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Business Case Analysis of Joint Base Pearl Harbor-Hickam 5G Initiative: Naval Information Warfare Center Pacific Building 992 and Building 998

June 2023

ENS Jacob L. Staples, USN
ENS Hayden T. Tidball, USN

Thesis Advisors: Dr. Nicholas Dew, Professor

Department of Defense Management

Naval Postgraduate School

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Prepared for the Naval Postgraduate School, Monterey, CA 93943.

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ABSTRACT

Naval Information Warfare Center (NIWC) Pacific Building 992 (B992) and Building 998 (B998) at Joint Base Pearl Harbor-Hickam (JBPHH) currently rely on costly and outdated time division multiplexing (TDM) switches, and this technology must be replaced to comply with Department of Defense (DOD) requirements. 5G technology offers the potential to improve service speed, quality, and security and decrease long-term maintenance costs for the DOD. This thesis uses NIWC Pacific B992 and B998 as a hypothetical test site to conduct a business case analysis (BCA) comparing the costs of the current telecommunications infrastructure with four different 5G-enabled modernization alternatives. After performing a 10-year net present value (NPV) analysis, the results of this study indicate that adopting 5G technology can enhance performance and produce significant long-term cost savings. This thesis provides a BCA spreadsheet tool that is intended to be used to evaluate similar 5G initiatives at other facilities or DOD installations.

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LIST OF ACRONYMS AND ABBREVIATIONS

5G	Fifth Generation
B992	Building 992
B998	Building 998
BCA	Business Case Analysis
C2	Command and Control
CAPEX	Capital Expenditures
CIO	Chief Information Officer of the Department of Defense
COTS	Commercial Off-The-Shelf
CVR	Commercial Virtual Network
DOD	Department of Defense
DSN	Defense Switched Network
FCC	Federal Communications Commission
FWA	Fixed Wireless Access
GAO	Government Accountability Office
GB	Gigabyte
Gbps	Gigabit per Second
JBPHH	Joint Base Pearl Harbor-Hickam
LTE	Long-Term Evolution
M365	Microsoft Office 365
MB	Megabyte
MS	Microsoft
NIWC	Naval Information Warfare Center
NMCI	Navy-Marine Corps Intranet
NPV	Net Present Value
O&M	Operations and Maintenance
OMB	Office of Management and Budget
OPEX	Operational Expenditures

OUSD(R&E)	Office of The Under Secretary of Defense for Research and Engineering
PRI	Primary Rate Interface
RDT&E	Research, Development, Test, and Evaluation
RoF	Radio-Over-Fiber
ROM	Rough Order of Magnitude
TCO	Total Cost of Ownership
TDM	Time Division Multiplexing
U.S.	United States
USMC	United States Marine Corps
VoIP	Voice Over Internet Protocol

EXECUTIVE SUMMARY

The Department of Defense (DOD) has determined to eliminate the use of legacy technologies and adopt modern systems to maintain a competitive edge over peer adversaries and safeguard its information. Many military installations currently rely on time division multiplexing (TDM) technology, which utilizes physical wires for telecommunications instead of the modern standard, Voice Over Internet Protocol (VoIP). This obsolete technology has become extremely expensive to operate and maintain, primarily due to the unavailability of replacement parts from original manufacturers. Consequently, replacing any equipment must be done through contractors resulting in especially high costs for the DOD. Additionally, the reliance on physical wires and TDM switches leaves DOD sites vulnerable to limited network infrastructure redundancy and potentially, inoperability in the event that the infrastructure is damaged.

The DOD Chief Information Officer (CIO) released two memorandums establishing the following requirements:

- All DOD Components must eliminate the use of Primary Rate Interface (PRI) circuits and networks that do not use VoIP by Fiscal Year 2023 (Department of Defense Chief Information Officer [DOD CIO], 2020);
- All DOD Components must eliminate the use of TDM switch technology by March 2025 (Department of Defense Chief Information Officer [DOD CIO], 2021b).

Naval Information Warfare Center (NIWC) Pacific Building 992 (B992) and Building 998 (B998) at Joint Base Pearl Harbor-Hickam (JBPHH) currently utilize TDM switches, and this technology must be replaced promptly. Therefore, NIWC Pacific B992 and B998 serves as an appropriate hypothetical site to conduct a study analyzing the financial impacts of upgrading its telecommunications infrastructure. 5G technology offers the potential to improve service speed, quality, and security and decrease long-term maintenance costs. We conducted a business case analysis for these two buildings which analyzed four 5G-enabled modernization options and aimed to answer the following research questions:

- What are the short and long-term costs of each of the four telephone and network infrastructure modernization options based on the NIWC Pacific B992 and B998 model?
- Which modernization option is the best choice for improving the telephone and network infrastructure at B992 and B998?
- What are the primary learnings from this study that can be applied to similar initiatives for other DOD installations?

In this study, we conducted a financial analysis considering five alternatives: NIWC Pacific B992 and B998's current infrastructure, Fixed Wireless Access, Fixed Wireless Access with Smartphones, Spidercloud, and a 5G Private Network. The basic principles of net present value (NPV) analysis were used to discount the associated cash flows over a 10-year period which provided a financial basis for comparing the different options. Table 1 shows the results of the 10-year NPV analysis of each alternative. It is important to note that the findings of this study are intended to be viewed as preliminary cost estimates aimed at assessing the cost-effectiveness of modernizing B992 and B998's network systems. These results should be interpreted with the understanding that further analysis would be necessary to obtain precise financial projections. Nonetheless, this study is certainly useful in serving as a starting point for developing comparisons and evaluating the feasibility of different network modernization alternatives.

Table 1. 10-Year Net Present Value Results

1: Baseline	$9,743,178
2: Fixed Wireless Access	$8,259,557
3: Fixed Wireless Access + Smartphones	$8,471,583
4: Spidercloud	$7,549,305
5: Private 5G Network	$11,524,454

From this analysis, we yielded the following conclusions:

- NIWC Pacific B992 and B998’s current, outdated infrastructure is more costly than several modernization alternatives, and replacing it would provide significant financial benefits.
- Alternative 3 (FWA + Smartphones) and Alternative 4 (Spidercloud) are viable modernization alternatives. Both options are less costly than Alternative 1 (Baseline), and both eliminate the use of TDM switch technology.
- The recurring operations and maintenance costs are the major cost drivers for all the alternatives. The initial upfront costs are less impactful.

We made two recommendations based on the results of this study. First, NIWC Pacific B992 and B998’s current infrastructure should be replaced with a 5G-enabled modernization solution immediately. Alternatives 2, 3, and 4 provide enhanced network capabilities while also producing long-term cost savings. To continue operating the current infrastructure would be an inefficient and irresponsible use of taxpayer dollars. Alternatives 3 and 4 both replace the use of hardwired desk phones with Flank Speed iPhones satisfying the requirements set forth by the DOD CIO to eliminate legacy technology (DOD CIO, 2020; DOD CIO, 2021b). Secondly, we recommend performing a similar analysis at other DOD installations. The results from this analysis indicate that modernizing the telecommunications network infrastructure at a hypothetical DOD site (e.g., NIWC Pacific B992 and B998) can enhance performance and produce significant long-term cost savings. We believe that other DOD organizations should explore modernization options that will likely yield similar results. By doing so, the DOD is better positioned to make informed decisions and allocate resources more efficiently. This thesis provides a BCA spreadsheet tool for Naval Information Warfare Center (NIWC) Pacific that is intended to be used to evaluate similar 5G initiatives at other facilities or Department of Defense (DOD) installations.

References

Department of Defense Chief Information Officer. (2020, September 4). *Defense switch network primary rate interface networking elimination – technical notification* [Memorandum]. Department of Defense.

Department of Defense Chief Information Officer. (2021b, October 18). *Time division multiplexing technology elimination* [Memorandum]. Department of Defense.

I. INTRODUCTION

This thesis is a business case analysis (BCA) examining the financial costs of the current network infrastructure and modern telecommunications network solutions for Building 992 (B992) and Building 998 (B998) operated by Naval Information Warfare Center (NIWC) Pacific at Joint Base Pearl Harbor-Hickam (JBPHH). Due to the rising costs of legacy technology and the Department of Defense (DOD) Chief Information Officer's (CIO) guidance to eliminate the use of these technologies, the current telecommunications network infrastructure at Buildings 992 and 998 must be replaced. This analysis serves as a data-driven starting point to evaluate modern telecommunications network solutions and determine the financial feasibility of upgrading the current infrastructure at DOD facilities.

A. PURPOSE

This BCA provides decision-makers from Naval Information Warfare Center (NIWC) Pacific and other DOD organizations with a model and the information needed to begin the process of selecting the best telecommunications network modernization solution while being responsible stewards of United States (U.S.) taxpayer dollars.

B. PROBLEM STATEMENT

NIWC Pacific B992 and B998 facilities' upkeep with modernization remains stagnant with its old technologies and the current network infrastructure in need of replacement (Naval Information Warfare Center Pacific (NIWC PAC), 2022). Most current base telecommunications services are provisioned and enabled through aging, marginally supported, and in some cases single-threaded Layer 1 (physical layer) telecommunications infrastructure technologies such as copper and fiber cables, distributed through both underground conduits and on poles (NIWC PAC, 2022). This aging infrastructure supports legacy (1980s) time division multiplexing (TDM) services which are still in use at many bases (NIWC PAC, 2022). Having such dated technologies provides limited network infrastructure redundancy or backup connectivity (NIWC PAC, 2022). These characteristics make NIWC Pacific B992 and B998 an appropriate site for analyzing the financial impacts of alternative modernized telecommunications network solutions. 5G technology offers the potential to improve service speed, quality, and security and decrease long-term maintenance costs. We conducted a business case analysis for NIWC Pacific B992 and B998 which analyzed four 5G-enabled modernization options and aimed to answer the following research questions:

1. Research Questions

- What are the short and long-term costs of each of the four telephone and network infrastructure modernization options?
- Which modernization option is the best choice for improving the telephone and network infrastructure at NIWC Pacific B992 and B998?
- What are the primary learnings from this study that can be applied to analyses of similar initiatives at other Department of Defense (DOD) installations?

C. BACKGROUND AND CONTEXT

1. NIWC Pacific Building 992 and Building 998

This study analyzed two NIWC buildings, designated Building 992 and Building 998. These buildings are currently used by NIWC Pacific and are the focus of this study. B992 is 87,660 square feet and hosts 265 users. B998 is 10,400 square feet and hosts nine users. The facility under analysis covers a total area of 98,060 square feet and supports 274 users. Both buildings were constructed with metal rooves and siding. The cellular service within the buildings is poor.

In both buildings, every desk has a wired telephone which relies on time division multiplexing (TDM) switch technology and an article from Yeaster states this technology dates to the early 1900s before the advent of the internet (Yeaster, 2020). The technology utilizes telephone lines and physical switches to route calls over copper wires while Voice over Internet Protocol (VoIP) transmits information over Internet Protocol (IP) networks (Natalie, 2020). VoIP, used by modern data-based smartphones and other internet-connected devices, converts the user's voice into digital signals and then back into an audible voice on the other end (Yeaster, 2020). Because an internet connection is the only requirement, maintenance costs and equipment requirements are lower than TDM technology (Yeaster, 2020).

