	98
CREW LIBRARY	2-300-2-L	25	OOD Station 2	01-220-2-Q	62	Supply Support Center	3-220-2-Q	99
CREW LIBRARY	2-300-2-L	26	OOD Station 3	1-399-1-Q	63	Supply Support Center	3-220-2-Q	100
CREW LIBRARY	2-300-2-L	27	OPS DEPT Office	1-163-1-Q	64	Supply Support Center	3-220-2-Q	101
CREW LIBRARY	2-300-2-L	28	OPS DEPT Office	1-163-1-Q	65	Supply Support Center	3-220-2-Q	102
CREW LIBRARY	2-300-2-L	29	OPS DEPT Office	1-163-1-Q	66	TECHNICAL LIBRARY ANNEX	01-110-01-Q	103
CREW TRAINING	01-319-2-L	30	Pilot House	04-130-0-C	67	TECHNICAL LIBRARY ANNEX	01-110-01-Q	104
Crews Mess	1-220-01-L	31	Pilot House	04-130-0-C	68	TEST LAB	2-300-4-Q	105
CSER 1	2-53-1-C	32	Radar Room 2	03-142-0-C	69	Tomahawk Equipment Room	2-153-2-C	106
CSER 2	2-126-2-C	33	Radar Room 3	01-274-1-C	70	TOOL ISSUE ROOM	2-300-4-Q	107
CSER 3	1-300-0-C	34	Repair 2	1-94-1-A	71	WARDROOM	02-126-4-L	108
CSER 3	1-300-0-C	35	Repair 3	2-410-2-A	72	Weapons Workshop/3MC	02-112-0-Q	109
CSER 3A	1-314-0-C	36	Repair 5	1-206-3-A	73	WEAPONS/AVIATION WRKSHP	01-300-0-Q	110
CSER 4	03-142-1-Q	37	Ships Office	1-78-4-Q	74	XO Stateroom	01-158-4-L	111

Table 26. Generic DDG Drop List (After Bath Maine Shipyard, 2013)

In order to establish a base case and obtain average server distances to the 23 additional WAP locations, I used an unclassified server and drop list from Bath, ME shipyard that detailed which installed drop locations connected to specific servers within a generic new construction DDG (see Table 26).

By making the following assumptions, offered by the shipbuilding office in Pascagoula, MS, I was able to determine the feet of cable and the time required to run from each drop listed in Table 26:

- If an Ethernet cable is to traverse through a bulkhead or wall it is assumed to add 1 foot to the cable run.
- In order to traverse the length or width of a compartment add approximately 10 feet of cable.

I then applied a few of my own assumptions based on my knowledge of Navy Destroyer construction to help determine how much length of cable to use and how much time it would take to install the cable:

- There are approximately 477 frames from perpendicular to perpendicular on a Navy Destroyer and each frame space can be assumed to represent a foot of space.
- A compartment on a DDG is considered to be on the left or right of centerline based on the third digit of its compartment number for example:
    - 2–220–1-Q, the first digit of this compartment number is 2, which indicates it is on the 2nd deck of the ship and the third digit of 220 indicates it is located on the 220th frame of the ship. The third digit of 1 indicates that the compartment is on the right side of the ship and is the first compartment right of the centerline of the ship. If the third digit is odd then the compartment is on the right side but if the digit is even then it is on the left side of the ship. Also, if the third digit is a 3 instead of a 1 then this would tell me that the compartment is on the right side but also that it is approximately one compartment over from the center line instead of being located adjacent to the center line. The last digit of the compartment number indicates what type of space it is, in this case a "Q" means it could be an engineering or electrical space.
- If a server were on the opposite end of the ship each compartment that is required to traverse would add 10 minutes per compartment to the installation time.
- It will take 90 minutes to install cable from one deck to the next.
- It will take 5 minutes to install cable across one frame.

In order to determine the amount of time it would take to mount a WAP or a drop I made the assumption that it will take 30 minutes to mount a WAP on the wall excluding the amount of time it takes to route the Ethernet cable for the WAP.

