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U.S. NAVY SHF SATCOM:
PAST, PRESENT AND FUTURE

by

Christoper J. Bushnell

June, 1994

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| Principal Advisor: | Dan C. Boger |
| Associate Advisor: | Carl R. Jones |

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U.S. Navy SHF SATCOM:
Past, Present and Future

by

Christopher J. Bushnell
Lieutenant, United States Navy
B.S., United States Naval Academy, 1988

Submitted in partial fulfillment
of the requirements for the degree of

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June 1994

Author: Christopher J. Bushnell
Christopher J. Bushnell

Approved by: Dan C. Boger
Dan C. Boger, Principal Advisor

Carl R. Jones
Carl R. Jones, Associate Advisor

Paul H. Moose
Paul H. Moose, Chairman

Department of Joint Command, Control, and Communications

ABSTRACT

This thesis discusses the Navy's Super High Frequency Satellite Communications (SHF SATCOM) capabilities prior to Desert Shield/Desert Storm, and the requirements for future systems that were generated due to Navy SATCOM shortcomings during the Gulf War. The four-phased evolutionary approach the Navy has designed (based on post-war requirements) to provide itself with a medium for SHF SATCOM into the 21st Century, as well as the Defense Satellite Communications Systems (DSCS), are examined in detail.

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I. INTRODUCTION

A. GENERAL

Operations Desert Shield and Desert Storm (DS/DS) reinforced the requirement for and greatly accelerated the introduction of the Navy's Super High Frequency Satellite Communications (SHF SATCOM) capability on aircraft carriers (CV/CVNs) and amphibious flagships. In order to satisfy minimum tactical command, control, and warfighting communications and intelligence requirements, dramatic developments would have to be undertaken with regard to the Navy's Military Satellite Communications (MILSATCOM) architecture. (NCCOSC, 1994, p. 1-2) Figure 1 represents the Navy's four phase SHF SATCOM program evolution that is scheduled to occur between 1990 and 1996.

While the Navy's MILSATCOM architecture was formed on the premise that no single satellite medium could satisfy all operational requirements, SHF SATCOM was designated as the primary communications medium for joint and Allied/North Atlantic Treaty Organization (NATO) interoperability. (NCCOSC, 1994, p. 1-1) The remaining three communications services incorporated in the Navy's MILSATCOM architecture are Extremely High Frequency (EHF), Ultra High Frequency (UHF), and commercial satellite systems.