2. Fifth Generation (5G) Technology

In comparison to 4G long-term evolution (LTE), 5G offers increased speed, lower latency, enhanced capacity, and increased bandwidth (Intel Corp., n.d.). 5G provides speeds that can perform 100 times faster than 4G LTE which can take downloading a multi-gigabyte (GB) file from minutes into seconds (Intel Corp., n.d.). According to Intel, latency "measures how long a signal takes to go from its source to its receiver, and then back again" (Intel Corp., n.d., Low Latency). 5G technology offers latency speeds of less than 5 milliseconds, which is faster than a human can visually process something enabling real-time control over remote devices (Intel Corp., n.d.). In other words, 5G latency speeds are so fast that human response time will be the only limiting factor for remote devices and machines. This technology also allows for levels of capacity, or how many devices can be used on the same network at once, over 1000 times greater than that of 4G LTE (Intel Corp., n.d.). For networks with many devices working simultaneously, 5G enables more devices to run at optimum speeds making processes more efficient. Lastly, 5G brings increased bandwidth which allows for more data to be transmitted at once from many devices within the network coverage area and is designed to better handle unusual variations in network traffic (Intel Corp., n.d.).

3. U.S. Navy's Flank Speed

To improve collaboration, productivity, and cyber security, the Navy has permanently transitioned to a cloud-based environment called Flank Speed. In a statement to the Senate Armed Services Committee in 2021, the former Acting Secretary of the Navy Thomas Harker states that Flank Speed is an "enduring cloud-based Microsoft Office 365 (M365) solution which will provide world-class security and collaboration tools to improve productivity" (Department of the Navy [DON] Posture, 2021, p. 19). Every member of the Navy now has access to the entire portfolio of M365 programs which includes PowerPoint, Word, and Excel as well as one terabyte of cloud storage via Microsoft's One Drive (Department of Defense Chief Information Officer [DOD CIO], 2021a).

The Navy began to rollout access to Flank Speed on June 1, 2021, and permanently replaces Navy-Marine Corps Intranet (NMCI) Office 365 (O365) and Commercial Virtual Network (CVR) (Flank Speed (DOD CIO, 2021a). Flank Speed is "built on the advanced security principles of zero trust" and has security Impact Level 5 (IL-5) while CVR only operated at IL-2 (DOD CIO, 2021a, Quick Facts). With IL-2 security, only material that is accessible to the public is permitted but Flank Speed's IL-5 security level allows for Controlled Unclassified Information (CUI) (Stone, 2022). Users can now access Flank Speed's M365 suite of programs from their personal devices with common access card (CAC) authentication (DOD CIO, 2021a).

D. PROJECT INITIATIVE

The introduction of 5G technology has garnered attention from all sectors of the public and private industry due to its enhanced capabilities and cost-saving potential. On May 2nd, 2020, the Secretary of Defense approved and released the Department of Defense 5G Strategy (Department of Defense (DOD), 2020). Later that year, the DOD announced $600 million in contract awards to 15 different vendors for the implementation of 5G technologies at five military installations (Office of the Under Secretary of Defense, Research and Engineering (OUSD(R&E), n.d.). Notably, Naval Base Coronado now features an operational smart warehouse to enhance efficiency in logistical operations, and Nellis Air Force Base is using 5G technology to strengthen its Command and Control (C2) environment for pilots and ground forces (Gimbel, 2021). Since the announcement of the 5G strategy, the DOD has increased the number of test bed locations to 16 (OUSD(R&E), n.d.). To date, 65 contracts have been awarded to over 100 vendors including major companies like AT&T, Ericsson, Verizon, Hughes, and General Electric (OUSD(R&E), n.d.).

The DOD released two tranches of test beds for 5G testing and experimentation. Tranche 1 includes Hill Air Force Base, Naval Base San Diego, Marine Corps Logistics Base Albany, and Nellis Air Force Base (OUSD(R&E), n.d.). Tranche 2 includes the Fort

Irwin National Training Center, Camp Pendleton, JBPHH, Tinker Air Force Base, Naval Station Norfolk, Naval Station Whidbey Island, Joint Base San Antonio, and Joint Base Lewis-McChord (OUSD(R&E), n.d.).

This report focuses on the 5G initiative at JBPHH, using NIWC Pacific B992 and B998 as a proxy site for the rest of JBPHH and other military installations, to provide innovative commercial technology for the defense environment. 5G technology can provide the installation with significant improvements in internet service speed, cybersecurity, and Layer 1 transport modernization. In peacetime or degraded scenarios, the adoption of 5G technology will provide invaluable enhancements in opportunities for service diversity, break-fix resilience, and C2 maneuverability.

Though this study is conducted for the JBPHH 5G initiative, the ultimate stakeholder is the Program Executive Office for Digital and Enterprise Services (PEO Digital). PEO Digital is the "Department of the Navy's enterprise-wide information technology acquisition agent" (NavWar, n.d., About). PEO Digital manages a portfolio of Information Technology (IT) services to ensure sailors and marines have the technology and capabilities to efficiently conduct their missions and operations (NavWar, n.d.). Their portfolio of IT services includes platform application services, digital workplace services, infrastructure services, cybersecurity and operational services, end-user services, strategic sourcing services, and public safety systems (NavWar, n.d.).

1. Eliminating Time Division Multiplexing (TDM) Technology

TDM, a legacy infrastructure technology for phone switches, was widely implemented in the 1980s and is still used at many U.S. military bases. TDM switches are used for the Defense Switched Network (DSN) and the Public Switch Telephone Network (PSTN). Both DSN and PTSN rely on primary rate interface (PRI) circuits that have reached their end-of-life and come at a great cost to the DOD to repair and sustain (Department of Defense Chief Information Officer [DOD CIO], 2020). The DOD Chief Information Officer (CIO) released a memorandum on September 4, 2020, requiring DOD Components to eliminate the use of PRI circuits and networks that do not use VoIP by fiscal year (FY) 2023 (DOD CIO, 2020).

TDM switches are no longer being supported by private vendors and are reaching their end-of-life and end-of-sale. Military installations that still rely on these switches are vulnerable to various risks. TDM switches have a high failure rate which disrupts telecommunications in the workplace, and the costs to fix and sustain these switches are increasing at an unsustainable rate (Department of Defense Chief Information Officer [DOD CIO], 2021b). TDM switches also pose threats to base cybersecurity from their continued use. On October 18, 2021, the DOD CIO released another memorandum requiring all DOD Components to eliminate the use of the TDM technology by March 2025 (DOD CIO, 2021b).

In our research, we found five reasons why a transition away from TDM should occur: users are locked into contracts with vendors, lack of mobility, limited scalability, requirement of on-site IT staff, and limited customization (Yeaster, 2020). Many of the vendors that sold TDM technology required all the hardware to come from them, because many of the parts were manufactured to be incompatible with cheaper parts from other vendors (Yeaster, 2020). Some vendors have dropped support for their technology entirely, and users are forced to hire expensive contractors and manufacturers to acquire replacement parts (Yeaster, 2020). Phones that use TDM technology are landlocked to a wire restricting mobility and potentially limiting productivity levels for workers (Yeaster, 2020). This technology is not easily scalable, because the number of phone lines is predetermined before installation, and significant resources are needed to add additional lines (Yeaster, 2020). Due to the aging analog nature of the TDM technology, maintenance and IT staff are contracted to keep systems updated and working properly resulting in significant costs over prolonged periods (Yeaster, 2020). Because the hardware is propriety, customization of any kind requires skilled technicians (Yeaster, 2020). The dated technology is unable to merge with modern VoIP-based productivity tools and communication ecosystems which significantly inhibits facilities that still rely on TDM switches (Yeaster, 2020).

This business case analysis is intended to inform and empower decision-makers to find the best solution for replacing aging telecommunications infrastructure with 5G-enabled network systems. This study analyzed NIWC Pacific B992 and B998 as a hypothetical test site and can be used as a proxy for other DOD facilities, stations, and potentially naval ships and vessels. Because many DOD installations still use TDM switches, Buildings 992 and 998 provided a suitable starting point to develop a cost analysis. Ideally, the study will be applicable and scalable for other DOD projects to compare the feasibility of different telecommunications network modernization solutions.

E. ORGANIZATION OF STUDY

There are six chapters in this thesis. Chapter II reviews essential background and prior studies. Chapter III lists the key assumptions and constraints used for this study and discusses the analysis methodology. Chapter IV details the business case alternatives, cost analyses, and qualitative benefits for each of the alternatives. Chapter V explains a sensitivity analysis for trenching costs and discusses the net present value results. Chapter VI lists our conclusions and recommendations as well as future studies and our final thoughts.

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II. LITERATURE REVIEW

This chapter provides an overview of previous research from three different studies that aided our research. These studies lay a foundation that supports the DOD's 5G initiative to modernize the telecommunications systems at sites like Naval Information Warfare Center Pacific Building 992 and Building 998. Previous research has shown that organizations, including the DOD, can achieve cost savings while also improving their capabilities by adopting current technologies. These findings reinforce the motivation of this thesis which is to analyze the financial costs of hypothetically upgrading the network infrastructure at NIWC Pacific B992 and B998 and identify the benefits of eliminating old, costly network systems.

A. TOTAL COST OF OWNERSHIP OF DIGITAL VS. ANALOG RADIO-OVER FIBER ARCHITECTURES FOR 5G FRONTHAULING

"Total Cost of Ownership of Digital vs. Analog Radio-Over Fiber Architectures for 5G Fronthauling" is a study that analyzed the TCO for 5G fronthauling solutions (Udalcovs et al., 2020). The paper analyzed the capital expenditures (CAPEX) and operational expenditures (OPEX) for three different radio-over-fiber (RoF) techniques that included a purely analog RoF technique, a purely digital RoF technique, and a combination of the two (2020). The CAPEX and OPEX of each technique were examined with the options of fiber trenching or fiber leasing (Udalcovs et al., 2020). Fiber trenching was assumed to be under CAPEX as it is a singular upfront capital cost and fiber leasing was assumed to be an OPEX due to regular leasing fees (Udalcovs et al., 2020). The study varied several other cost contributors including the number of aggregated subcarriers and the mean fiber-hop length (2020). CAPEX includes the purchasing and installation of the initial equipment required for the 5G fronthaul as well as the infrastructure to house it all, fiber deployment, and installation (Udalcovs et al., 2020). OPEX is composed of energy costs, spectrum and fiber leasing, maintenance, fault management, and floor space costs over 10 years (Udalcovs et al., 2020).