After determining the distances and mounting times for each drop location on Table 8, I determined how much cable on average it took to install a WAP and how long it would take to install the WAP on average with the cable installation time averaged in. I then applied the baseline number of 4.57 hours to install cable in preparation for mounting 1 WAP or drop to all 23 additional WAPs needed to install for the successful coverage case.

In order to assist the reader in understanding the overall calculations of the WAP installation time, I have attached a detailed graphic in Figure 20. By using the overall time computed in Figure 20 and multiplying it by the average wage rate given from Pascagoula, MS and Bath, ME shipyards I determine the total cost of installation to be approximately $14,000 for the first installation. The installation cost would then decrease along a 85% learning curve per ship installation.

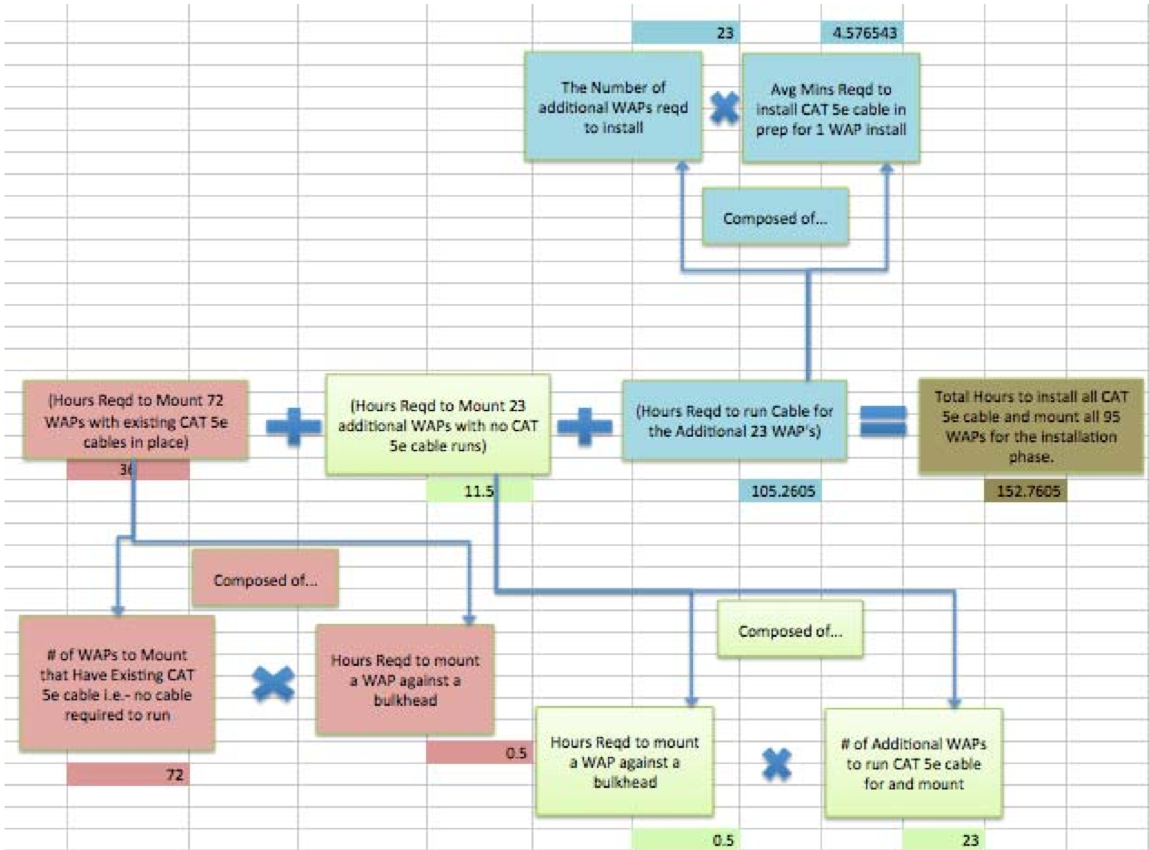

Figure 25. Hours Required to Install WAPs Calculation

Server 1 2-220-1-Q SNAP #2 PORT

Compartent Number	Distance From Server (Feet)	Frames Traversed	Athwart Bulkheads Traversed	Decks Traversed
01-220-1-Q	22	0	0	2
01-220-2-Q	22	0	2	2
1-126-0-C	105	4	1	1
1-126-0-C	105	4	1	1
1-126-0-Q	105	94	1	1
1-206-3-A	25	14	1	1
1-220-01-L	11	0	0	1
1-220-3-L	11	0	1	1
1-254-0-Q	45	34	1	1
1-254-0-Q	45	34	1	1
1-254-0-Q	45	34	1	1
1-254-0-Q	45	34	1	1
1-254-0-Q	45	34	1	1
1-258-1-Q	49	38	0	1
1-258-3-Q	49	38	1	1
1-258-3-Q	49	38	1	1
1-258-3-Q	49	38	1	1
1-258-3-Q	49	38	1	1
1-268-0-C	49	48	1	1
2-126-1-C	94	94	0	0
2-126-1-C	94	94	0	0
2-126-1-C	94	94	0	0
2-126-2-Q	94	94	2	0
2-153-2-C	67	67	2	0
2-200-2-Q	20	20	2	0
2-220-1-Q	0	0	0	0
2-220-1-Q	0	0	0	0
3-200-4-Q	31	20	3	1
3-220-2-Q	31	0	2	1
3-220-2-Q	31	0	2	1
3-220-2-Q	31	0	2	1
3-220-2-Q	31	0	2	1