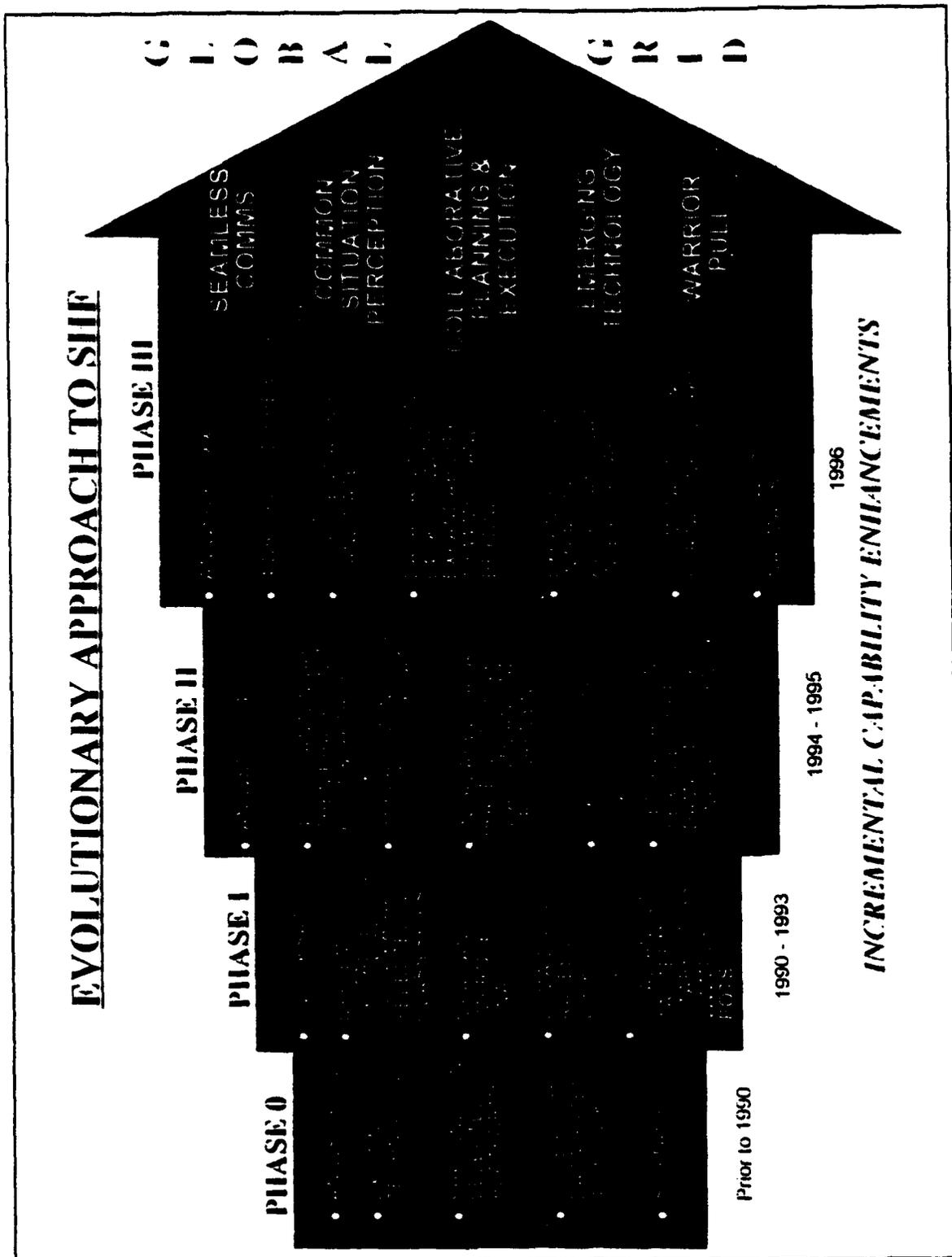


Figure 1. The Navy's Four Phase Evolutionary Approach to SHF (NCCOSC, 1994, p. 1-3)

Memorandum of Policy Number 37 (MOP 37) is the Chairman of the Joint Chiefs of Staff (CJCS) document which establishes operational policy, procedures and provides guidance on MILSATCOM systems. MOP 37 also defines warfighting requirements for MILSATCOM connectivity as either hard core, core or general purpose. An illustration of the applicability of these terms to DoD missions is depicted in Figure 2. MOP 37 defines these terms in the following manner:

Hard Core - Supports critical command, control, communication and intelligence (C³I) needs of the single integrated operational plan (SIOP), integrated tactical warning and attack assessment (ITW/AA), and nonstrategic nuclear forces (NSNF) missions. Characteristics include survivability against the maximum threat for jamming, high-altitude electromagnetic pulse (HEMP) attack, scintillation, and includes low probability of intercept (LPI), low probability of detection (LPD), global coverage, and near-real-time access and network reconfiguration.

Core - Provides communications connectivity to support theater/contingency operations, force projection, tactical intelligence support, and counternarcotics requirements. Characteristics include survivability against a medium threat for jamming (tactical jammer) and limited LPI/LPD.

General Purpose - Provides communications connectivity to support day-to-day operations for logistic, administrative, intelligence, and common-user networks, and counternarcotics requirements, as well as non-DoD organizations. (CJCS MOP 37, 1992, pp. GL-5 - GL-6)

The MILSTAR Satellite encompasses the EHF communications in the Navy's MILSATCOM architecture. MILSTAR can currently provide low data rate (LDR) transmissions in the EHF frequency band which serve to provide the primary protected, or hard core communications service. Improvements are planned for future MILSTAR satellites to support medium data rate (MDR)

transmissions which will provide high capacity "in-theater" protected communications.