The study found that the TCO for digital RoF architectures was lower than the TCO for analog RoF architectures in every scenario examined (2020). Udalcovs et al. found that the CAPEX for digital RoF architectures was much higher than analog RoF architectures but had several advantages that could lead to a lesser TCO (2020). The study also found that there was a minor difference in CAPEX between fiber trenching and fiber leasing scenarios (2020). According to Udalcovs et al., the cost to trench electrical conduit is expensive but becomes a sunk cost after completion and there is often excess space to run more fiber in the same duct in the future (2020). Because of this, Udalcovs et al. found there was little difference between the CAPEX of digital RoF and analog RoF in fiber trenching scenarios (2020). To strengthen their findings, the authors conducted a sensitivity analysis that revealed that "small deviations in the price or other parameter values do not change the overall conclusions" (2020, TCO Results).

The cost difference between fiber trenching and fiber leasing among the different scenarios of digital and analog RoF architectures provides valuable insight for future projects and considerations. Furthermore, the population density between urban and rural sites plays a large role in influencing the respective costs of fiber leasing and the number of aggregated subcarriers (Udalcovs et al., 2020). The complementary findings from Udalcovs et al. should be regarded in conjunction with the insights of this paper for any future 5G projects to maximize cost effectiveness.

B. DEPARTMENT OF DEFENSE STRATEGIC AND BUSINESS CASE ANALYSIS FOR COMMERCIAL PRODUCTS IN SECURE MOBILE COMPUTING

"Department of Defense Strategic and Business Case Analysis for Commercial Products in Secure Mobile Computing" is a study that analyzes whether the incorporation of commercial technology over technology designed specifically for the military would enhance productivity and offer cost savings (O'Neal & Dixon, 2011). The study finds that "the DOD has been unable to acquire a suitable device, or set of devices, that meets all of its needs" (2011, Executive Summary). O'Neal and Dixon found that the greatest challenge in finding such devices was the DOD's security requirements for sensitive and classified material that are, at the time the study was published, beyond what commercial devices offer (2011). The government-obtained secure communications at that time were far more costly and often lacked the necessary capabilities which yielded decreased productivity (O'Neal & Dixon, 2011).

The criteria the authors followed in the analysis are as follows: reduce the DOD's high device and service costs, increase overall smartphone functionality for the DOD, and maintain or increase the level of security functionality available in commercial devices for the DOD (2011). The authors explain that because commercial off-the-shelf (COTS) devices are made in the open market, the companies that produce them can operate at economies of scale and sell them at reduced costs relative to the equipment and technology the DOD has developed (2011). The report notes that many of the DOD employees and servicemembers are already using publicly available mobile devices (2011). Due to the familiarity with the COTS devices, integration of this technology into DOD operations would have a reduced learning curve. Once the application of DOD networks and software is successful, the study estimates that employee productivity would increase (2011). The authors argue that the government can leverage its position and power as a customer to incentivize companies with similar goals in terms of security to further develop their devices to meet the requirements of the DOD (2011). Once COTS devices obtain the proper amount of security, the DOD will need to adopt a vigilant integration to ensure that security levels are maintained and the operational tempo is not negatively affected (O'Neal & Dixon, 2011).

Concerning the productivity of DOD employees and integration of commercial smartphones and similar devices, the findings of this report align with those of "Smartphones in the Tactical Environment: A Framework for Financial Analysis of U.S. Marine Corps Options." Both reports are aligned with the current DOD initiatives to integrate and maximize the capabilities of 5G telecommunications networks and devices which supports the purpose of this study. The three criteria the authors followed in this paper's analysis parallel the intentions set forth by NIWC Pacific (2011). The findings of O'Neal and Dixon support the argument to remove the legacy TDM switch system and replace it with a more robust and modernized telecommunications network infrastructure that allows increased use and productivity of smartphone and laptop devices.

C. SMARTPHONES IN THE TACTICAL ENVIRONMENT: A FRAMEWORK FOR FINANCIAL ANALYSIS OF U.S. MARINE CORPS OPTIONS

"Smartphones in the Tactical Environment: A Framework for Financial Analysis of U.S. Marine Corps Options" is a study that performed a business-case analysis of smartphone use in the USMC (Cook et al., 2013). The study was originally looking to see if smartphones could provide tactical utility in the field for newer generations of Marines who are already skilled in using smartphone technology to improve squad-level effectiveness (2013). The business case for smartphone usage in offices to boost productivity was later integrated into the original purpose of the study (2013).

The authors used the net present value (NPV) method, inflation, and discount rates, and considered the replenishment rates of technology as they become outdated or simply worn out from usage (2013). The squad-level analysis of 13 people included five alternatives including replacing the standard radio (PRC-152/152A) with smartphones in the field and similar devices for official use only within the barracks (Cook et al., 2013). The authors of the study conducted another baseline analysis at the company level with three alternatives and a sensitivity analysis of multiple variables to include the consumer surplus (2013). The primary conclusion of the paper is that "the business case for deploying sleeved smartphones in the tactical environment complements the military rationale for adopting this technology" (2013, Introduction). In other words, the study found that under certain conditions a successful rollout starting at the squad level could result in tens of millions of dollars in cost savings at a low productivity level and hundreds of millions of dollars at higher levels of productivity (2013).

Overall, this paper is useful for our analysis by providing a reference for a thesis paper using the OMB A-94 guidelines with a military-focused topic. Our report used this study as an exemplar of how an NPV and sensitivity analysis should be presented. The paper also affirms the argument for replacing older analog technology with modern alternatives that are more scalable and improve productivity. Our paper intends to look at replacing older desk phones that rely on TDM switches with modernized alternatives including Flank Speed enabled smartphones. In terms of cost savings and increased productivity levels, the findings of this study agree with those of the "Department of Defense Strategic and Business Case Analysis for Commercial Products in Secure Mobile Computing" study and support the purpose of our study.

D. SUMMARY

The papers mentioned in this chapter informed the development of this study in several ways. DOD integration of commercial smartphone devices has been shown to improve productivity in the tactical environment, and this concept can be applied to office spaces as well (Cook et al., 2013). The TCO for digital RoF architectures is less than those of analog RoF architectures which justifies replacing B992 and B998's legacy TDM switch systems with a faster, stronger, and more secure telecommunications infrastructure (Udalcovs et al., 2020). The criteria that O'Neal and Dixon followed in their analysis are congruent with the objectives of this study to replace costly legacy systems with cheaper, more capable networks (2011). The analyses by Cook et al. and O'Neal and Dixon both agree that integrating smartphone devices into the DOD workplace would increase productivity (2013; 2011). Though this analysis does not quantitatively analyze the productivity benefits of incorporating smartphone and mobile devices at NIWC Pacific B992 and B998, the qualitative benefits will be discussed in later chapters. However, there is a gap in the literature for business case analyses focused on 5G infrastructure for DOD-specific facilities. This report fills that gap by providing a financial analysis that can be used for a baseline understanding and evaluating cost estimates of 5G alternatives.

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III. METHODOLOGY AND APPROACH

This chapter discusses the financial methods, data sources, and cost assumptions used to compute 10-year cost estimates for the five alternatives compared in this study.

A. BUSINESS CASE ANALYSIS OVERVIEW

This business case analysis created a financial model using Microsoft (MS) Excel that can be used at various DOD facilities to estimate the costs of different network modernization options. We modeled the costs associated with different options available through Verizon to provide enhanced telecommunications services to users for a hypothetical technology update at NIWC Pacific B992 and B998. These updates are analyzed with respect to the baseline case, B992 and B998's current systems, to aid decision-makers in identifying important financial factors associated with this initiative. The five alternatives listed below are considered in this analysis.

- Alternative 1 (Baseline): Current Infrastructure
- Alternative 2: Fixed Wireless Access (FWA)
- Alternative 3: FWA + Smartphones
- Alternative 4: Spidercloud
- Alternative 5: Private 5G Network

The study produced an easy-to-use MS Excel model that allows analysts to input their choice of key variables and see the financial outcomes from the combinations of data they entered for Alternatives 1–5.

B. ANALYSIS METHODOLOGY

This financial analysis used the basic principles of net present value analysis to compare the expected costs of each of the five business case alternatives. To begin, we identified and measured all the primary costs associated with the baseline infrastructure and each of the modernization options. Our process for acquiring this data is discussed further in the Data Collection section. Only those costs which differ among the alternatives are considered relevant and have an impact on the results.

Next, we estimated the cash flows for each year within the period used for the analysis. A ten-year timeframe was chosen to analyze a long enough period to capture the effects of the recurring costs while also taking into consideration the eventual need to modernize again with the rapid advancement of telecommunications technology. Year 0 has been designated as the point in time during which the project is initiated. For this analysis, non-recurring upfront costs are assigned to Year 0. Recurring costs are allocated in yearly amounts starting in Year 0 and occurring every year thereafter.

After estimating all relevant costs for each alternative, we used the net present value method to discount the future cash flows back to a present value. The Office of Management and Budget (OMB) outlines the standard process for analyzing proposed investments or projects using economic principles in Circular A-94 (1992). This analysis adheres to the guidance presented in Circular A-94 and computes an NPV for each of the alternatives as the primary method for financial comparison. Net present value is defined as "the discounted monetized value of expected net benefits (i.e., benefits minus costs)" and is calculated by applying a discount rate to the expected cash flow resulting from a proposed program or project (OMB, 1992, p. 4). The purpose of the discounting process is to convert cash flows occurring in future periods into a common unit of measurement (1992). This method aids decision-makers in determining which course of action will be the most financially favorable over a specified period of time.

To calculate the NPV for each proposed alternative, an appropriate discount rate was selected. The discount rate expresses the time value of money and is especially important for this analysis because many of the costs associated with this project will occur in future periods. Following OMB's guidance in Appendix C of Circular A-94, dated February 17, 2023, the real interest rate on treasury notes and bonds of 10-year maturities is 1.5% (Young, 2023). We used this value as the discount rate for our analysis. Applying the selected discount rate to each of the yearly cash flows produces a discounted cash flow. The final NPV is calculated by simply summing up the discounted cash flows and can then be used to compare the estimated financial viability of the five alternatives considered.

C. DATA COLLECTION

To generate an effective financial analysis, we gathered a significant amount of cost data. For Alternative 1 (Baseline): Current Infrastructure, we acquired data for the current infrastructure's costs directly from the occupants of B992 and B998, NIWC Pacific. NIWC Pacific also provided data for relevant cost drivers of this analysis, including but not limited to the number of users, building size (square footage), and the current number of phones and laptops.

For Alternative 2: Fixed Wireless Access, we acquired all cost data directly from a team of Verizon public sector specialists. See the Appendix for Verizon's FWA cost estimate. Additionally, Verizon's specialists provided guidance related to other options considered in the study, including Spidercloud and Private 5G Network.

For Alternative 3: Fixed Wireless Access plus Smartphones, we acquired cost data from a Waveform commercial specialist. Waveform frequently works with Verizon to design and implement cellular signal solutions for large businesses and government projects. See the Appendix for Waveform's preliminary cost estimate for Alternative 3.

For Alternative 4: Spidercloud, we acquired cost data from WilsonPro Electronics. WilsonPro frequently partners with Verizon to implement commercial 5G repeater systems for enterprise applications. See the Appendix for WilsonPro's rough order of magnitude (ROM) estimate for a Spidercloud solution.