Server 2 1-300-0-C CSER 3 CTR

Compartent Number	Distance From Server (Feet)	Frames Traversed	Athwart Bulkheads Traversed	Decks Traversed
01-274-1-C	37	26	1	1
01-300-0-Q	11	0	0	1
01-300-4-L	11	0	2	1
01-314-1-L	25	14	1	1
01-314-2-L	25	14	1	1
01-314-4-A	25	14	2	1
01-319-2-L	30	19	1	1
01-320-1-L	31	20	1	1
01-377-1-Q	88	77	1	1
1-258-3-Q	42	42	2	0
1-300-0-C	0	0	0	0
1-300-0-C	0	0	0	0
1-314-0-C	14	14	0	0
1-330-0-A	30	30	0	0
1-399-1-Q	99	99	1	0
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-2-L	11	0	1	1
2-300-4-A	11	0	2	1
2-338-4-L	49	38	2	1
2-358-2-L	69	58	1	1
2-370-5-A	81	70	3	1
2-381-1-Q	92	81	1	1
2-410-2-A	121	110	1	1
3-300-0-C	22	0	0	2
3-300-0-C	22	0	0	2
3-357-2-Q	79	57	1	2
4-410-1-A	143	110	1	3

Server 3 03-128-2-Q ARRAY RM #2 STBD

Compartent Number	Distance From Server (Feet)	Frames Traversed	Athwart Bulkheads Traversed	Decks Traversed
0.5-42-1-Q	119	88	2	3
0.5-50-1-Q	111	78	2	3
01-110-01-Q	40	18	1	2
01-110-01-Q	40	18	1	2
01-130-0-Q	24	2	1	2
01-130-0-Q	24	2	1	2
01-130-0-Q	24	2	1	2
01-130-2-C	24	2	0	2
01-158-4-L	52	30	1	2
01-174-2-Q	68	46	0	2
01-188-2-Q	82	60	0	2
02-112-0-Q	27	16	1	1
02-126-1-L	13	2	2	1
02-126-2-L	13	2	0	1
02-126-4-L	13	2	1	1
02-136-1-L	19	12	2	1
02-136-2-L	19	8	0	1
02-145-1-L	28	17	2	1
02-145-2-L	28	17	0	1
02-146-1-L	29	18	2	1
02-158-7-L	41	30	4	1
03-142-0-C	14	14	1	0
03-142-1-C	14	14	2	0
03-158-2-Q	30	30	0	0
04-130-0-C	13	2	1	1
04-130-0-C	13	2	1	1
04-130-0-C	13	2	1	1
04-150-0-C	33	22	1	1
04-158-2-L	41	30	0	1
1-126-0-C	35	2	1	3
1-163-1-Q	68	35	2	3
1-163-1-Q	68	35	2	3
1-163-1-Q	68	35	2	3
1-174-0-L	79	46	1	3
1-18-0-Q	143	110	1	3
1-206-1-Q	111	78	2	3
1-78-4-Q	83	60	1	3
1-78-4-Q	83	60	1	3
1-78-4-Q	83	60	1	3
1-79-4-Q	82	49	1	3
1-84-1-Q	77	44	2	3
1-94-1-A	67	34	2	3
2-42-1-Q	130	86	2	4
2-50-2-C	122	78	0	4
2-53-1-C	119	75	2	4
4-94-0-C	100	34	1	6