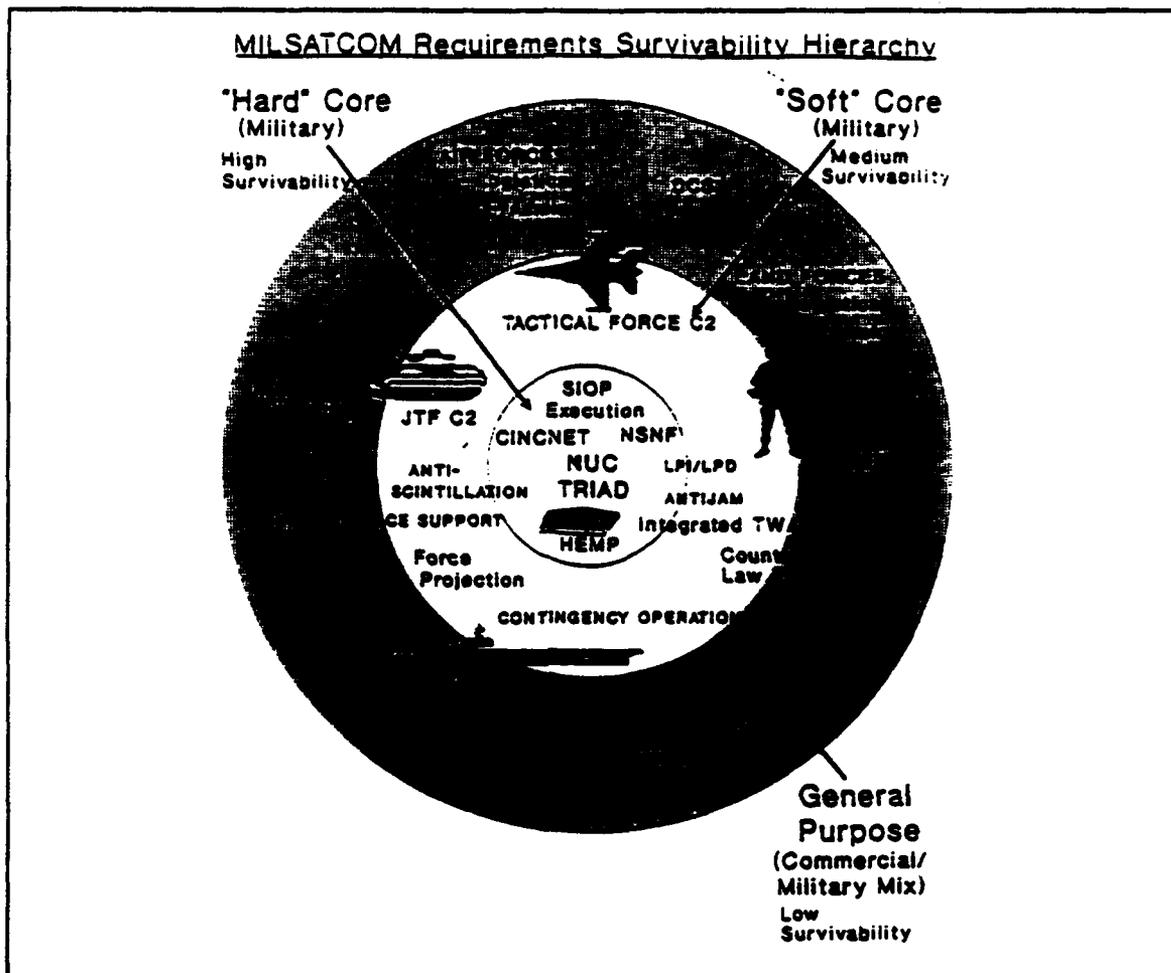


Figure 2. MILSATCOM Requirements Survivability Hierarchy (CJCS MOP 37, 1992, p. A-4)

The Navy's most cost effective satellite communication systems are those which provide communications in the UHF frequency range. These systems make up the worldwide backbone for unprotected and general purpose military communications.

Commercial satellite communication systems serve to provide a "surge" capacity for the military when MILSATCOM assets are either overburdened or not available due to the physical constraints of orbital mechanics. The SATCOM services provided by commercial satellite systems are unprotected general purpose communications.

The Defense Satellite Communications Systems (DSCS) serves as the MILSATCOM system that provides high capacity, core and general purpose communications to tactical users in the SHF frequency band. The Navy's SHF SATCOM program is the focus of this report.

B. SCOPE

The goal of this study is to provide an in-depth examination of the Navy's SHF SATCOM program before, during, and after Desert Shield/Desert Storm. Additionally this thesis provides insight into the political discussions going on between Congress and DoD over future developments in military satellite communications and the application of commercial satellite systems in the MILSATCOM architecture.

C. ORGANIZATION

This document is organized into seven chapters. The first chapter describes the purpose of this thesis and provides general background information on the Navy's SHF SATCOM program. The second chapter provides the reader with a

complete overview of the Navy's SHF capabilities prior to Desert Shield/Desert Storm, and the requirements that were generated for future systems due to Navy SATCOM shortcomings during the Gulf War. The third chapter discusses the four-phased evolutionary approach the Navy has designed to provide itself with a medium for SHF SATCOM into the 21st Century. In Chapter IV the Defense Satellite Communications System (DSCS) is described in detail from its initial design to current operating status. Chapter IV closes with a description of possible DSCS follow-on programs. The fifth chapter introduces the network encryption system (NES) as a means to migrate fixed-site-to-fixed-site DSCS SATCOM transmissions to terrestrial fiber optic networks. Chapter VI discusses studies and applications of commercial satellite systems in the MILSATCOM architecture. Additionally, Chapter VI provides a cost comparison between the annual operating costs of a single DSCS III satellite and the fees the Navy pays for INMARSAT connectivity for one year. The final chapter provides conclusions and recommendations to problems that surfaced during the examination of this program.