For Alternative 5: Private 5G Network, data collection was more difficult as this solution is very dependent on specific applications. However, discussions with Verizon's public sector specialists generated rough estimates for the cost of implementing a standalone 5G network at the NIWC facilities.

D. ASSUMPTIONS

All portions of this study were analyzed for a specific application to the NIWC Pacific B992 and B998. This site is comprised of two buildings, Building 992 (main office) and Building 998 (warehouse). Building 992 is the primary office facility and has a footprint of 87,660 square feet. There are 265 desks in the main office. Building 998 is a warehouse used for shipping and receiving. The warehouse is 10,400 square feet and has 9 desks, significantly fewer than the main office. In total, the facilities cover 98,060 square feet and have 274 desks, and it is assumed that an individual user is assigned to each desk. This study also assumed that the number of users at the buildings remained constant throughout the period of analysis.

We assumed that every user at the facility currently has one hardwired desk telephone, and no user has a Flank Speed smartphone. For Alternatives 3–5, we assumed that every desk phone is going to be replaced with one Flank Speed smartphone. The transition from hardwired desk phones to wireless smartphones eliminates the use of legacy TDM-based infrastructure. Therefore, the current operations and maintenance (O&M) costs for desk phones are eliminated with the acquisition of Flank Speed smartphones.

For this study, every user is assumed to have one NMCI laptop computer, and some users have an RDT&E laptop computer as well. About 61% of total employees at NIWC Pacific in Hawaii have both an RDT&E and NMCI laptop while the other 39% have only an NMCI laptop. We assumed that these proportions apply to our analysis of B992 and B998. For this analysis, we assumed that 168 of the 274 total users have an RDT&E laptop and an NMCI laptop, and 106 users only have an NMCI laptop. This assumption was applied to all five alternatives. The availability of 5G cellular-enabled laptops is extremely limited at this time, so we assumed that the current quantity and costs of NMCI and RDT&E laptop computers will not change throughout the period of analysis. A summary of the major facility inputs and cost drivers is shown in Table 1.

Table 1. NIWC Pacific B992 and B998 Key Cost Drivers

# of Buildings	2
Total Size (square feet)	98,060
Total Users	274
Total Desk Phones	274
Total Flank Speed Phones	0
Total Flank Phones	274
Total NMCI Laptop Computers	274
Total RDT&E Laptop Computers	168
Total Laptop Computers	442

The cost of trenching to bury underground cable is important to this project because Alternatives 2–5 eliminate the need for a physical wired connection. Trenching costs are extremely variable depending on several factors including geographic location, availability of existing conduits and distance from the nearest fiber connection. To consider the effects of this ranging cost, this study includes a sensitivity analysis using low, middle, and high assumptions for both the cost and required distance of trenching. This analysis is discussed in the Sensitivity Analysis section. However, for this analysis of NIWC Pacific B992 and B998, trenching and cabling have already been performed to install the current wired infrastructure. Therefore, trenching is a sunk cost, and we assumed that no additional trenching is required.

Currently, the facilities have two networks, NMCI and RDT&E. The cost of internet service for these networks was not easily attainable, because these costs are covered by PEO Digital, not the end users. The NMCI network delivers about 10 Gigabits per second (Gbps) of bandwidth, and the RDT&E network provides 80 Gbps. The total bandwidth provided to the buildings is 90 Gbps. Verizon's FIOS Business Gigabit internet costs $250 per month per Gbps of bandwidth (Verizon, n.d. a). Using this rate, we assumed that the current cost for cable internet service at NIWC Pacific B992 and B998 is $22,500 per month or $270,000 per year. This service cost only applies to Alternative 1 (Baseline). Alternatives 2–5 explore other means of providing internet service to the buildings.

NMCI and RDT&E laptops are paid for in monthly increments. The current cost for NMCI laptops is $101.72 per month (per device) and this cost covers the device, a periodic device refresh, and tech services. RDT&E laptops cost $96.57 per month (per device), but this does not cover the cost of the device itself. The RDT&E device cost is paid for through a separate line of accounting, so $96.57 is the only relevant cost that was considered in this analysis. To support 274 NMCI laptop computers, a yearly cost of $334,455 is incurred. The yearly cost for 168 RDT&E laptop computers is $194,685. We assumed that these costs remain constant throughout the period of analysis. Additionally, this business case analysis assumed that the current use of NMCI and RDT&E laptops is not affected by any of the modernization options, and therefore these costs appear in the analysis of each of the five alternatives. It is important to note that these costs do not differ among the options and do not affect the comparison of alternatives. But they were included in each of the five NPV analyses to ensure that this study provided an encompassing projection of the major costs associated with B992 and B998's telecommunications infrastructure.

NIWC Pacific is currently paying $154,000 per year to operate and maintain hardwired desk phones. This cost includes the maintenance and upkeep of the legacy TDM switch infrastructure as discussed in the Background/Context section. We assumed that this cost is driven by the number of desk phones used at the facility. With 274 desk phones, the O&M cost per phone is $562.04 per year.

For Alternatives 3–5, each hardwired desk phone is replaced with a Flank Speed iPhone 12. Flank Speed iPhones cost $52.58 per month (per device) which includes the device, device refresh, data plan, and tech services. We assumed that this monthly cost remains constant throughout the period of analysis.

At the NIWC Pacific buildings, users typically use their devices for basic work productivity tasks including email, web browsing, and occasional video conferencing. We assumed that on average, individual users require 10 GB of cellular data per month. This assumption was calculated using data usage estimates from an online calculator. A summary of the calculations is shown in Table 2. The calculator estimated a total monthly data usage of 9.71 GB. For this analysis, we used 10 GB per month as a safe assumption. With a constant workforce of 274 individuals, we assume that the total monthly data usage at the NIWC Pacific buildings is 2,740 GB of cellular data.

Table 2. Individual Data Usage Calculation. Adapted from PenTeleData (n.d.)

Task	Estimated Usage	Average Data Rate	Total
Web surfing	8 hours/day	18 MB/hour	4.22 GB/month
Emailing	150 emails/day	.02 MB/email	0.09 GB/month
Video streaming	1 hour/month	2 GB/hour	2 GB/month
Video conferencing	10 hours/month	0.34 GB/hour	3.4 GB/month
		TOTAL:	9.71 GB/month

For this analysis, non-recurring upfront costs which typically consist of hardware and installation were assigned to Year 0 of the analysis. Recurring costs which are usually paid for monthly are adjusted for allocation into yearly periods. This simplified the process of performing a 10-year NPV analysis of each alternative. All inputs and costs used in this analysis can be changed in the MS Excel model that we produced in this study. A summary of the major cost assumptions is shown in Table 3.

Table 3. Major Assumptions and Cost Inputs for Financial Analysis

Required Trenching Distance (feet)	-
Local Trenching Cost (per 100 feet)	-
Cable Internet Service Cost (per month)	$22,500.00
NMCI Device Cost (per month)	$101.72
RDT&E Device Cost (per month)	$96.57
Desk Phone Device O&M Cost (per year)	$562.04
Flank Speed Phone Cost (per month)	$52.58
Individual Data Usage (GB per month)	10
Total Data Usage (GB per month)	2,740

E. SCOPE OF ANALYSIS

This study encompassed only unclassified networks; secured spaces and classified networks were not considered. For this analysis, the network is assumed to only service non-critical functions which include the enterprise network (email, online training, MS Teams, video meetings, etc.). Security functions including fire/smoke alarms and building access points were not considered. Elevators, fax machines, and Supervisory Control and Data Acquisition (SCADA) systems were out of scope as well.

IV. ALTERNATIVES CONSIDERED

This chapter provides an in-depth cost analysis of the alternatives considered in this business case analysis. For each option, a description and explanation of the relevant costs is provided. Then, the results of the 10-year NPV analysis as well as the qualitative benefits of each alternative are discussed.

A. ALTERNATIVE 1 (BASELINE): CURRENT INFRASTRUCTURE

1. Overview

An analysis of the current infrastructure at NIWC Pacific B992 and B998 served as the foundation for this study. To determine the expected costs or savings of upgrading the telecommunications systems, Alternative 1 is used as the basis for all comparisons. Currently, users working at the two buildings are equipped with laptops and telephones. Laptops being used are either one of two types of devices: Navy/Marine Corps Intranet (NMCI) or Research, Development, Test & Evaluation (RDT&E). Users also have a hardwired desk telephone. Currently, the network systems use an underground cable connection to transmit data to and from the nearest provider tower.

2. Costs

The major costs associated with the baseline case are the cable internet service cost, O&M cost for the current hardwired desk telephones, and NMCI and RDT&E laptop costs. The recurring costs for NMCI and RDT&E laptops from the baseline case remain the same for Alternatives 2–5 as discussed in the Assumptions section. However, the $154,000 yearly cost to operate and maintain desk phones ($562.04 per phone) is significant and must be eliminated due to the obsolescence of TDM switch technology as discussed in the Background and Context section. Trenching costs are zero, because this is a sunk cost that does not affect future cash flows at this site (see Chapter V for a detailed look into the financial impacts of trenching costs which may be relevant for other analyses). A summary of the costs relevant to the analysis of Alternative 1 is shown in Table 4.

Table 4. Alternative 1 (Baseline: Current Infrastructure) Cost Inputs

Initial Costs	$	Quantity	
Trenching	$0.00	-	
Recurring Costs	**$**	**Frequency**	**Quantity**
Cable Internet Service Cost	$22,500.00	per month	-
Desk Phone O&M (per phone)	$562.04	per year	274
NMCI (per laptop)	$1,120.64	per year	274
RDT&E (per laptop)	$1,158.84	per year	168

3. NPV Analysis

Using a discount rate of 1.5% over a 10-year period, the total cost for the current telecommunications infrastructure is $9,743,178 in present-value dollars. The discounted cash flow analysis is shown in Table 5. The major costs that are eliminated in the modernization options are the cable internet service cost and desk phone O&M cost. Because future trenching is not required to provide a network connection to NIWC Pacific B992 and B998, this cost does not impact Alternative 1. However, if this analysis were being performed at another site where trenching and cabling would be required, this cost could have a significant impact on the NPV for Alternative 1. The Sensitivity Analysis section discusses the effects of trenching on the baseline NPV.

This NPV was used as a baseline for comparison when estimating the costs of Alternatives 2–5. This comparison is discussed in the Analysis of Results chapter of this report.