TOTAL DROPS TO INSTALL	135
TOTAL FEET OF CABLE USED	7053
TOTAL DECKS TRAVERSED	205
TOTAL FRAMES TRAVERSED	3444
TOTAL ATHWART BH TRAVERSED	140
TOTAL WAPS TO INSTALL	95
TOTAL ADDTL WAPS TO INSTALL	23

ASSUMPTIONS

1. It will take 90 minutes to traverse a cat 5e cable from one deck to the next
2. It will take 5 minutes to travers a cat 5e cable from one frame to the next
3. It will take 30 minutes to install a mount for a WAP against the bulkhead excluding CAT 5e cable routing
4. It will take 10 minutes to traverse a cat 5e cable through one athwart ship bulkhead

GUIDANCE: Given by Pascagoula, MS shipyard

CAT 5e cables have a length restriction of 328' (100 meters)
Any runs longer than 328 feet require LAN (EDGE) Switches
1 Bulkhead=1 foot
10 feet added to every run to extend connection from the cableway

KNOWLEDGE

There are approximately 477 frames from perpindicular to perpindicular of the ship
The frames are essentially 1 foot apart.

Table 27. Generic DDG Server and Drop Location List with Distance Determination (After Bath Maine Shipyard, 2013)

APPENDIX B. PRODUCTIVITY SAVINGS CALCULATIONS

This Appendix discusses how the productivity saving of 22 seconds was determined per sailor per ship for 5 years. In order to start the calculation, a baseline case of average pay on a DDG was established by determining the different pay grades and pay rates on a DDG. In order to determine full pay, basic allowance for housing as well as subsistence and sea pay was considered as well.

To ensure the pay was averaged out over the correct period the total amount of actual working days was determined to be 303, which excluded federal holidays, and half of the weekends in a year. Half of the weekends are considered working days due to regular duty and deployment schedules.

Average Pay Determination				
Ranks	Monthly Salary	Total Pay Per Rank	Strength	Total Pay by Strength
O-5	$ 16,285.25	$ 195,423.00	1	$ 195,423.00
O-4	$ 14,528.58	$ 174,343.00	2	$ 348,686.00
O-3	$ 12,475.17	$ 149,702.00	5	$ 748,510.00
O-2	$ 9,836.42	$ 118,037.00	2	$ 236,074.00
O-1	$ 7,943.58	$ 95,323.00	18	$ 1,715,814.00
WO-2	$ 10,835.25	$ 130,023.00	2	$ 260,046.00
E-9	$ 12,017.75	$ 144,213.00	1	$ 144,213.00
E-8	$ 10,241.50	$ 122,898.00	2	$ 245,796.00
E-7	$ 9,151.17	$ 109,814.00	24	$ 2,635,536.00
E-6	$ 8,011.33	$ 96,136.00	30	$ 2,884,080.00
E-5	$ 6,823.33	$ 81,880.00	96	$ 7,860,480.00
E-4	$ 5,533.50	$ 66,402.00	138	$ 9,163,476.00
E-3	$ 4,624.08	$ 55,489.00	8	$ 443,912.00
E-2	$ 4,105.83	$ 49,270.00	1	$ 49,270.00
			330	$26,931,316.00
Weighted Average Yearly Salary				$ 81,610.05

Table 28. DDG Average Pay Determination

Total Working Hours Determination						
Days In Year	Weekend Days in a Year (Days)	Working Weekends Days (Days)	Federal Holidays (Days)	Total Working Days in a Year (Days)	Total Working Hours in a Day (Hours)	Total Working Hours in a Year (Hours)
365	104	52	10	303	12	3636

