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Implementation of a submarine ship-wide, common network architecture

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THESIS

IMPLEMENTATION OF A SUBMARINE SHIP-WIDE, COMMON NETWORK ARCHITECTURE

by

Troy D. Terronez

September 2000

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13. ABSTRACT

This research examines the proliferation of multiple local area network (LAN) and information technologies aboard United States Navy Submarines and the evolution of Congressional Defense Acquisition Reforms which mandate the use of Commercial Off The Shelf (COTS), Non-developmental items (NDI), and commercial items. The impact of these policies on the submarine force as it relates to burdens imposed in regard to training of personnel, technology refresh and insertion, obsolescence, and logistics will be addressed.

This study will propose the implementation of a submarine ship-wide, mission critical, tactical network, based upon open systems architecture to provide the ability to process classified, unclassified, and administrative data, as well as providing a migration path to a common hardware and software baseline across all submarine classes. The implementation of this technology would result in the initial instantiation of such an information system on any class of United States Navy warship and may potentially provide a template for use Navy-wide. Finally, a conceptual model is proposed for implementation of a Submarine Ship-wide, Common Network Architecture.

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IMPLEMENTATION OF A SUBMARINE SHIP-WIDE, COMMON NETWORK ARCHITECTURE

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Submitted in partial fulfillment of the
requirements for the degree of

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September 2000

ABSTRACT

This research examines the proliferation of multiple local area network (LAN) and information technologies aboard United States Navy Submarines and the evolution of Congressional Defense Acquisition Reforms which mandate the use of Commercial Off The Shelf (COTS), Non-developmental items (NDI), and commercial items. The impact of these policies on the submarine force as it relates to burdens imposed in regard to training of personnel, technology refresh and insertion, obsolescence, and logistics will be addressed.

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LIST OF ACRONYMS

ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
CNO	Chief of Naval Operations
COMSUBLANT	Commander, Submarine Force, U.S. Atlantic Fleet
COTS	Commercial Off the Shelf
DII COE	Defense Information Infrastructure Common Operating Environment
FDDI	Fiber Distributed Data Interface
ILS	Integrated Logistics Support
IPT	Integrated Product Team
IT	Information Technology
LAN	Local Area Network
LANE	Local Area Network Emulation
Mbps	Megabits Per Second
MCSC	Marine Corps Systems Command
MIME	Multi-purpose Internet Mail Extensions
MIB	Management Information Base
MOA	Memorandum of Agreement
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NEC	Navy Enlisted Classification
NDI	Non-developmental Item

NIIN IPT	Navy Integrated Information Networks Integrated Product Team
NTCSS	Naval Tactical Command Support System
PARM	Participating Manager
SHAPM	Ships Acquisition Program Manager
SONET	Synchronous Optical Network
SNIWG	Submarine Networks Integration Working Group
SNMP	Simple Network Management Protocol
SPAWAR	Space and Warfare Systems Command
SSM	Ships System Manual
SUBLAN	Submarine Ship-wide Common Network Architecture
TM	Technical Manual

EXECUTIVE SUMMARY

A. INTRODUCTION

Recent Navy strategic concept papers repeatedly address the need for information superiority to enable our fighting forces to be effective and successful in warfare and maritime dominance. This thesis will examine the proliferation of multiple local area networks (LANs), information systems, and information technologies aboard United States Navy submarines. The author will address the evolution of Congressional Defense Acquisition Reforms mandating the use of Commercial Off The Shelf (COTS) and Non-Developmental Items (NDI). The resulting impact of these policies on the submarine force with regard to training of personnel, technology refresh and insertion, obsolescence, and logistics will be addressed.

B. VISION

The author's vision for this research is the eventual implementation of a submarine ship-wide, common network architecture (SUBLAN). SUBLAN will be a mission critical, tactical network based on Defense Information Infrastructure Common Operating Environment (DII COE) open systems architecture, and will provide the ability to process classified, unclassified, and administrative data, as well as provide a migration path to a common hardware and software baseline across all submarine classes.

C. CONCLUSION

The implementation of this technology presents an opportunity for significant reductions in submarine and surface ship life-cycle ownership costs, and when implemented, will be the initial instantiation of such an information system on any class of United States Navy warship. A successful implementation may potentially provide a template for use Navy-wide.

ACKNOWLEDGMENTS

I would like to thank my children – Morgan, Britton, and Tyler – and Robin, my first and only love, for their prayers, patience, support, and unwavering faith in leading me to a personal relationship with Jesus Christ which forever changed my life and gave me the strength to complete this project.

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I. INTRODUCTION

A. BACKGROUND

Recent Navy strategic concept papers such as *Forward ... From the Sea: Anytime, Anywhere; Enduring Impact ... From the Sea;* and *Forward ... From the Sea, the Navy Operational Concept* repeatedly address the need for information superiority to enable our fighting forces to be effective and successful in warfare at the Joint Vision 2010 vision for maritime dominance. The Chief of Naval Operations (CNO) emphasizes this need in addressing the increasing demands placed on today's Navy as he states "...access to ...information is becoming more and more critical. Naval forces must be able to accomplish networked operations..." [Ref. 1]. This research will examine the proliferation of multiple local area networks (LANs), information systems, and information technologies aboard United States Navy submarines. The author will address the evolution of Congressional Defense Acquisition Reforms mandating the use of Commercial Off The Shelf (COTS) and Non-Developmental Items (NDI). The resulting impact of these policies on the submarine force and burdens imposed with regard to training of personnel, technology refresh and insertion, obsolescence, and logistics will also be addressed. Chapter II will examine the non-integrated proliferation of COTS and NDI information systems and equipments within the United States submarine force.