Table 5. Alternative 1 (Baseline: Current Infrastructure) 10-Year Costs, Discounted Cash Flow, and NPV

Year	0	1	2	3	4	5	6	7	8	9	10
COSTS											
Trenching	$0										
Cable Internet Service Cost	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000
Desk Phone O&M	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000
NMCI Laptops	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455
RDT&E Laptops	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685
TOTAL COSTS	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**	**$953,140**

DISCOUNTED CASH FLOW	**$953,140**	**$939,055**	**$925,177**	**$911,504**	**$898,034**	**$884,762**	**$871,687**	**$858,805**	**$846,113**	**$833,609**	**$821,290**

NET PRESENT VALUE (NPV)	**$9,743,178**

B. ALTERNATIVE 2: FIXED WIRELESS ACCESS (FWA)

1. Overview

Verizon's Fixed Wireless Access, which can support 5G technology, is an innovative concept that enables wireless broadband access (Verizon, n.d. b). FWA systems consist of a fixed base station, also referred to as customer premises equipment (CPE), that is typically attached to a stationary structure or building. The CPE receives a wireless, high-speed internet signal using an indoor or outdoor antenna via radio waves from a Verizon transmitter typically affixed to a cell tower (Verizon, n.d. b). See Figure 1 for a basic overview of how FWA works. A notable advantage of FWA is the eliminated need for fixed or wired broadband (Simon, IoT, 2021). Currently, Verizon's infrastructure in the Hawaii region only supports 4G LTE and 5G Nationwide. 5G Ultra-Wideband, including C-Band and millimeter wave, provides the greatest network speeds with the lowest latency but is not expected to be available in Hawaii for 2 more years.

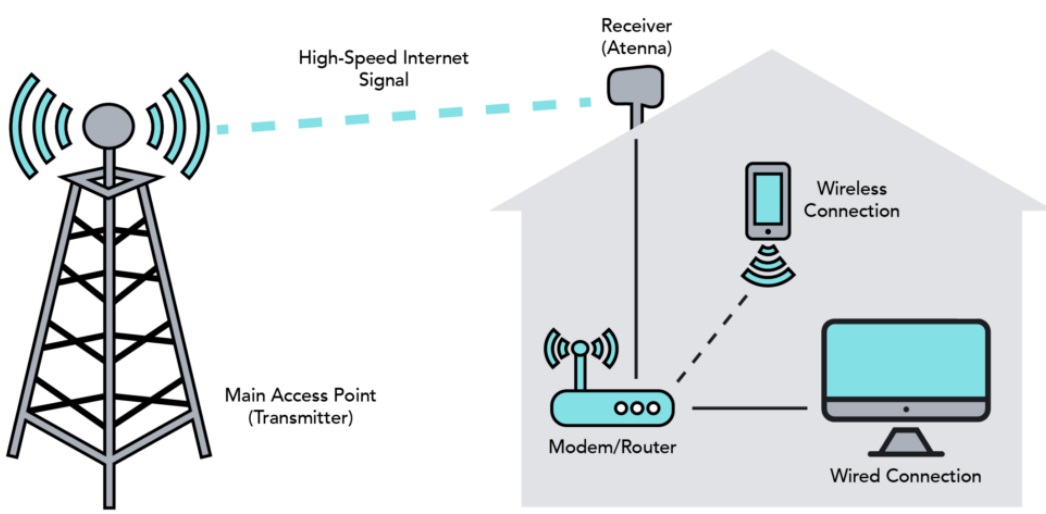

Figure 1. Fixed Wireless Internet. Source: Simon IoT (2021).

Alternative 2 analyzed the costs of utilizing Verizon 5G Nationwide through a Fixed Wireless Access system to provide network services to NIWC Pacific B992 and

B998. All other characteristics of Alternative 1 remain the same, including wired desk phones and the buildings' internal network infrastructure. This alternative simply provides a cost estimate for transitioning from a cable internet connection to an FWA connection.

2. Costs

For this study, the FWA solution uses the Cradlepoint E300, shown in Figure 2, as the CPE device to provide internet access to the buildings. The Cradlepoint E300 is a 5G-enabled enterprise router that is designed for large-scale network applications (Cradlepoint, n.d.). A single E300 can support up to 50 active devices at a given time (n.d.). With a baseline requirement of one E300 for each building, an additional 13 routers are required to support all connected devices at the NIWC buildings. Ultimately, this option requires 15 Cradlepoint E300s at a unit cost of $3,000. The total cost for E300s is $45,000 which is a one-time upfront outlay.

Figure 2. Cradlepoint E300 Enterprise Router. Source: Cradlepoint (n.d.)

The Parsec Chinook is a cellular antenna that is to be mounted outdoors. This antenna receives the 5G Nationwide signal from the nearest Verizon cellular transmitter or tower and is then passed off to the router (Verizon Business email to author, March 8, 2023). One antenna is required for each Cradlepoint E300. Parsec Chinooks are $600 each summing to a total one-time cost of $9,000.

For each router, a monthly cellular data plan is required. Verizon's 5G internet plan costs $160 per month for 100 GB of 5G data (Verizon Business Client Partner, email to author, March 8, 2023). With 15 plans, this equates to a total monthly data allowance of

1500 GB. The previously discussed assumption regarding internet data usage indicates a monthly requirement of 2,740 GB. Therefore, 1,240 GB of data is charged at Verizon's monthly overage rate of $6 per month (Verizon Business Client Partner, email to author, March 8, 2023). Alternative 2 requires a yearly cost of $28,800 for the 100 GB data plans and an additional yearly cost of $89,280 for data overage.

A $100 yearly Netcloud Manager subscription fee is required for each Cradlepoint E300 router. This software provides the user with the ability to configure, operate, manage, and troubleshoot the wireless network (Cradlepoint, n.d.). The cost for Netcloud Manager is $1,500 per year.

The recurring costs for NMCI and RDT&E laptops from the baseline case remain the same for Alternative 2 as discussed in the Assumptions section. A summary of the costs relevant to the analysis of Alternative 2 is shown in Table 6.

Table 6. Alternative 2 (Fixed Wireless Access) Cost Inputs

Initial Costs	$	Quantity	
Cradlepoint E300	$3,000.00	15	
Parsec Chinook	$600.00	15	
Recurring Costs	**$**	**Frequency**	**Quantity**
Data Rate Plan (per 100GB)	$160.00	per month	15
Data Overage Charge (per GB)	$6.00	per month	1240
Netcloud Manager	$100.00	per year	15
Desk Phone O&M (per phone)	$562.04	per year	274
NMCI (per laptop)	$1,120.64	per year	274
RDT&E (per laptop)	$1,158.84	per year	168

3. NPV Analysis

Using a discount rate of 1.5% over a 10-year period, the total cost of implementing a Fixed Wireless Access solution is $8,259,557 in present-value dollars. The discounted cash flow analysis for Alternative 2 is shown in Table 7.

Table 7. Alternative 2 (Fixed Wireless Access) 10-Year Costs, Discounted Cash Flows, and NPV

Year	0	1	2	3	4	5	6	7	8	9	10
COSTS											
Cradlepoint E300	$45,000										
Parsec Chinook	$9,000										
Data Rate Plans	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800
Data Overage Charges	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280
Netcloud Manager	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
Desk Phone O&M	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000	$154,000
NMCI Laptops	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455
RDT&E Laptops	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685
TOTAL COSTS	**$856,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**	**$802,720**

DISCOUNTED CASH FLOW	**$856,720**	**$790,858**	**$779,170**	**$767,655**	**$756,311**	**$745,134**	**$734,122**	**$723,273**	**$712,584**	**$702,053**	**$691,678**

NET PRESENT VALUE (NPV)	**$8,259,557**

4. Qualitative Benefits

The primary benefit of implementing a Fixed Wireless Access solution is eliminating the requirement to have a physical connection to provide network services to the facility. FWA bypasses this connection and enables the wireless transmission of data to and from the nearest cellular tower. This benefit can be extensive, especially for military installations where underground trenching can be extremely expensive or not feasible.

Regarding installation, Alternative 2 is relatively simple to install and operate, because no changes would be made to the current in-building network infrastructure. All previously installed wiring, ethernet cabling, and Wi-Fi access points would continue to be used.

C. ALTERNATIVE 3: FIXED WIRELESS ACCESS + SMARTPHONES

1. Overview

Alternative 3 is a build-off from Alternative 2. Instead of using an underground cable to provide a network connection to the buildings, FWA will be employed. But in addition to FWA, Alternative 3 includes the replacement of all current wired desk phones with Flank Speed smartphones. eFemto devices will be utilized to provide a cellular connection for these phones.

Verizon’s Network Extenders, also referred to as eFemto cells, provide the ability to amplify Verizon cellular coverage within the NIWC buildings (Waveform, n.d.). These devices are typically used within homes and office spaces for businesses (n.d.). Currently, Verizon only offers 4G LTE Network Extenders, however, 5G network amplifying devices are expected to become readily available soon.

Implementing an eFemto solution is quite simple. Small cells are directly installed using the current broadband internet infrastructure within the building typically with an ethernet connection. The device creates a fresh Verizon LTE signal which is then distributed throughout the building. This solution provides reliable, indoor cell service for all users inside the coverage area (Waveform, n.d.). A diagram demonstrating the basic eFemto cell concept is shown in Figure 3.

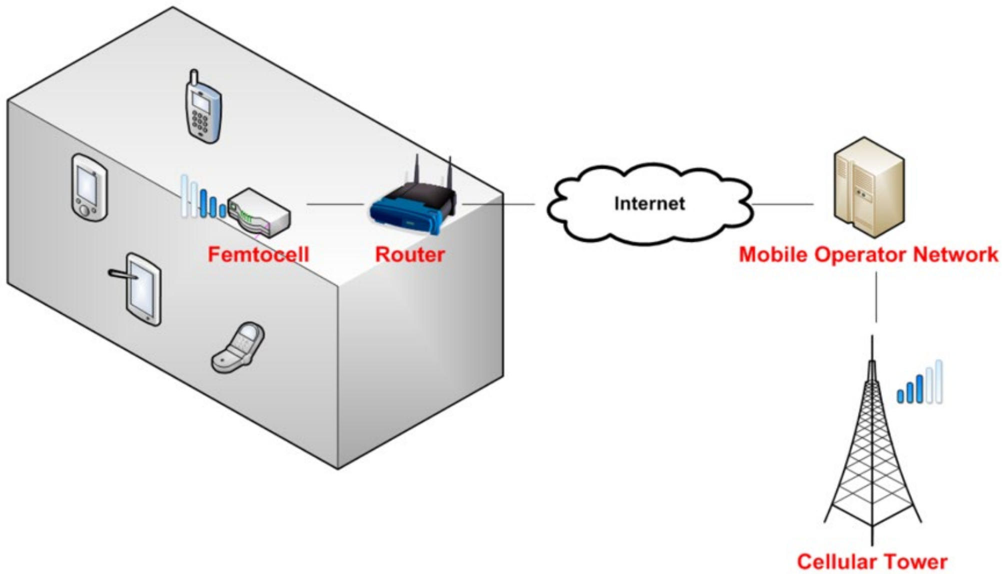

Figure 3. eFemto System Architecture Diagram. Source: Houngninou (2010).

2. Costs

All costs for employing an FWA system, as estimated in the Alternative 2: Fixed Wireless Access section, are applied to Alternative 3 as well.

The eFemto cell used for Alternative 3 is the Verizon LTE Network Extender 3 for Enterprise, shown in Figure 4. This small cell can provide up to 50,000 square feet of coverage and support 64 active users simultaneously (Waveform, n.d.). NIWC Pacific B992 and B998 cover about 100,000 square feet, and this system is required to support 274 Flank Speed devices. Therefore, the number of devices is the constraining factor to determine the quantity of eFemto cells required. Four Verizon LTE Network Extender 3s will be necessary equating to a total cost of $18,000 ($4,500 per device). Additionally, there is a one-time system design and installation cost of $1,000 for this solution.