II. HISTORY OF NAVY SHF SATCOM

A. INTRODUCTION

Prior to the development of satellites, the Navy relied on semaphore, flashing light, flag-hoist signals, Ultra High Frequency (UHF) line of sight, and High Frequency (HF) surface wave signals for communication. The advent of satellite communications (SATCOM) for the Navy first came through leasing commercial communication satellites that had been placed in orbit over the Atlantic, Pacific and Indian Oceans in the mid 1970s. These satellites covered the UHF spectrum, and the program these satellites were leased under was called the Maritime Satellite (MARISAT) Program. The leased MARISAT assets were later given the name GAFILLER. (NOSC, 1991, p. 93) Additional UHF satellite capabilities were later provided by the Fleet Satellite Communication (FLTSATCOM) program in the late 1970s, the Leased Satellite (LEASAT) program in the early 1980s and the UHF Follow-On (UFO) program in the early 1990s. (NOSC, 1991, pp. 93-101) Due to bandwidth considerations and the need to support strategic "general purpose, core, and hard core" requirements, the Navy Super High Frequency Satellite Communications (SHF SATCOM) program was initiated in 1971. It was determined that the Defense Satellite Communications System (DSCS) would be utilized as

the space segment, since the Department of Defense (DoD) had been experimenting with this orbiting constellation since 1968 to satisfy DoD communication "needs." (Aerospace, 1991, p. 100)

1. Initial Requirements

The initial requirements for the SHF SATCOM capability started in 1971 were to provide a robust, Anti-Jam (AJ) protected, ship/shore/ship communications service. Specific data rates were not mandated, the driving force was simply to have to capability to communicate through SHF communications via satellite.

2. Initial Systems

The first SHF shipboard terminals were the AN/SSC-6 and AN/WSC-2 Terminals. These terminals have since been replaced by the AN/WSC-6(V) Terminal. AJ-protected communications service was provided by the OM-55(V)/USC Pseudo-Noise (PN) spread spectrum modulation subsystem which, in the late 1970's, was made interoperable with the Army AN/USC-28(V) spread spectrum modulation subsystem within the Defense Satellite Communications System (DSCS) Electronic Counter-Counter Measure (ECCM) network. (ACS, 1994, p. 2-8)

B. PHASE 0: AN/WSC-6(V)1,2 AND AN/SSC-6

In 1976, the need for high-capacity SHF satellite communications was identified for the Surveillance Towed Array Sensor System (SURTASS) operational mission. SURTASS ships

are basically "submarine hunters" that use advanced towed array sonar systems. This period of time marked the mid-point of the "Cold War," thus the current application of SHF SATCOM was primarily "strategic" in nature only.

1. Phase 0 Requirements

A letter from the Office of the Chief of Naval Operations (CNO) in June 1976 stated an operational requirement to provide an SHF SATCOM capability for the SURTASS T-AGOS ships and Navy combatant and Fleet Flagships. (CNO Letter, 14 June 1976; ACS, 1994, pp. 2-8; SPAWAR, 1994, p. 3) The operational requirements for the Navy SHF SATCOM systems in 1976 were: the system had to be jam resistant, provide for a single carrier, have a Mean Time Between Failures (MTBF) for the antenna greater than or equal to 1300 hours, MTBF for the radio greater than or equal to 900 hours, MTBF for the modem greater than or equal to 1200 hours, have a Mean Time To Repair (MTTR) for the antenna less than or equal to eight hours, MTTR for the radio less than or equal to five hours, MTTR for the modem less than or equal to four hours, have an operational availability of 0.94, and be able to initially support data rates of 32 kbps with expansion to 64 kbps. (SPAWAR, 1994, p. 9) This trend towards "high-capacity" SHF SATCOM communication would continue on into the next century. Typical circuit loading utilized by the SURTASS platforms was a 64 kbps ship-shore SURTASS data link

and a 1.35 kbps full duplex Orderwire circuit. The Fleet Flagship's data rates vary from platform to platform ranging from 16 kbps to 52 kbps. Circuits employed by these vessels included: Worldwide Military Command and Control System (WWMCCS) at 2400 kbps, Contingency Theater Automated Planning System (CTAPS) at 2400 kbps, Secure Telephone Unit-Third Edition (STU-III) at 2400 kbps, Advanced Narrowband Digital Voice Terminal (ANDVT) at 2400 kbps, and Orderwire and Teletype at 75 bps. (SPAWAR, 1993, p. 6)