This proliferation was recognized by then Assistant Secretary of the Navy for Research, Development and Acquistion (ASN(R,D&A)), the Honorable John W. Douglas in 1996. Secretary Douglas directed the implementation of a "Memorandum of Agreement (MOA) for Naval Shipboard Integrated Information Systems" [Ref. 2] which served to establish "...policies and responsibilities for development, implementation and management of Naval Integrated Information Networks aboard new construction or in-service ships". Secretary Douglas specifically noted in this MOA:

> In recent years implementation of shipboard LAN's has been accomplished either by separate, uncoordinated programs endorsed by Navy Systems Commands, or as earnest attempts by the Commanding Officer to improve the working environment for their crews. Taken to its natural conclusion, continuing this direction will lead to non-integrated networks onboard ships, with significant naval resources being expended to maintain and support these networks, and significant frustration at the user level. [Ref. 2]

1. Navy Integrated Information Networks IPT

As a direct result of Secretary Douglas's MOA, the Navy Integrated Information Networks Integrated Product Team (NIIN IPT) was chartered in 1998. The NIIN IPT Charter was jointly developed by the Commanders of Naval Sea Systems Command (NAVSEA), Naval Air Systems Command (NAVAIR), Marine Corps Systems Command (MCSC), and Space and Naval Warfare Systems Command (SPAWAR). The primary mission of the NIIN IPT is to act "as the principal technical forum for planning, designing, and preparing for the implementation of shipboard networks as a method for achieving Network Centric Warfare" [Ref. 3].

2. Submarine Networks Integration Working Group

In addition to the mission addressed in the preceding paragraph, the NIIN IPT was also tasked to "...coordinate the design of integrated information networks for specific ship classes..." [Ref. 3]. The NIIN IPT chose to perform this task by implementing specific ship class working groups which would work under the authority of and within the guidance of the NIIN IPT. For submarines, this group was chartered as the Submarine Networks Integration Working Group (SNIWG).

The SNIWG consists of a consortium of over fifty members from government, academia, and industy. The author served as the Chairman of this group for over one and a half years as the group labored to define a network architecture for the platform-wide integration of submarine weapons systems. Chapter IV will outline a conceptual model to achieve this goal.

B. PURPOSE

This thesis will examine the potential for implementation of a submarine ship-wide, mission critical, tactical network, based upon open systems architecture which provides the ability to process classified, unclassified, and administrative data; as well as providing a migration path to a common hardware and software baseline across all submarine classes. The implementation of this technology presents an opportunity for significant reductions in life-cycle ownership costs and would be the initial incorporation of such an information system on any class of United States Navy warship. A successful implementation may potentially provide a template for use Navy-wide. Finally, a conceptual model will be put forth for the implementation of a Submarine Ship-wide, Common Network Architecture (SUBLAN).

C. SCOPE AND METHODOLOGY

1. Scope

While proliferation of multiple local area networks (LANs), information systems, and information technologies exists throughout the Navy, both afloat and ashore, the scope of this paper will be limited to examining only in-service submarine force requirements. Naval surface vessels and new construction submarines will not be addressed here.

2. Methodology

In addition to literature searches and other sources of information which relate to submarine shipboard information system and LAN and proliferation, the author will also draw upon his own body of knowledge gained while Chairman of the SNIWG. In this capacity the author has consulted with recognized government, academic, and industry leaders in the fields of information systems, information technology and networking, and submarine weapons systems.

D. ORGANIZATION OF THE STUDY

This thesis is organized into five chapters: 1) Introduction, 2) Submarine Network Proliferation, 3) Conceptual Levels of Submarine Network Integration, 4) Conceptual Model for Implementation of a Submarine Ship-wide, Common Network Architecture (SUBLAN), and 5) Conclusion and Recommendations.

E. CHAPTER SUMMARY

Chapter I provides a brief background which addresses the proliferation of multiple local area networks (LANs), information systems, and information technologies that exist both ashore and aboard ship in the United States Navy. The recognition of this proliferation as a cause of concern by ASN(RDA) and subsequent incorporation of the NIIN IPT and SNIWG were previously addressed. Finally, a conceptual model for the implementation of a Submarine Ship-wide, Common Network Architecture (SUBLAN) is proposed.

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II. SUBMARINE NETWORK PROLIFERATION

A. INTRODUCTION

In parallel with the formal establishment of the NIIN IPT and SNIWG, NAVSEA's Ship Acquisition Program Manager (SHAPM) for submarines forwarded a "Submarine Network Architecture Requirements Questionnaire" [Ref. 4] to all submarine Participating Managers (PARMS). The SHAPM is responsible for all aspects of life cycle modernization and support for a naval vessel at the platform level. A PARM shares the same responsibility for individual subsystems within these platforms.

The purpose of this questionnaire was to "...gather requirements for a submarine backbone cable plant that can support...platforms over their planned lifetimes" [Ref. 4]. The results of the questionnaire were staggering with respect to stovepipe network and information systems proliferation either planned or in process by submarine PARMs. In mandating the use of COTS and NDI technology, Public Law 103-355, the Federal Acquisition Streamlining Act of 1994 [Ref. 5] had truly manifested itself within the arena of submarine weapons systems modernization and the submarine force as a whole. No less than ten systems currently supporting the mission effectiveness of our Los Angeles Class attack submarines and Ohio Class TRIDENT ballistic missile submarines had stovepipe LAN strategies either already in place or in a preliminary design phase.