Figure 4. Verizon LTE Network Extender 3 for Enterprise Femtocell.
Source: Waveform (n.d.).

Alternative 3 includes the replacement of all current hardwired desk telephones with Flank Speed iPhone 12s. This cost was previously discussed in the Assumptions section. For 274 phones, this cost equates to $172,883 per year. Additionally, the recurring costs for NMCI and RDT&E laptops from the baseline case remain the same for Alternative 3 as discussed in the Assumptions section. A summary of the costs relevant to the analysis of Alternative 3 is shown in Table 8.

Table 8. Alternative 3 (FWA + Smartphones) Cost Inputs

Initial Costs	$	Quantity	
Cradlepoint E300	$3,000.00	15	
Parsec Chinook	$600.00	15	
Verizon LTE Network Extender 3	$4,500.00	4	
Design & Installation	$1,000.00	-	
Recurring Costs	**$**	**Frequency**	**Quantity**
Data Rate Plan (per 100GB)	$160.00	per month	15
Data Overage Charge (per GB)	$6.00	per month	1240
Netcloud Manager	$100.00	per year	15
Flank Speed (per phone)	$630.96	per year	274
NMCI (per laptop)	$1,120.64	per year	274
RDT&E (per laptop)	$1,158.84	per year	168

3. NPV Analysis

Using a discount rate of 1.5% over a 10-year period, the total cost of implementing a Fixed Wireless Access solution with the addition of Flank Speed iPhones and indoor cell service extenders is $8,471,583 in present-value dollars. The discounted cash flow analysis for Alternative 3 is shown in Table 9.

Table 9. Alternative 3 (FWA + Smartphones) 10-Year Costs, Discounted Cash Flow, and NPV

Year	0	1	2	3	4	5	6	7	8	9	10
COSTS											
Cradlepoint E300	$45,000										
Parsec Chinook	$9,000										
LTE Network Extenders	$18,000										
eFemto Design & Installation	$1,000										
Data Rate Plans	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800	$28,800
Data Overage Charges	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280	$89,280
Netcloud Manager	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
Flank Speed iPhones	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883
NMCI Laptops	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455
RDT&E Laptops	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685
TOTAL COSTS	**$894,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**	**$821,604**

DISCOUNTED CASH FLOW	**$894,604**	**$809,462**	**$797,499**	**$785,713**	**$774,102**	**$762,662**	**$751,391**	**$740,287**	**$729,347**	**$718,568**	**$707,949**

NET PRESENT VALUE (NPV)	**$8,471,583**

4. Qualitative Benefits

Alternative 3 provides the same benefits as Alternative 2 and more. In addition to bypassing the physical connection between the NIWC buildings and Verizon's base station, Alternative 3 includes the adoption of Flank Speed iPhones. The current use of hardwired desk phones and TDM switch infrastructure is eliminated. This option forgoes the excessive $154,000 per year O&M cost for this obsolete technology. Acquiring smartphones for every user at B992 and B998 will be slightly more expensive ($172,883 per year), however, this transition may provide considerable benefits for employees at the facilities. A major qualitative benefit will be increased productivity enabled through additional capabilities provided by smartphones over desk phones and increased mobility of employees with their work devices physically with them throughout the day.

Regarding installation, Alternative 3 would be moderately simple to install and operate, because no changes would be made to the current in-building network infrastructure. The currently installed wiring, ethernet cabling, and Wi-Fi access points would continue to be employed. However, a system design and installation of the LTE Network Extenders are required to ensure that the indoor cell service is effectively distributed to all users within the buildings.

D. ALTERNATIVE 4: SPIDERCLOUD

1. Overview

A Spidercloud system is a 5G signal repeater solution that will provide indoor 5G cellular service to users at NIWC Pacific B992 and B998 (Ekho Comm, n.d.). The primary differences with a Spidercloud solution are that it does not utilize the building's current internet infrastructure and does not use a dedicated Fixed Wireless Access connection. The Spidercloud solution consists of several outdoor, mounted antennas that will receive cellular signal from the nearest 5G tower (shown as point 1 in Figure 5). The signal booster (shown as point 2 in Figure 5) will receive, amplify, and then distribute the 5G signal throughout the buildings via several indoor dome antennas (shown as point 3 in Figure 5). In essence, the Spidercloud system will boost the existing Verizon 5G cellular service in the area to be used within the NIWC buildings. Combined with 5G mobile hotspots, Alternative 4 provides indoor Wi-Fi and 5G service for all users without the reliance on underground cabling.

Figure 5. Spidercloud Cellular Signal Amplifying System Diagram. Source: Ekho Comm (n.d.).

2. Costs

Alternative 4 uses the Enterprise 4300 Signal Booster, shown in Figure 6, as the primary device for amplifying 5G coverage into the buildings. This booster, offered through WilsonPro Electronics, is designed for commercial use (Wilson Amplifiers, n.d.). The Enterprise 4300 uses three donor antennas to reliably receive a 5G signal from the local cellular tower. When used in conjunction with 10 indoor dome antennas, the Enterprise 4300 will provide a boosted indoor signal covering up to 25,000 square feet (n.d.). For this analysis, five Enterprise 4300 amplifiers are required at a unit cost of $12,899.99 (n.d.). This equates to a total cost of $64,500. The cost for 50 indoor dome antennas ($119.99 each) is $6,000 (Wilson Inside Sales Representative, email to author, March 14, 2023). Lastly, 15 outdoor donor antennas cost $99.99 each or $1,500 total (Wilson Inside Sales Representative, email to author, March 14, 2023).

To connect the external antennas, signal boosters, and indoor antennas spaced throughout the buildings, a significant amount of coax cable is required. WilsonPro estimated a total of 7000 feet of ½ inch cable for a 98,000 square-foot application (Wilson Inside Sales Representative, email to author, March 14, 2023). For $2.76 per foot of cable, the total cost for coax cable is $19,320 (Wilson Inside Sales Representative, email to author, March 14, 2023).

An additional cost for the design and installation of this Spidercloud system is expected to be $18,750 for a project of this size (Wilson Inside Sales Representative, email to author, March 14, 2023). This cost is primarily driven by the square footage of the NIWC Pacific buildings which determines the amount of hardware and cabling needed to be installed.

Figure 6. WilsonPro Enterprise 4300 Signal Booster for Large Enterprise. Source: Wilson Amplifiers (n.d.).

5G business hotspots are used to provide Wi-Fi service within the buildings. The Inseego MIFI PRO, shown in Figure 7, is Verizon's business 5G hotspot and requires an accompanying data plan (Verizon Business, n.d.). The MIFI PRO can provide Wi-Fi for up to 32 connected devices (n.d.). Using this criterion, 14 hotspot devices would be required to provide an internet connection for 442 laptop computers. However, Verizon's mobile hotspot data plan only provides 150GB of premium data (5G) per month (n.d.). To satisfy the data requirement of 2,740 GB per month, Alternative 4 will require 19 Inseego MIFI PROs. With a unit cost of $349.99, the total cost for hotspot devices is $6,650. The monthly data plan cost is $110 per month totaling $2,090 per month or $25,080 per year for all 19 hotspots.

Figure 7. Inseego MIFI X PRO 5G Mobile Hotspot. Source: Verizon Business (n.d.).

Alternative 4 includes the replacement of all current hardwired desk telephones with Flank Speed iPhone 12s. This cost was previously discussed in the Assumptions section. For 274 phones, this cost equates to $172,883 per year. Additionally, the recurring costs for NMCI and RDT&E laptops from the baseline case remain the same for Alternative 4 as discussed in the Assumptions section. A summary of the costs relevant to the analysis of Alternative 4 is shown in Table 10.

Table 10. Alternative 4 (Spidercloud) Cost Inputs

Initial Costs	$	Quantity	
Enterprise 4300	$12,899.99	4	
Server Dome Antenna	$119.99	40	
Donor Antenna	$99.99	12	
Coax Cable (per foot)	$2.76	7000	
Inseego MIFI Pro 5G	$349.99	19	
Design & Installation	$15,000.00	-	
Recurring Costs	**$**	**Frequency**	**Quantity**
Hotspot Data Plan (per 150GB)	$110.00	per month	19
Flank Speed (per phone)	$630.96	per year	274
NMCI (per laptop)	$1,120.64	per year	274
RDT&E (per laptop)	$1,158.84	per year	168

3. NPV Analysis

Using a discount rate of 1.5% over a 10-year period, the total cost of implementing a Spidercloud cell service amplifier system with Wi-Fi hotspots is $7,549,305 in present-value dollars. The discounted cash flow analysis for Alternative 4 is shown in Table 11.

Table 11. Alternative 4 (Spidercloud) 10-Year Costs, Discounted Cash Flow, and NPV

Year	0	1	2	3	4	5	6	7	8	9	10
COSTS											
Enterprise 4300	$64,500										
Server Dome Antenna	$6,000										
Dome Antenna	$1,500										
Coax Cable	$19,320										
Inseego MIFI Pro Hotspots	$6,650										
Design & Installation	$18,750										
NMCI Laptops	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455
RDT&E Laptops	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685
Flank Speed Phones	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883
Hotspot Data Rate Plans	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080	$25,080
TOTAL COSTS	**$843,823**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**	**$727,104**

DISCOUNTED CASH FLOW	**$843,823**	**$716,358**	**$705,772**	**$695,341**	**$685,065**	**$674,941**	**$664,967**	**$655,140**	**$645,458**	**$635,919**	**$626,521**

NET PRESENT VALUE (NPV)	**$7,549,305**

4. Qualitative Benefits

The benefits provided by a Spidercloud solution are similar to those of Alternative 3: FWA + Smartphones. Alternative 4 eliminates the need for a building-to-tower cable connection and also includes the transition from hardwired desk phones to smartphones, eliminating TDM switch technology. Additionally, Alternative 3 provides reliable, indoor 5G coverage to users within the buildings. The technological benefits of 5G's speed, reliability, and security are discussed in the Background and Context section.

E. ALTERNATIVE 5: 5G PRIVATE NETWORK

1. Overview

A standalone private 5G network for NIWC Pacific B992 and B998 would provide the greatest capabilities and improvements out of all the alternatives considered in this analysis. Private networks are specifically designed and customized to the user's needs. This alternative would give NIWC Pacific complete control and ownership of the network infrastructure, including the base station/tower (Verizon, n.d. c). Verizon would provide dedicated bandwidth to NIWC, and NIWC would manage the network (controlling devices allowed on the network, security measures, etc.). This alternative would also require an on-site maintainer to operate and maintain the private network (Verizon Business Client Partner, email to author, March 8, 2023). Primary benefits include increased network reliability, flexibility, and security (Verizon, n.d. c).