2. Phase 0 Systems

The first shipboard SHF installation was in 1974 on a SURTASS T-AGOS platform, but this conducted as a result of the effort started in 1971. The direct result of the CNO's letter stating the operational requirement was the installation of 25 SHF SATCOM systems. Specifically these 25 were: 18 AN/WSC-6(V)1 terminals on SURTASS T-AGOS ships, 1 AN/SSC-6 (forerunner of AN/WSC-6(V)2) on the flagship USS LASALLE, 5 AN/WSC-6(V)2 terminals on Navy fleet flagships (USS CORONADO, USS BLUE RIDGE, USS MT. WHITNEY, USS BELKNAP, and USS NASSAU), and one AN/WSC-6(V)2 terminal was installed at the Fleet Training Center (FTC), Norfolk, VA. (ACS, 1994, p. 2-8; SPAWAR, 1993, p. 5)

The technical characteristics of the three different variants of Phase 0 included different combinations of antenna groups, radio groups and modems.

a. AN/WSC-6(V)1

This variant utilizes the OE-279 Antenna Group, as do the other two. It uses the OZ-43 Radio Group, which includes an 8 KW High Power Amplifier (HPA), and the MD-1030A Modem.

b. AN/SSC-6

Variant two shares the same OE-279 Antenna Group as the AN/WSC-6(V)1,2. The Radio Group is unnomencatured, and employs the OM-55(V) modem for jam resistant secure communications.

c. AN/WSC-6(V)2

Variant three of Phase 0 shares the common OE-279 Antenna Group and OZ-43 Radio Group, which includes an 8 KW HPA. Since AN/SSC-6 is the forerunner of the AN/WSC-(V)2, they share the same OM-55(V) modem. (SPAWAR, 1993, p. 5)

C. SHF SATCOM POST DESERT SHIELD/DESERT STORM

The Phase 0 SHF SATCOM variants remained the status quo for the Navy until 02 August 1990 when Iraq invaded Kuwait. Operation Desert Shield/Desert Storm (DS/DS) demonstrated the need for the Navy to have more communications "pipes" for all types of information, as well as connectivity between all operational forces. The other services were using SHF because of its wide bandwidth, which makes it ideal for data transmission, and also because it is inherently more jam resistant than Ultra High Frequency (UHF) transmissions. The

Navy deemed that it was necessary to improve current SHF SATCOM capabilities "to satisfy minimum tactical command and control, intelligence and war-fighting communications requirements, and improve Joint and Allied/NATO communications interoperability." (NAVSPACECOM, 1992, pp. 1-2) One glaring example of how an improved SHF SATCOM capability would have helped the Navy during the Gulf War is how it could have helped eliminate the problems associated with dissemination of the Air Tasking Order (ATO).

1. Post Gulf War Requirements

Desert Shield/Desert Storm transformed the Navy's usage of SHF SATCOM from a "strategic" to a "tactical" nature and provided the impetus for a rapid increase in the numbers of SHF SATCOM terminals in the fleet. Recognizing the need for an improved SHF SATCOM capability, the Office of the CNO mandated the accelerated fielding of SHF shipboard terminals in August 1990. (CNO Letter, 28 August 1990) As a result of this order, the Navy's use of DSCS expanded significantly over the next few years.

The operational requirements of the improved SHF SATCOM system the Navy was seeking were vastly different from those SATCOM systems that the Navy had been operating since 1974. Operational requirements as of 1992 were: the system must be able to support multiple carriers; MTBF for the system 300-1200 hours; MTTR for the system 2.5-7 hours; operational

availability of 0.85-0.98; be able to support data rates of up to 640 kbps; have a modular design to permit future component level upgrades as component technology improves; and be able to support pre-planned product improvement (P³I) for data rates of T1 (1.544 Mbps) and E1 (2.048 Mbps). (SPAWAR, 1994, p. 10)