Responses to the "Submarine Network Architecture Requirements Questionnaire" [Ref. 4] presented networking strategies utilizing LAN architectures which ranged from Ethernet to Fiber Distributed Data Interface (FDDI) to Asynchronous Transfer Mode (ATM) and transport mediums from 10BaseT to Synchronous Optical Network

(SONET). Figure 1 is a sample representation of submarine systems whose response to the "Submarine Network Architecture Requirements Questionnaire" [Ref. 4] indicated a stovepipe LAN strategy.

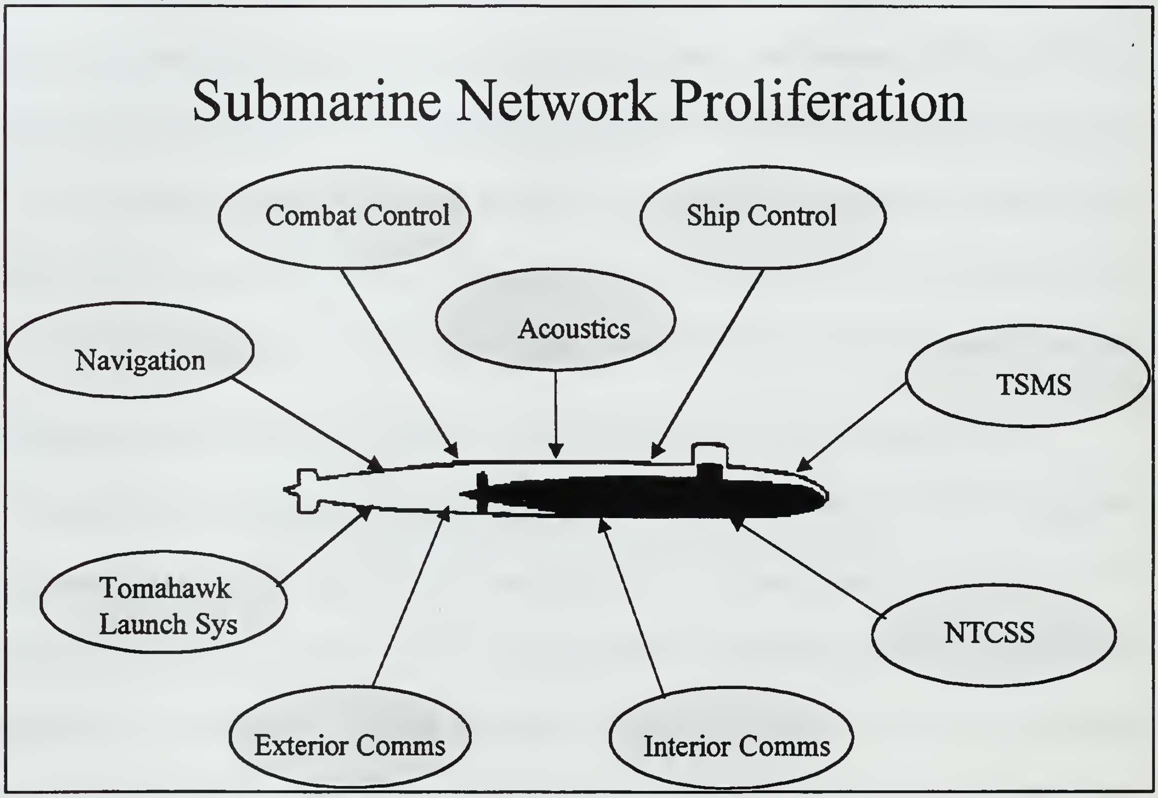

Figure 1. Current Submarine Network Proliferation

B. EXAMPLES OF SUBSYSTEM LAN PROLIFERATION

Each of the submarine subsystems depicted in Figure 1 currently have in place an independent shipboard LAN or have plans in place to migrate to a networked, cable plant environment. Table 1 summarizes the respective phased modernization protocol plans of these subsystems as described in PARM responses to the "Submarine Network

Architecture Requirements Questionnaire" [Ref. 4]. While these networking technologies are diverse, they are not mutually exclusive therefore presenting the opportunity for integration. Chapter IV will put forth a conceptual model for the integration of these technologies and subsystems.

Acoustics	FDDI, Ethernet, Fibre Channel, ATM
Combat Control	FDDI, Ethernet, ATM
Exterior Communications	FDDI, ATM
Interior Communications	LAN (undecided protocol)
Naval Tactical Command Support System (NTCSS)	Ethernet
Navigation	LAN (undecided protocol)
Ship Control	Undecided protocol, requirement for Layer 1 fiber
Tomahawk Launch	FDDI
Total Ship Monitoring System (TSMS)	Ethernet, requirement for Layer 1 fiber

Table 1. Subsystem Migration Plans

C. BURDENS OF SUBSYSTEM LAN PROLIFERATION

Burdens imposed upon a submarine crew by subsystem LAN proliferation are significant. The author will draw upon his experience as a submarine crewmember as well as insight gained as Chairman of the SNIWG to address burdens in the areas of technology, manning, and training. Each of these burdens ultimately result in increased platform life-cycle total ownership cost.

1. Technology Refresh, Insertion and Obsolescence Burden

Commercial networking technologies are constantly evolving as hardware manufacturers incorporate new capabilities to meet the needs of their clients. Hoffman notes "Cost and capabilities of information technology are improving dramatically and will continue to do so for the foreseeable future" [Ref. 6]. If one assumes Hoffman's assertion is true, an aggressive, systematic technology insertion program must be in place to overcome increasingly short hardware obsolescence cycles. These technological advances prove difficult for the most trained technician. The fleet submarine sailor is not adequately equipped with either time or resources to stay abreast of such rapidly changing technologies.