2. Costs

Building and implementing a private network is extremely costly. Expected costs for implementing a private 5G network include hardware, installation, a data rate plan, and operations and maintenance (Verizon Business Client Partner, email to author, March 8, 2023). Private networks are custom-built for specific applications and therefore we found it difficult for vendors (e.g., Verizon) to provide a projected cost for the B992 and B998 without a detailed, technical design. For this analysis, a "ballpark" estimate of $2,000,000 was used for the design, hardware, and installation costs for a standalone private 5G network. This estimate was formulated from discussions with Verizon specialists about previously completed projects (Verizon Business Client Partner, email to author, March 8, 2023).

Alternative 5 includes the replacement of all current hardwired desk telephones with Flank Speed iPhone 12s. This cost was previously discussed in the Assumptions section. For 274 phones, this cost equates to $172,883 per year. Additionally, the recurring costs for NMCI and RDT&E laptops from the baseline case remain the same for Alternative 5 as discussed in the Assumptions section. A summary of the costs relevant to the analysis of Alternative 4 is shown in Table 12.

Table 12. Alternative 5 (5G Private Network) Cost Inputs

Initial Costs	$	Quantity	
Design, Hardware & Installation	$2,000,000.00	-	
Recurring Costs	**$**	**Frequency**	**Quantity**
Data Rate Plan (per 100GB)	$160.00	per month	27
Data Overage (per GB)	$6.00	per month	40
On-site Maintainer (per FTE)	$175,000.00	per year	1
Flank Speed (per phone)	$630.96	per year	274
NMCI (per laptop)	$1,220.64	per year	274
RDT&E (per laptop)	$1,158.84	per year	168

3. NPV Analysis

Using a discount rate of 1.5% over a 10-year period, the total cost of designing, buildings, and operating a private 5G network is $11,524,454 in present-value dollars. The discounted cash flow analysis for Alternative 5 is shown in Table 13.

Table 13. Alternative 5 (Private Network) 10-Year Costs, Discounted Cash Flow, and NPV

Year	0	1	2	3	4	5	6	7	8	9	10
COSTS											
Design, Hardware & Installation	$2,000,000										
Data Rate Plans	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840	$51,840
Data Overage Charges	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,880
On-Site Maintainer	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000	$175,000
Flank Speed Phones	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883	$172,883
NMCI Laptops	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455	$334,455
RDT&E Laptops	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685	$194,685
TOTAL COSTS	**$2,931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**	**$931,744**

DISCOUNTED CASH FLOW	**$2,931,744**	**$917,974**	**$904,408**	**$891,042**	**$877,874**	**$864,901**	**$852,119**	**$839,526**	**$827,119**	**$814,896**	**$802,853**

NET PRESENT VALUE (NPV)	**$11,524,454**

4. Qualitative Benefits

The benefits provided by a 5G private network are the greatest of all five alternatives considered. Alternative 5 eliminates the need for a building-to-tower cable connection and also includes the transition from hardwired desk phones to smartphones. In principle, Alternative 5 would provide extremely reliable 5G coverage to users at NIWC Pacific B992 and B998. The technological benefits of 5G's speed, reliability, and security are discussed in the Background and Context section.

A private network provides NIWC Pacific with complete ownership and control over the facility's network. NIWC leadership can directly manage the distribution of network bandwidth to ensure that users have the exact capabilities needed to perform their jobs. Alternative 5 is expected to also provide the highest level of reliability and security.

V. ANALYSIS OF RESULTS

This chapter provides a sensitivity analysis highlighting the importance and variability of trenching costs related to analyzing a wired broadband network system. Additionally, a financial comparison of the five alternatives considered in this study is discussed.

A. SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the impact of distance and local rates on trenching costs for network cabling. Trenching costs refer to the expenses associated with the installation of underground cables, sometimes referred to as "laying" cables, which are used for establishing a physical broadband connection between a building and an internet service provider (Kim, 2022). This study of NIWC Pacific B992 and B998 does not involve trenching costs, because this cost has been previously incurred and does not impact the future decision to modernize NIWC's systems. However, it is important to consider the potential effects of trenching costs if this business case analysis were applied to another site where the installation of underground cable may be required. Alternative 1: Current Infrastructure, which relies upon a broadband network connection, serves as a baseline for comparison to Alternatives 2–5. The sensitivity of the trenching cost may significantly impact the NPV analysis of Alternative 1, consequently influencing the evaluation of the modernization alternatives analyzed in this study.

Trenching costs vary based on the local rates for laying cable at different locations, which are influenced by factors such as geographic location, availability of existing conduits, type of soil, and the existence of physical obstructions (Noori, 2022). According to the Federal Communications Commission (FCC), the deployment cost for buried fiber construction can range from $25,000 to $165,000 per mile (Goldstein, 2014). The FCC's figures were used in this sensitivity analysis to examine the effects of varying local rates on the overall cost of laying underground cables.

Additionally, this sensitivity analysis considers the distance between the facility and the nearest underground conduit. To analyze the effects of distance on trenching costs, upper and lower estimates were selected. An upper estimate of seven miles was selected as this is the maximum range of Verizon's 5G Nationwide (Verizon Business Client Partner, email to author, March 8, 2023). Any distance greater than seven miles would not be feasible for comparing the alternatives considered in this business case analysis. The lower bound, one mile, was selected to provide a reasonable approximation for projects involving relatively short trenching distances.

The findings from this analysis indicate that both distance and local trenching rates have a significant impact on estimating the cost of installing underground network cables. Trenching costs range from as low as $25,000 to a considerably higher cost of $1,155,000. This wide range highlights the sensitivity of trenching costs and emphasizes the importance of careful consideration when developing cost projections and comparing modernization options for telecommunications infrastructure. The results of the sensitivity analysis are shown in Table 14.

Table 14. Sensitivity Analysis of Trenching Cost

		Distance (miles)				
		1	**2.25**	**3.50**	**5.25**	**7**
$ per mile	**$25,000**	$25,000	$56,250	$87,500	$131,250	$175,000
	$60,000	$60,000	$135,000	$210,000	$315,000	$420,000
	$95,000	$95,000	$213,750	$332,500	$498,750	$665,000
	$130,000	$130,000	$292,500	$455,000	$682,500	$910,000
	$165,000	$165,000	$371,250	$577,500	$866,250	$1,155,000

B. DISCUSSION OF RESULTS

The results of this business case analysis support the pursuit of modernizing NIWC Pacific B992 and B998's telecommunications infrastructure as a cost-effective solution. The net present value analysis reveals that Alternative 1 (Baseline): Current Infrastructure has a higher NPV compared to Alternative 2, 3, and 4, indicating that continuing to operate and maintain the current network systems is expected to be more costly over 10 years, based on the cost data we have used in this study. In other words, based on the data we have, upgrading the network infrastructure at B992 and B998 is expected to provide cost savings for the DOD. However, it is also important to note that Alternative 5 has the highest NPV out of the five alternatives, indicating that the most technically advanced solution, a private cellular network, is more expensive than the other options we considered in this study.

Alternative 2 explores the replacement of a cable internet connection with a Fixed Wireless Access system while keeping all other aspects of the current infrastructure unchanged. The analysis results indicate that implementing FWA at B992 and B998 would cost approximately $8,259,557 over a 10-year period, $1,483,621 cheaper than retaining the current systems (Alternative 1). This cost difference is driven by the monthly recurring costs of wireless versus a cable internet connection.

Alternative 3 includes the implementation of an FWA system along with smartphones and required eFemto cell network extenders. This option eliminates the use of TDM switch technology by replacing the current desk phones with Flank Speed iPhones, which will be required by DOD policy in the near future. This option is marginally more expensive than Alternative 2. However, the NPV for Alternative 3 is $8,471,583, which is still lower than the NPV for the current infrastructure (Alternative 1) by approximately $1,271,595.

Alternative 4 involves a different approach to upgrading the telecommunications systems at B992 and B998. This option analyzes a Spidercloud solution and is estimated to cost $7,549,305 over a 10-year period in present value dollars. Alternative 4 is expected to cost $2,193,873 less than the current systems over a 10-year period. Similar to Alternative 3, this option includes the adoption of Flank Speed iPhones. Based on the data we have, Alternative 4 has the lowest 10-year NPV of all alternatives considered in this analysis, indicating that Spidercloud is the most cost-effective solution for modernizing NIWC Pacific B992 and B998's network infrastructure and eliminating the use of TDM switch technology.

Alternative 5 provides an estimate for installing and operating a private 5G network. The NPV results reveal that this option is more costly than Alternatives 1–4, with an NPV of $11,524,454, which is $1,781,276 more than Alternative 1. Given that this cost exceeds all other alternatives, a private 5G network is the least cost-effective and does not provide a financially attractive option for upgrading B992 and B998's current infrastructure. However, private 5G networks do have some technical and security benefits that we have not evaluated in our analysis. Further analysis would allow decision-makers to develop a more accurate cost estimate of a private 5G network. Then, they can evaluate whether the technical and security benefits of a private 5G network may outweigh the additional cost.

As discussed in Chapter III, the results from this study should only be interpreted as initial cost estimates, rather than precise cost projections, for gauging the cost-effectiveness of the five alternatives considered. Table 15 provides a summary of the results from the analysis conducted in this study.

Table 15. 10-Year Net Present Value Results

1: Baseline	$9,743,178
2: Fixed Wireless Access	$8,259,557
3: Fixed Wireless Access + Smartphones	$8,471,583
4: Spidercloud	$7,549,305
5: Private 5G Network	$11,524,454

VI. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this business case analysis is to provide decision-makers from NIWC Pacific with a financial model to analyze the replacement of legacy TDM technology with modernized telecommunications network solutions. We achieved this by building a spreadsheet model and have provided the model to the sponsoring team at JBPHH. We have included the results of the baseline analysis in this study as well.

As TDM technology gets older, the costs of maintaining, altering, and contracting for replacement parts will continue to rise. The compatibility and scalability of modern technologies, such as 5G, will only expand with the development of future capabilities and economies of scale. Not only are TDM switches required to be replaced by 2025, but this analysis shows that modernized systems are less costly over the long term (DOD CIO, 2021b).

In this analysis, we applied the NPV method and discounted cash flows to cost out five alternatives over a period of ten years. These alternatives included a hypothetical baseline of the current costs for NIWC Pacific B992 and B998, Fixed Wireless Access, Fixed Wireless Access + Smartphones, Spidercloud, and a 5G Private Network.

A. CONCLUSIONS

The major conclusions of this study are listed in this section.

1. There are Financial Benefits to Replacing Old Infrastructure at DOD Sites (e.g., NIWC Pacific B992 and B998)

Our analysis revealed that Alternative 1 (Baseline) has a 10-year NPV of $9,743,178. The 10-year cost of the current infrastructure in present dollars is greater than Alternatives 2, 3, and 4. In addition to Alternative 1 being more costly than Alternatives 2, 3, and 4, the memorandums from the DOD CIO require eliminating the use of TDM technology and any other technology that does not use VoIP (DOD CIO, 2020; DOD CIO, 2021b). The current infrastructure does not satisfy the requirements from either of these memorandums.