III. SHF SATCOM TERMINAL IMPROVEMENT

The SHF SATCOM terminal improvements that were deemed necessary as a result of the shortcomings of the Navy's SHF SATCOM capabilities during Desert Shield/Desert Storm were programmed to be completed in an incremental evolution process totaling three phases. The AN/WSC-6(V) terminals that were installed on the SURTASS platforms and Fleet Flagships are not one of the phased improvements, but those variants were recognized as Phase 0 installations. Upon the completion of the three phase process, a significantly improved SHF SATCOM capability will be installed on most naval combatants. (ACS, 1994, p. 2-8)

A. PHASE I: QUICKSAT

To meet the urgent joint interoperability requirement to satisfy minimum tactical command, control, communications and intelligence (C³I), war-fighting communications, and high data rate communications, the Navy obtained and modified U.S. Air Force (USAF), Army, and Marine Corps AN/TSC-93B Ground Mobile Force (GMF) SHF SATCOM equipment. Modifications to the vans were limited to use of the standard Navy SHF antenna system, the SURTASS digital modem, two low speed time division multiplexers (LSTDMS), and additional patch panels. The modified SATCOM vans and racked equipment were designated

"QUICKSAT." The introduction of these terminals into the fleet marked the beginning of Phase I of the Navy's SHF SATCOM fielding plan. The objective was to quickly provide the maximum capability with the highest probability of success. In meeting its goal of increased and responsive command, control, communications, computers and intelligence (C⁴I) support to operational war fighters, the Navy relied increasingly on selected commercial off-the-shelf (COTS) equipment. (NCCOSC, 1994, pp. 1-2)

QUICKSAT was to provide a diverse range of host systems. These host systems services include voice, narrative text, database transactions, graphics, bit-mapped imagery, video, and combinations of those listed. A more detailed description of the hosted systems is included in Appendix B.

The original intention of the QUICKSAT program was to have five ships outfitted with "borrowed" equipment on an interim basis so that these five SHF SATCOM systems would be operational during DS/DS. The first QUICKSAT system (installed in USS Tarawa) was actually not operational until after DS/DS, and the "interim" program has now been installed on thirteen ships. (Martin, 06 April 1994) The initial units were installed in the form of deck-mounted terminal vans on the "island" superstructure, and the later installations were in a rack-mounted terminal within the superstructure. The single four foot stabilized tracking antenna was mounted high on the "island" superstructure to minimize structural

masking/blockage and mutual radio frequency interference (RFI). QUICKSAT utilized two configurations, one utilizing "borrowed" equipment from other services, and the later installations used purchased equipment. The "borrowed" configuration employed the AN/TSC-93B radio, a Navy OE-279 antenna group, and an MD-1030A modem. The later installations utilized the AN/WSC-6(V) radio group, Navy OE-279 antenna group, and MD-1030A modem. (SPAWAR, 1993, p. 7)

A basic block diagram of the QUICKSAT system is enclosed in Appendix C. The QUICKSAT van is powered electrically from shipboard systems, and has a dedicated external air conditioning system for cooling purposes. Two of the QUICKSAT installations (USS Nimitz and USS Wasp) replaced the AN/WSC-6(V) radio group with the AN/WSC-6(V)2. This version of the radio group contains a medium power amplifier (MPA) [300 Watts] instead a high power amplifier (HPA). This adjustment was made due to the air conditioning units experiencing difficulties with dissipating heat from the HPAs. Space limitations would not allow for a larger cooling system which was deemed necessary if HPAs were to be kept.

The QUICKSAT installation was completed on aircraft carriers (CV/CVNs) and selected "L" class ships (Amphibious Assault Ship - LHA, Landing Platform Helicopter Ship - LPH, and the Multi-purpose Amphibious Assault Ship - LHD). The three phase evolution of the SHF SATCOM architecture for the Navy mandates that the amphibious ships maintain QUICKSAT as

their SHF capability until Phase III is implemented, and the only platforms that will receive Phase II will be the CV/CVNs. (SPAWAR, 1993, p. 11)