2. Manning Burden

No active submarine in the fleet has a dedicated LAN administrator. This position is deemed a "collateral duty", that is to say, the position of LAN administrator is in addition to that crewmembers' full time job. Commander, Submarine Force, U.S. Atlantic Fleet (COMSUBLANT) keeps statistics on the number of hours a week the NTCSS LAN administrator spends in this collateral duty. The SUBLANT fleet average is over thirty hours a week. The author contends this clearly represents a significant manning burden which will only increase with subsystem LAN proliferation.

3. Training Burden

The current implementation methodology, subsystem LAN proliferation, leads to an assortment of network hardware being installed on each platform. To adequately support the planned migrations of Table 1, our submarine training facilities must develop and maintain curricula for both operation and maintenance of multiple configurations and baselines. Ship Systems Manuals (SSM) and component Technical Manuals (TM) have to include sections representative of each different configuration and component. This is not a feasible option from a life cycle cost perspective.

Vena addresses the burden of training in categories of general literacy and functional competencies [Ref. 7].

a. General Literacy

Vena proposes two target groups for general IT literacy education. These target groups are entry-level and existing personnel. Entry level training should cover at least the following areas:

- Basic computing theory.
- Basic network theory.
- Basic computer security.
- Introduction to computer applications.
- Hands on hardware configuration lab.

Ongoing training consists of more complex information systems training targeted at fleet sailors with the goal of providing the tools to become more efficient/effective IT users.

b. Functional Competencies

Vena further defines four functional competencies required by our Navy's IT specialists. These competencies represent broad areas of knowledge and are defined as Network Managers, Network Installer/Maintainer, End System Configuration Managers, and Information Operators. In Reference 7, Vena describes his vision for the responsibilities inherent in each functional competency.

D. CHAPTER SUMMARY

Chapter II introduces the reader the to the real world fleet problem of submarine network and information systems proliferation. Examples of existing subsystem LAN proliferation and the associated burdens this proliferation imposes on the fleet submarine sailor are identified and discussed.

III. CONCEPTUAL LEVELS OF SUBMARINE NETWORK INTEGRATION

A. INTRODUCTION

This chapter introduces and describes four conceptual levels of shipboard network integration. While not intrinsic to networking technology itself, the definition of these conceptual levels will lay a foundation which will allow the reader to better understand recommendations of subsequent chapters. The origin of these conceptual levels of network integration is traced to the Naval Integrated Information Networks Integrated Product Team (NIIN IPT). The author relies upon his own body of knowledge to define them to the reader.

B. LEVEL ZERO NETWORK INTEGRATION

Level Zero network integration, Independent Networks, is best described by the numbering schema itself. It is characterized by the chaos experienced due to early implementation of numerous unrelated, uncoordinated projects, each implementing networking technologies based upon the information technology requirements of an individual weapons system or organization. At this level, each weapons system or organization has the individual responsibility for life cycle Integrated Logistics Support (ILS), network configuration management, and network administration. Individual weapons systems networks meet mission critical requirements in support of their respective missions. Separate Navy enlisted rates or Navy Enlisted Classifications (NEC) may be required to maintain both the physical components of the network as well as fill the roles of network administrators. As Level Zero Independent Networks proliferate our submarine platforms, the need for a common architecture solution becomes evident. Figure 2 represents a pictorial representation of Level Zero network integration.

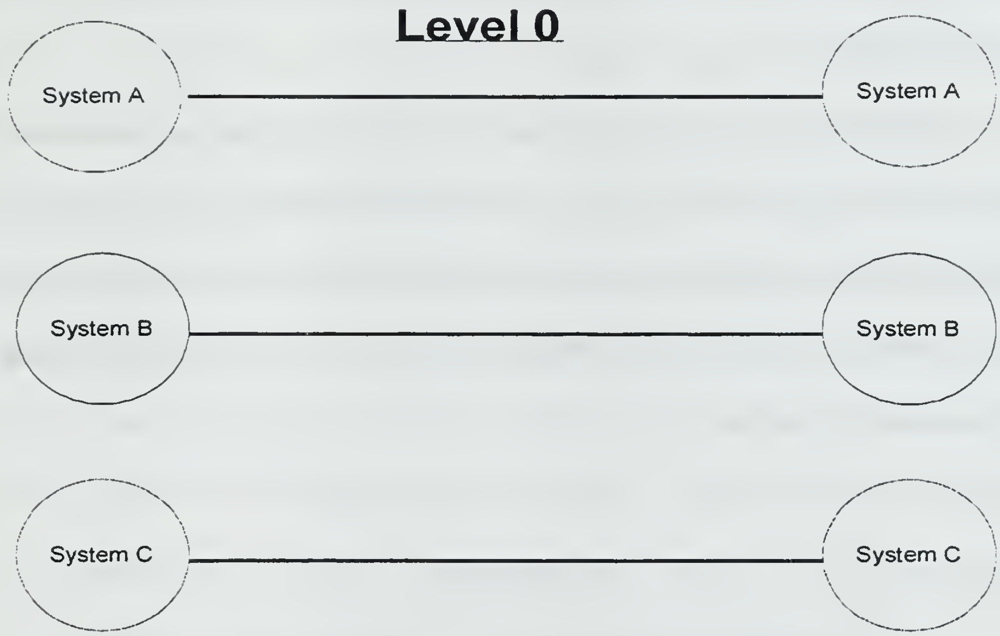

Figure 2. Level Zero Network Integration – Independent Networks

C. LEVEL ONE NETWORK INTEGRATION

Level One network integration is defined as an Integrated Passive Fiber Optic Cable Plant (FOCP) and is best described as "some degree of coordinated installation", rather than a true network integration effort. This coordination likely manifests itself in the simultaneous installation of two or more shipboard networks in a fashion so as to efficiently leverage the resources of a single installation process. As in a Level Zero network, each shipboard network maintains its own transport medium – optical fiber will be recommended as the preferred transport medium in a subsequent chapter - and continues to maintain individual responsibility for life cycle Integrated Logistics Support

(ILS), network configuration management, and network administration. Again, separate Navy enlisted rates or Navy Enlisted Classifications (NEC) may be required to maintain both the physical components of the network as well as fill the roles of network administrators.