2. Alternative 3 and Alternative 4 are Viable Solutions for the NIWC Pacific B992 and B998

In our analysis, Alternative 3 (FWA + Smartphones) and Alternative 4 (Spidercloud) are the only viable solutions. Of the five alternatives analyzed, these are the only alternatives that are less costly than the current infrastructure in Alternative 1 (Baseline). Because both alternatives replace the old desk phones with Flank Speed iPhones, they satisfy the requirements set forth by the DOD CIO in the cited memorandums (DOD CIO, 2020; DOD CIO, 2021b). Alternative 2 (FWA) does not satisfy the DOD CIO memorandum requirements, and Alternative 5 (5G Private Network) is more costly than the current infrastructure in Alternative 1.

To determine whether Alternative 3 (FWA + Smartphones) or Alternative 4 (Spidercloud) is the most effective for a site like NIWC Pacific B992 and B998, an additional analysis that focuses on the technical benefits should be conducted. We are unable to recommend one alternative or the other based on the technical benefits each provides as it is beyond the scope of this report.

3. Recurring O&M Costs are the Major Cost Drivers for All Alternatives

The 10-year NPV estimates for each alternative are significantly impacted by the recurring operations and maintenance/service costs, overpowering the initial hardware and installation expenses. While the initial investment for hardware and installation is an important consideration, the ongoing costs have a much greater influence on the overall financial viability of each alternative considered. The major recurring costs for a site like B992 and B998 are the O&M of hardwired desk phones and cable internet service. For the modernization options analyzed in this study, Alternatives 2–5, the impactful costs are Flank Speed iPhones and 5G internet data plans with associated overage charges. Therefore, it is crucial for decision-makers to carefully evaluate the long-term O&M costs when comparing the cost-effectiveness of each network modernization alternative with the current infrastructure.

B. RECOMMENDATIONS

To ensure that the most cost-effective alternatives are considered, the following recommendations are made.

1. Replace Current Telecommunications Infrastructure with a 5G-Enabled Alternative Immediately

Based on our analysis of NIWC Pacific B992 and B998, we recommend replacing legacy systems with a 5G-enabled modernization alternative immediately. In relation to Alternative 1 (Baseline), our 10-year net present value analysis found that Alternatives 2, 3, and 4 all result in cost savings and significant network improvements. The current infrastructure should be replaced immediately, because any delay in replacement would be an inefficient and irresponsible use of taxpayer dollars.

2. Perform a Similar Business Case Analysis at Other DOD Installations

We recommend using the spreadsheet tool we developed for this thesis to do a financial analysis for other DOD facilities that currently rely on aging telecommunications technologies. We modeled a hypothetical situation to develop a financial model that contains the key telecommunications cost drivers for a typical DOD installation. The results from this business case analysis indicate that modernizing network systems can not only enhance network performance but also provide significant long-term cost savings. Our spreadsheet tool can help DOD organizations explore their modernization options. By doing so, the DOD is better positioned to make informed decisions and allocate resources more effectively.

C. FUTURE STUDIES

This section contains ideas that were beyond the scope of our analysis and should be considered for future research.

1. Business Case Analysis for Enhanced Aircraft Carrier Telecommunications Networks

Our analysis and model provided a baseline estimate of costs for five telecommunications infrastructure alternatives. A future analysis using our framework could be conducted for large naval vessels such as aircraft carriers. An improved and more secure 5G telecommunications infrastructure aboard our Nation's aircraft carriers may provide benefits to ships' crews and generate cost savings for the DOD.

2. Application of Model for Other DOD Sites

NIWC Pacific B992 and B998 have been held back by its legacy technology, and this cost model serves as a tool to provide decision-makers with baseline estimates for modern network solutions. Other military bases are likely experiencing similar problems such as excessive costs and degraded workplace performance. Our cost analysis could be used to provide a starting point in choosing an appropriate and cost-effective telecommunications network solution to satisfy their needs. Our findings will provide key decision-makers at Naval Information Warfare Center and other bases an opportunity to be better stewards of taxpayer dollars while creating more conducive environments for productivity.

3. Reevaluation of Findings with Future Accessible Technology

More advanced technologies such as 5G mm Wave and C-Band are at least two years away from becoming available in Hawaii. Not only will 5G technology evolve, but it will also reach economies of scale and decrease in price. As 5G becomes more ubiquitous, it will become more common and compatible with products like laptops. In future years, the rapid pace of technological innovation will require a replication of this study to consider the relevant available options.

4. Quantitatively Capturing the Qualitative Benefits of Modern Telecommunications Networks

This analysis considered the costs of the different alternatives and briefly addressed the qualitative benefits that each alternative would provide such as increased productivity and security. A thorough analysis quantifying these benefits would provide a more complete economic analysis. This may especially be true for the private 5G network option (Alternative 5), which based on our research, offers additional security and operational benefits compared to the other alternatives we considered. With an expanded analysis, decision-makers may be better able to determine the overall most beneficial telecommunications network solution.

D. FINAL THOUGHTS

It is important to note that the findings of this study are intended to be viewed as preliminary cost estimates aimed at comparing the cost-effectiveness of modernizing the network systems for a hypothetical case (e.g., NIWC Pacific B992 and B998). While this business case analysis is certainly a valuable tool for project managers, it should be interpreted with the understanding that further analysis would be necessary to obtain precise financial projections since the costs of telecommunications infrastructure and services differs by location. We built a spreadsheet model that is easily adjusted to accommodate these differences and is a useful starting point for developing comparisons and evaluating the feasibility of different network modernization alternatives.

Aligned with the DOD's mandate to eliminate the outdated technologies currently used at NIWC Pacific B992 and B998, the results of this analysis reinforce the case for modernization (DOD CIO, 2020; DOD CIO, 2021b). The NPV analyses indicate that implementing leading-edge telecommunications systems, such as FWA or Spidercloud, would result in cost savings compared to the continued operation and maintenance of B992 and B998's existing legacy infrastructure. To the extent that this site is representative of a typical DOD site, similar results would be expected if this analysis were applied to other DOD facilities.

This study serves as data-based evidence justifying the importance of prioritizing similar modernization initiatives across the DOD. By adopting advanced technologies, the DOD can eliminate its reliance on obsolete, ineffective technologies that hinder workplace performance. Additionally, our analysis suggests these efforts have the potential to achieve cost savings satisfying the DOD's responsibility to be a diligent user of taxpayer dollars.

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APPENDIX. COST ESTIMATES

This appendix includes the cost data and estimates that were directly acquired from different vendors to guide our financial analysis of the various alternatives. Table 16 shows a summary of the cost data acquired from Verizon to implement an FWA system.

Table 16. Alternative 2 (Fixed Wireless Access) Cost Estimate. Adapted from Verizon Business Client Partner (email to author, March 8, 2023).

Required Cost	$
Router: Cradlepoint E300 (w/ Netcloud Manager)	$3000 per unit ($100 per year)
External Antenna: Parsec Chinook	$600 per unit
Installation (self-install)	-
Data Rate Plan	$160 per month (100 GB)
Data Overage	$6 per month (Every 1 GB over)

Figure 8 shows the cost estimate provided by Waveform that guided our analysis for Alternative 3 (FWA + Smartphones). We used the estimates provided for the small cell distributed antenna systems (DAS) solution. However instead of the Verizon Network Extender 2 for Enterprise, we chose to use a newer device, the Verizon Network Extender 3 for Enterprise.

Preliminary Cost Estimate

We will work with you to design a custom system, uniquely tailored to your requirements to fit your building and signal environment. Below is an estimate of the hardware and services we expect you will require to improve cellular signal for some of their buildings.

Services

- Professional iBwave design including wiring diagrams, system layouts and propagation mapping;
- Lifetime expert support;
- Cost: $1000, with a 50% credit towards hardware

Hardware Options

Building 998 (10,400 sq ft, no design needed, ~2 days for a two-person team to do installation)

Off-Air DAS - Single-Carrier Solution

- Go X Amplifier, ~1 donor antennas, ~5 server antennas or similar;
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $1,900 - $2,300

Off-Air DAS - Multi-Carrier Solution (AT&T, T-Mobile, Verizon)

- SureCall Force5 2.0 Amplifier, ~1 donor antennas, ~5 server antennas or similar;
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $4,600 - $5,500

Small-Cell DAS Solution (*We only support a Verizon version)

- Verizon Network Extender 2 for Enterprise;
- Estimated cost: $3,000 - $4,000

Building 992 (87,660 sq ft, ~5 days for a two-person team to do installation)

Small-Cell DAS Solution (*Supports a max of 64 active users and ~250 passive users for each unit)

- ~2 Verizon Network Extender 2 for Enterprise, ~10 server antennas or similar;
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $8,600 - $10,500

Hybrid DAS - Single-Carrier Solution

- Quatra 1000, ~2 donor antennas, ~21 server antennas or similar;
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $15,900 - $21,700

Hybrid DAS - Dual-Carrier Solution (AT&T, Verizon)

- Quatra 2000, ~4 donor antennas, ~21 server antennas or similar
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $21,900 - $27,700

Hybrid DAS - Multi-Carrier Solution (AT&T, T-Mobile, Verizon)

- Quatra 4000, ~6 donor antennas, ~21 server antennas or similar
- Assorted passive components, cabling and installation hardware;
- Estimated cost: $51,100 - $64,600

Waveform | 52 Maxwell | Irvine, CA 92618 | 1-800-761-3041

Figure 8. Alternative 3 (FWA plus Smartphones) Cost Estimate. Source: Waveform Commercial Signal Specialist (email to author, March 29, 2023).

Figure 9 shows the cost estimate provided by WilsonPro Electronics that guided our analysis for Alternative 4 (Spidercloud). We used this data to estimate the requirements and associated costs for the initial hardware and installation of this solution. System installation costs were not included in this estimate.

WILSONPRO™

ROM Estimator (input highlighted cells only)

*Download a copy to your desktop for use of this tool.

Area to be covered (Sq Ft)	90,000	
Cable Type	1/2 Inch Cable	
Assign percentage below for the area to be covered		
		Sq Footage
Open Area (no general obstructions)	30%	27,000
Cubes with some offices (most typical environment)	30%	27,000
Drywall office with no open areas	20%	18,000
Concrete rooms with no open areas	20%	18,000
Total Area	100%	90,000
	must equal 100 must equal 100	

BOM

SKU	Description	QTY	Units	MSRP	Extended Cost
461052	Enterprise 4300 (wall-mount)	4	ea	$12,899.99	$51,599.96
314407	Server Dome Antenna	40	ea	$119.99	$4,799.60
1/2 Inch Cable	Coax Cable	7000	feet	$2.76	$19,320.00
970014-10	Cable Connectors (10 pack)	20	ea	$349.99	$6,999.80
859114	7dB Tap	24	ea	$69.99	$1,679.76
311245	Donor Antenna (using MTT Configuration)	12	ea	$99.99	$1,199.88
992208	1/2 Inch Prep Tool	1	ea	$349.99	$349.99
*rack mount versions of 1300 & 4300 also available at the same price (460050 - 1300; 461053 - 4300)				**Total BOM Cost**	**$85,948.99**

Figure 9. Alternative 4: Spidercloud Cost Estimate. Source: Wilson Inside Sales Representative (email to author, March 14, 2023).

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Acquisition Research Program
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net