B. PHASE II: AN/WSC-6(v)4

Commencing in Fiscal Year (FY) 1994, Phase II of the SHF SATCOM evolution plan started replacing QUICKSAT terminals on CV/CVNs with AN/WSC-6(V) terminals. In an effort to reduce system costs, Non-Developmental Item (NDI) technology began to be utilized in the Phase II installations. Use of NDI technology was also chosen to help minimize the delay of the advanced service to the fleet by taking advantage of components that were available commercially off the shelf (COTS) and had depot support and documentation to back them up, as well as increase the data rate capability from 50 kbps to 256 kbps. The two major components that were provided through the NDI approach were the 300 Watt Traveling Wave Tube (TWT) Medium Power Amplifier (MPA) and the Stanford Telecommunications (STel) 1105 Demand Assigned Multiple Access (DAMA) Time Division Multiple Access (TDMA) modem. A basic block diagram of the Phase II system is enclosed in Appendix C. Another modification that will be introduced with Phase II is the seven foot antenna. The larger antenna will support higher data rates as a result of improved gain and signal quality. Cost estimates for a Phase II system using a four foot antenna without NDI technology are approximately \$2.5

million per system, while the seven foot antenna system without NDI technology would cost approximately \$3.5 million. Market estimates for an NDI system with a 7 foot antenna are approximately \$1.9 million. This apparent savings coupled with the fact that the three phase plan calls to outfit 150 ships (but Congress has only allocated funding for 32) suggests that the NDI approach is the trend of the future. (Martin, 01 February 1994)

The CV/CVNs are being retrofitted with the Stel 1105 TDMA modem, a generic Bi-phase Shift Keying (BPSK) modem, and Timeplex TDMA multiplexer. The decision to utilize the Stel 1105 modem was made in late 1990-early 1991 over another competitive model. Not only was the Stel 1105 modem cheaper, but it was a reliable system. The Stel 1105 had proven to be an excellent performer for numerous years while being employed in "black" programs for intelligence agencies. The Navy purchased 35 Stel 1105 modems (at approximately \$65K per copy), 26 of which came from previous acquisitions through "black" programs, but does not plan to buy any more. Frequency division multiple access (FDMA) modems which could accommodate the same data rates cost approximately \$10k. The reason for the higher cost of the TDMA modems is due to the precision timing requirements associated with the components controlling time division multiplexing. While QUICKSAT's use of the 1030 modem and FCC 100 multiplexer were based on the needs of the Navy in late 1991-early 1992, the needs

changed/increased, and have continued to do so. Originally the STel 1105 modem was designed for use with five or six ships operating at 16 kbps apiece (256 kbps aggregate). Now a single ship can run 256 kbps; hence the STel 1105 B and C, which can handle up to 5 Mbps. (Martin, 06 April 1994) Phase II installations have been tested and have proved the capabilities of the STel modem in Tandem Thrust 92, Ulchi Focus Lens 92 (Defense of Korea) and Secure Tactical Data Network Four (STDN4) demonstration held in September 1993.

There is significant disagreement between the services and the Defense Satellite Communications System (DSCS) system manager, Defense Information System Agency (DISA), over how to more efficiently utilize the SATCOM assets (DSCS). The Navy is uniquely at a disadvantage relative to the other services in that the Navy platforms that require SHF SATCOM service are continuously mobile while maintaining communications. The Ground Mobile Force (GMF) users are only tasked with maintaining communications while their SHF SATCOM site is in a fixed location. If the GMF user is tasked with shifting locations, they either shift the "guard" for the SHF circuit to another fixed unit, or drop out of the SHF SATCOM communications grid completely until they have shifted and set up their SATCOM capability again. This, coupled with the fact that the size of the antenna the Navy uses is four feet instead of the eight or 20 foot antenna used by GMF users and the 40 and 60 foot medium and heavy terminals used by larger

facilities. This disadvantage is demonstrated by the significantly smaller throughput values encountered by Naval forces utilizing SHF SATCOM in Figure 3.