With the implementation of Level One networks, weapons systems can begin to leverage not only the resources of a coordinated installation, but also that of a single, passive cable plant with common cable routing – perhaps within the same trunk or tube – and common termination points. Figure 3 represents a pictorial representation of Level One network integration.

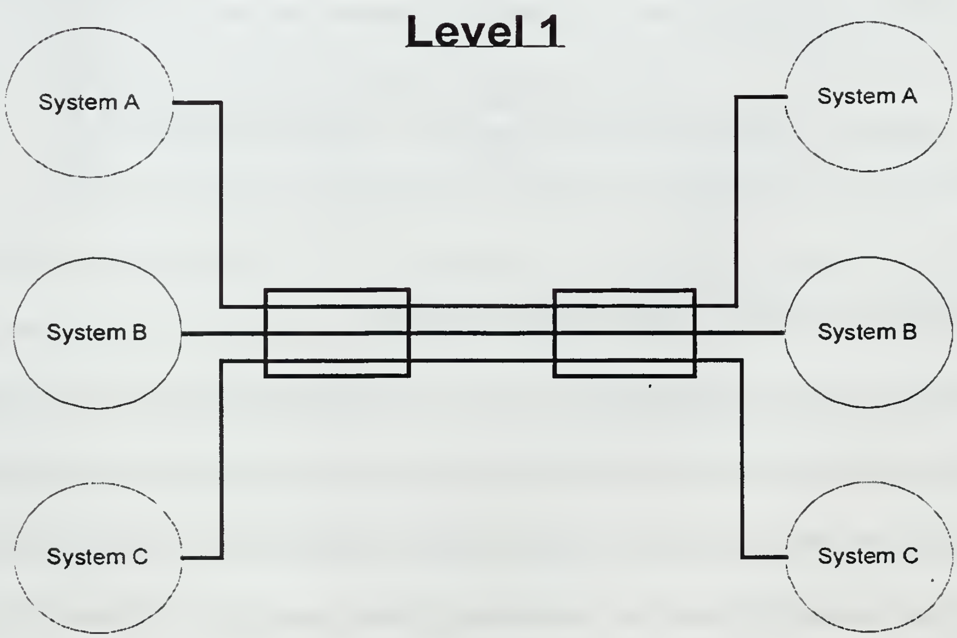

Figure 3. Level One Network Integration – Integrated Passive Fiber Optic Cable Plant

D. LEVEL TWO NETWORK INTEGRATION

The author defines Level Two integration as Platform Centric network integration. This level of integration represents the first true level of submarine network integration. At this level of integration, individual weapons systems are able to communicate with one another using industry standard protocols across common network hardware such as switches and routers; however, there still does not exist a single, common, ship-wide Local Area Network architecture which services all information systems of the submarine. Functionally similar systems may be integrated onto a single network or across the backbone cable plant. While specific mission critical requirements may still be tailored to the requirements of individual weapons systems subnets, all aspects of the backbone network and cable plant meet mission critical requirements in support of providing a migration path for future mission critical users.

Level Two network integration also progresses beyond Level Zero and Level One integration in that while various weapons systems networks maintain accountability for individual subnets, the backbone network and cable plant act as the protocol and transport medium for subsystem data transmission and is maintained by the submarine's logistics and configuration manager. At this level of integration a coordinated network administration organization would exist aboard the submarine and maintainers would be trained to a common NEC. All life cycle Integrated Logistics Support (ILS) would be coordinated by the submarine's organic network organization. Figure 4 represents a pictorial representation of Level Two network integration.