Table 29. Total Working Hours Determination

Productivity Determination					
Discounted Sum of First 5 Years of Total Crew Salary of 13 DDGs	Initial Investment of 1 ships	Productivity Required to meet 5 year payback	Time Savings Required Per Person Per Year (hours)	Time Savings Required in a Day Per Person (Minutes)	Time Savings Required in a Day Per Person (Seconds)
$ 129,779,466.33	$ (66,920.29)	0.052%	1.87489	0.37	22.28

Table 30. Productivity Determination

APPENDIX C. PRODUCT SPECIFICATION SHEETS

This Appendix takes a closer look at each of the specification sheets for the products discussed in the thesis in order to point out the power usage.

Energy Consumption (in accordance with US Energy Star test method)	115VAC, 60Hz	230VAC, 50Hz	100VAC, 60Hz
Normal Operation	16.05W	16.45W	16.27W
Sleep	0.52W	0.49W	0.51W
Off	0.39W	0.37W	0.42W

Figure 26. HP Compaq LA1751g 17-inch LCD Monitor Energy Consumption Specifications (From Hewlett-Packard Development Company, 2011)

Energy Consumption	115 VAC	230 VAC	100 VAC
Normal Operation	12.1 W	12.2 W	12.1 W
Sleep (Energy Star low power mode)	NA	NA	NA
Off	0.43 W	0.52 W	0.41 W

Figure 27. HP t5745 Thin Client Energy Consumption Specifications (From Hewlett-Packard Development Company, 2013a)

	115 VAC		230 VAC		100 VAC	
	LAN Enabled	LAN Disabled	LAN Enabled	LAN Disabled	LAN Enabled	LAN Disabled
Windows Idle (S0)	38.1 W		39.6 W		38.2 W	
Windows Busy Typ(S0)	149.1 W		147.3 W		150.2 W	
Windows Busy Max (S0)	163.4 W		162.0 W		164.6 W	
Sleep (S3)	3.27 W	2.93 W	3.45 W	3.10 W	3.27 W	2.92W
Off (S5)	1.31W	1.15 W	1.47W	1.31 W	1.30 W	1.14 W
Zero Power Mode (EuP)	0.18 W		0.29 W		0.17W	

Figure 28. HP Z210 CMT Workstation Energy Consumption Specifications (From Hewlett-Packard Development Company, 2013b)

Power Consumption for iPad 2 (Wi-Fi + 3G)

Mode	100V	115V	230V
Sleep	0.46W	0.41W	0.45W
Idle—Display on	3.10W	3.08W	3.16W
Power adapter, no-load	0.07W	0.07W	0.09W
Power adapter efficiency	80.9%	80.8%	79.9%

Figure 29. iPad 2 Energy Consumption Specification Sheet (From Apple, 2012a)

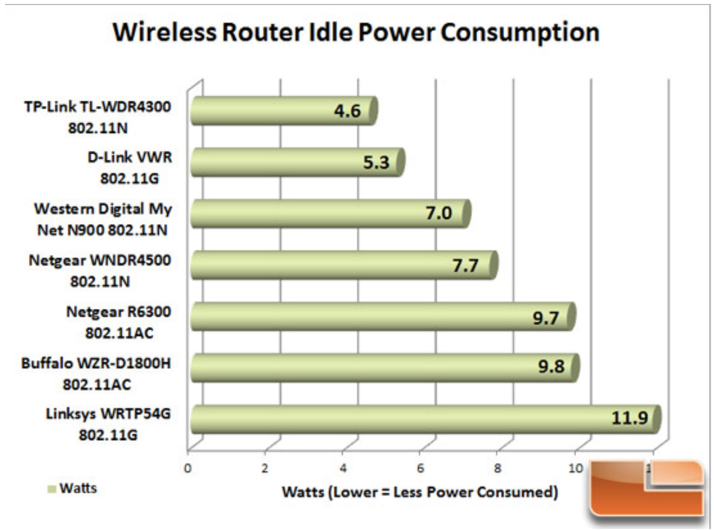

Figure 30. Average Wireless Router Power Consumption (From Brown, 2012)

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