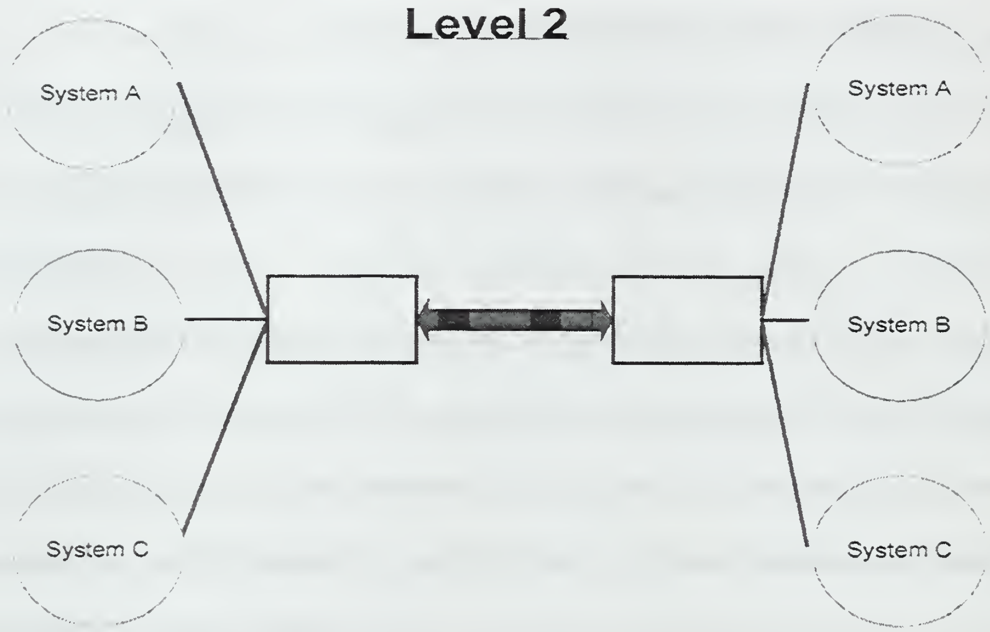

Figure 4. Level Two Network Integration – Platform Centric

E. LEVEL THREE NETWORK INTEGRATION

Level Three integration is defined as Network Centric network integration. This level of network integration embodies the author's vision of network centricity. In a network centric environment, individual "systems" no longer exist, but rather, "functions" are performed as part of a common, ship-wide distributed network architecture. Functions communicate with one another via standardized protocols and messenging services therefore availing themselves for efficient use by other functions. A centralized ship-wide time standard is maintained and dissiminated by network management software through the backbone network. Multiple levels of security could coexist upon each fiber. Pier side connectivity could be established as simply as any standard ship's utility hookup.

At this level of network integration, the entire submarine is "wired" by a mesh network fiber optic cable plant. The entire network architecture is mission critical, is tested and certified as an entity, and is has some level configuration management at the platform level. All network resources, including endpoint workstations, are considered common resources which are reconfiguable upon demand by system network administrators. External communications with the National Command Authority, other battle group assets, or fleet headquarters activities are a seamless extension of internal communications. A hierarchical network monitoring and reporting system is extendable to off-platform nodes via the submarines external communications system. Figure 5 represents a pictorial representation of Level Three network integration.

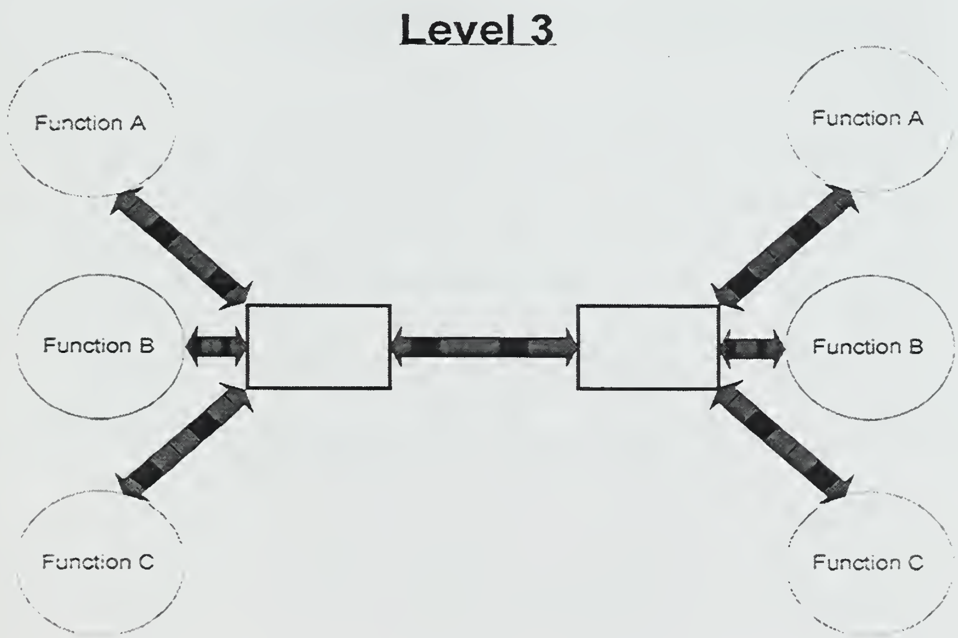

Figure 5. Level Three Network Integration – Network Centric

F. CHAPTER SUMMARY

This chapter introduces four conceptual levels of shipboard network integration. This introduction will provide the reader insight into the author's recommendation of a Level Two, Platform Centric network architecture for the Navy's in-service submarine fleet.

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IV. CONCEPTUAL MODEL FOR IMPLEMENTATION OF A SUBMARINE SHIP-WIDE COMMON NETWORK ARCHITECTURE

A. INTRODUCTION

This chapter will introduce a conceptual model for the implementation of a Submarine Ship-Wide Common Network Architecture (SUBLAN). This proposed network architecture will be defined as a layered framework for the platform wide integration of subsystems. It is intended to "...help eliminate the overly diverse proliferation of multiple LAN technologies aboard naval ships (to include submarines) which in turn leads to incompatibility problems, training problems, and support problems" [Ref. 8].

The underlying goal of this thesis is to lay the foundation for the ultimate accomplishment of the integration of a network architecture which will meet existing shipboard requirements as well as facilitate the migration of submarine weapons subsystems modernization with COTS and NDI technologies. The following fundamental terms will assist the reader in understanding the author's goal:

1. <u>Network</u> – A group or system of interconnected or cooperating individuals. An interconnected collection of autonomous computers. [Ref. 9]

2. <u>Architecture</u> – The design and interaction of components of a computer system or computer network. The science, art, or profession of designing

and constructing buildings, bridges, boats,...networks. Also, from the Greek Architekton. [Ref. 9]

- Archi – chief.
- Tekton – carpenter.

3. Integrate – "to make whole". To bring parts together into a whole. To remove barriers to movement and association and communication. [Ref. 9]

B. VISION

The vision of SUBLAN is the ultimate implementation of a ship-wide, mission critical, tactical network based on Defense Information Infrastructure Common Operating Environment (DII COE) open systems architecture, which provides the ability to process classified, unclassified, and administrative data as well as provide a migration path to a common hardware and software baseline across all submarine classes.

C. THE ARCHITECTURE APPROACH

The SUBLAN architecture, comprised of the layers described in the next section, must be capable of providing the following attributes:

1. A framework for the integration of subsystems into a connected, coordinated ship-wide network.

2. A migration path for the technical evolution of subsystems within this framework.

3. Integration of multiple subsystems and technologies.

4. A phased integration of a given subsystem at the time and in the manner which best suits the requirements of that subsystem.

5. A common physical media infrastructure.

6. Common network management services and resources.

D. LAYERED FRAMEWORK OF THE SUBLAN ARCHITECTURE

A conceptual model of the SUBLAN architecture which would achieve the author's vision must consist of two networking layers; a physical cable plant, and a method for subsystems to access the backbone physical cable plant.

1. Layer One - Physical Cable Plant and Protocol

Based upon responses received from the "Submarine Network Architecture Requirements Questionnaire" [Ref. 4] it is recommended the physical cable plant consist of a wired mesh fiber optic cable plant network. This fiber optic cable plant network would consist of fiber cable, fiber interconnection boxes (FIB), and connectors. Current guidance set forth in References 8 and 10 recommends a backbone network consisting of an Asynchronous Transfer Mode (ATM) protocol utilizing a Synchronous Optical Network (SONET) signaling scheme. However, the author believes recent advances in Ethernet technologies, specifically gigabit Ethernet, present a better solution and provide an opportunity to implement this proven technology for the submarine force of the future. The recommendation for Layer One of SUBLAN is a gigabit Ethernet fiber optic cable plant backbone. Figure 6 represents a conceptual model of the SUBLAN physical cable plant.

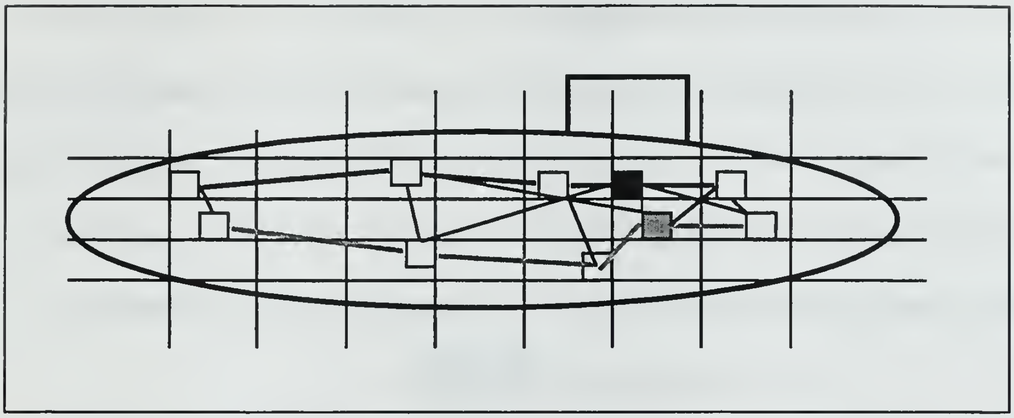

Figure 6. Conceptual Physical Cable Plant

2. Layer Two – Access to the Physical Cable Plant

SUBLAN must provide legacy technologies a means not only to physically connect to the cable plant, but also the technology to integrate onto it and distribute data. The author again refers the reader to the "Submarine Network Architecture Requirements Questionnaire" [Ref. 4] and the resulting information displayed in Table 1. Table 1 lays out the multiple networking technologies either currently in place or planned for subsystem modernization. These technologies are not mutually exclusive. Therefore, SUBLAN must provide a vehicle by which these multiple technologies can communicate across a single physical cable plant. Buddenberg [Ref. 11] and Graves [Ref. 12] present similar approaches to enable subsystem networks to integrate into the physical cable plant backbone LAN. The author believes these approaches to successful intergration are sound and uses them here. All subsystems utilizing SUBLAN must adhere to a common interface definition consisting of a hardware LAN interface, an enveloping interface, and a management interface.

a. LAN Interface

A LAN interface would allow for the physical connection of a legacy or new subsystem into SUBLAN via one of may FIBs located throughout the ship. This interface could be an Ethernet Network Interface Card (NIC) – preferred; or a tailored device based upon subsystem mission specific requirements – less preferred.

c. Enveloping Interface

A common enveloping interface is required which will support subsystem data transmission, and the eventual sharing of data among subsystems. A Multi-purpose Internet Mail Extension (MIME) compliant e-mail message is recommended and would provide the following advantages [Ref. 11]:

- Data can be organized into fields to meet MIME definitions allowing subsequent incorporation into destination databases.
- MIME lays the foundation for data element standardization.
- Allows the use of everyday internet technology in the form of message transfer agents for data transfer.

c. Management Interface

Common Network management and resource sharing are a vital component of the SUBLAN vision. References 11 and 12 both recommend Simple Network Management Protocol (SNMP) in the form of the Management Information Base (MIB). Graves [Ref. 12] specifically addresses the use of this management interface in a Navy weapons system application. The author believes the existing research to be sound and recommends SNMP-MIB for SUBLAN network management.

Figure 7 presents a conceptual model of legacy subsystems with multiple LAN technologies integrated onto and utilizing the SUBLAN physical cable plant to distribute data.

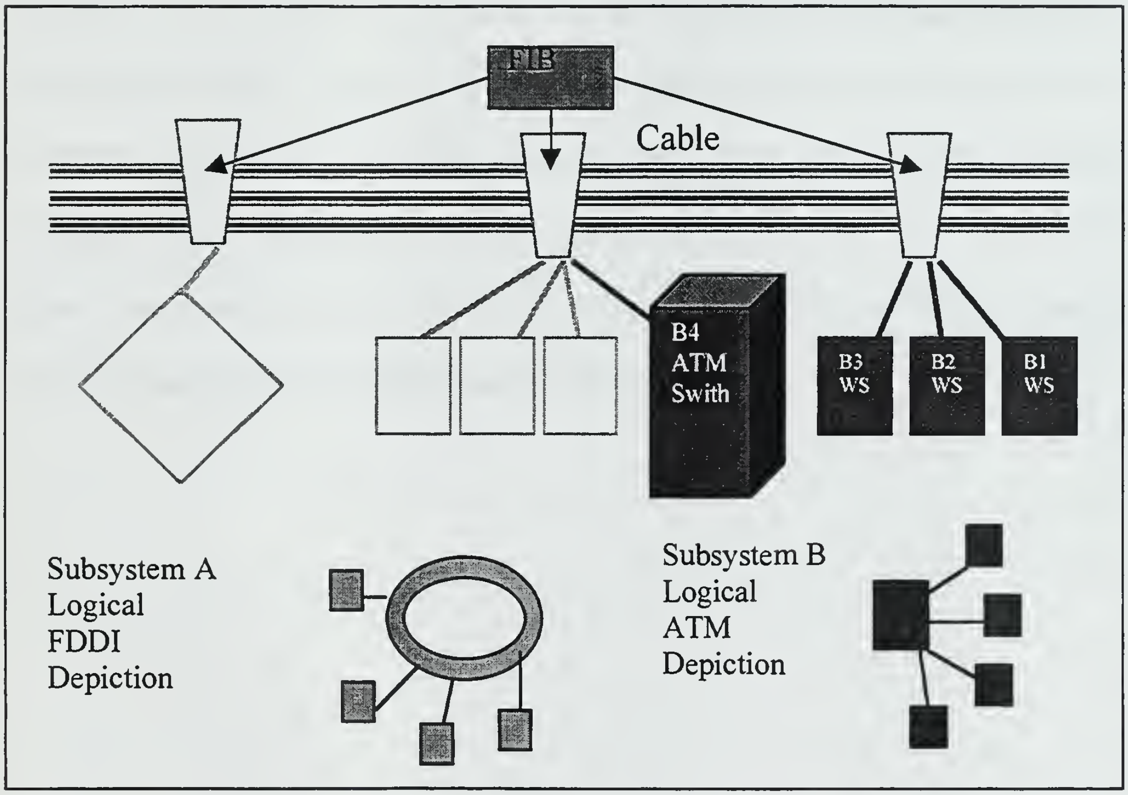

Figure 7. Subsystem Integration to SUBLAN

E. CHAPTER SUMMARY

This chapter presented a conceptual model for the implementation of a Submarine Ship-Wide Common Network Architecture (SUBLAN). The author's vision of SUBLAN was described followed by the architecture and technology by which this vision can be achieved. The recommendation of a fiber optic backbone cable plant utilizing an Ethernet protocol was set forth and the benefits were described. The reader was introduced to the interfaces necessary for subsystems to utilize SUBLAN for data transmission. Additionally, conceptual models of the physical cable plant and the integration of legacy subsystems onto the cable plant were presented to assist the reader in visualizing these concepts.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION AND RECOMMENDATIONS

Based upon the body of knowledge gained through this research, the author concludes significant life-cycle cost savings could be realized by the implementation of a Submarine Ship-Wide, Common Network Architecture and recommends the NIIN IPT and SNIWG continue engineering studies which will lead to implementation across the submarine force. Additionally, it is recommended the NIIN IPT and SNIWG look beyond current programmatic and budgeting decisions to new and innovative commercial networking technologies; specifically gigabit Ethernet.

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LIST OF REFERENCES

1. Department of the Navy (DON), *Vision, Presence, Power - A Program Guide to the U.S. Navy*, 2000

2. Assistant Secretary of the Navy (Research, Development and Acquisition), *Memorandum of Agreement for Naval Shipboard Integrated Information Systems*, 1996

3. Navy Integrated Information Networks Integrated Product Team (NIIN IPT), *Charter*, 1997

4. Commander, Naval Sea Systems Command letter 2000, Ser 92C12/089, *Submarine Network Architecture Requirements Questionnaire*, 1997

5. Public Law 103-355, *Federal Acquisition Streamlining Act of 1994*, 1994

6. Hoffman, Gerald M., *The Technology Payoff, How to Profit with Empowered Workers in the Information Age*, Irwin Professional Publishing, 1994

7. Vena, Lieutenant Commander Peter D., *Information Technology Competencies for Navy Enlisted Personnel*, 1998

8. Navy Integrated Information Networks Integrated Product Team (NIIN IPT), *Near Term Guidance for Shipboard Networks*, 1998

9. *Webster's New Collegiate Dictionary*, G. & C. Merriam Co., 1999

10. Department of the Navy Chief Information Officer (DONCIO), *Information Technology Standards Guidance*, Version 99-1, 1999

11. Buddenberg, Rex, *Of Good Network Citizens and Internet Toasters*, Lecture Notes, 2000, http://web1.nps.navy.mil/~budden/lecture.notes/good_net_citizen.htm

12. Graves, Lieutenant Stephen Mitchell, *Internetworking: Airborne Mine Countermeasures C4I Information Systems*, 1996

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