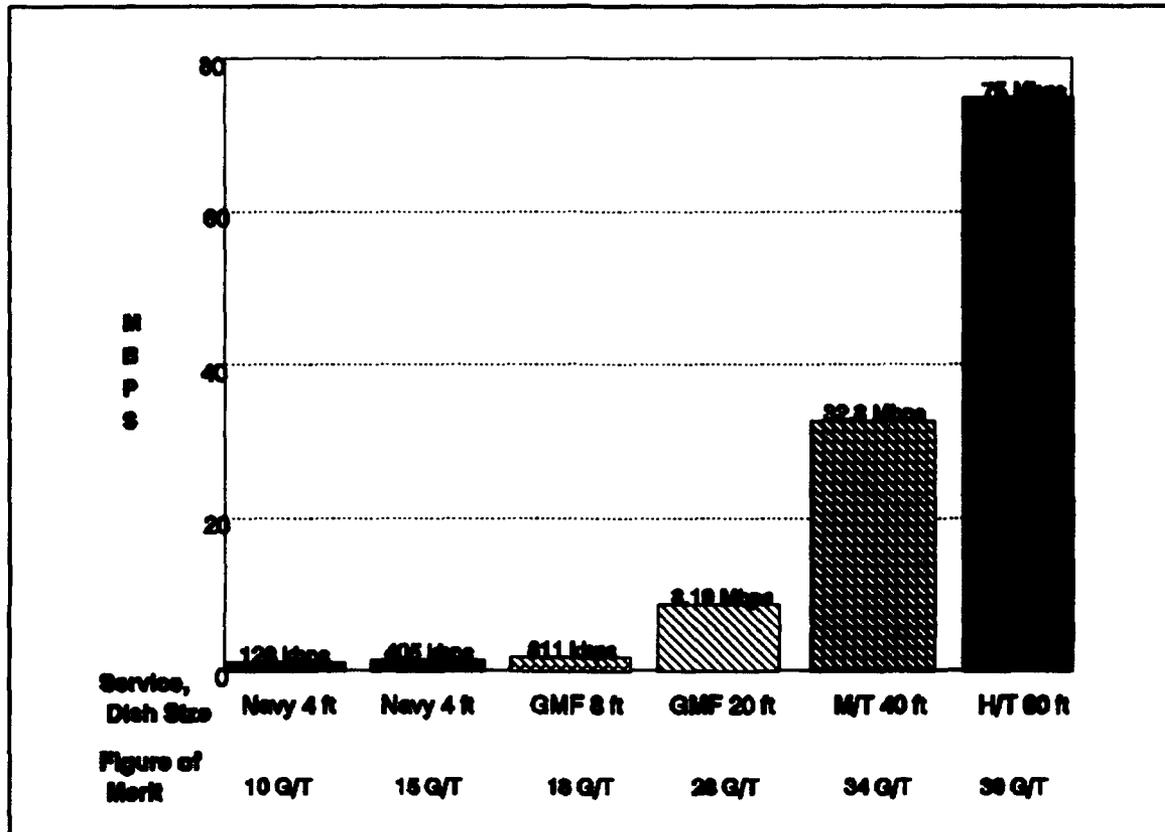


Figure 3. Satellite Dish Throughput Comparison

Because of these disadvantages the Navy requires higher power, either on the ship or on the DSCS satellite. Other ways to possibly alleviate this problem are to increase DSCS power, put larger antennae on ships, or utilize beam forming networks on the satellites. The Navy is in the process of increasing the size of the antennae on the ships by introducing the seven foot antenna with the Phase II

installation. Other possible future modifications to the DSCS satellites will be discussed in Chapter IV.

1. DISA DAMA Standard

In April 1992 the Military Communication Electronics Board (MCEB) tasked the Defense Information Systems Agency (DISA) with preparing a standard for SHF DAMA. The objectives of developing a standard were to ensure more efficient use of DSCS satellite resources, ensure interoperability between all users (as mandated by C⁴IFTW [J6I, 1993]), support all user platforms, as well as support all user service requirements. The self-imposed constraints that DISA was operating under in the development of the DISA DAMA Standard were: the standard had to be a direct derivative of commercial DAMA practices; be an open-ended standard that would allow for evolving technology; operate in X(DSCS), C, and Ku bands; and also be inexpensive. (DISA, 1994, pp. 1-4)

The requirement for increased throughput led Navy engineers to begin pursuing SHF DAMA as a solution in early 1990. A market survey conducted in 1991 revealed only two available NDI DAMA modems that would be candidates for the Navy. As previously discussed, it was determined in October of 1991 that the STel 1105A was the most cost-effective choice for DAMA modems, so in early April of 1992, the Navy acquired shore 1105A modems from STel. (SPAWAR, 1994, p. 10)

DISA established the first government/industry SHF DAMA Standard Working Group, and held its first meeting in June of 1992. The first draft of the DISA DAMA Standard was presented by the working group for government/industry review in January of 1993, and a second draft was again presented in May of 1993. The "final draft" of the SHF DAMA Standard was released on 30 September 1993, over three years after the Navy had begun pursuing DAMA modems as an answer for more efficient use of DSCS. DISA does not anticipate publishing the final SHF DAMA Standard until September of 1995. (SPAWAR, 1994, p. 10)

In order to compensate for the "late" development of a DAMA Standard after the Navy had begun procuring modems to help solve the problem, DISA wrote the standard to include two profiles.

a. Profile 1

This standard includes a requirement for a common control element and a basic communications package. This profile is mandatory for all new terminals. The network control terminal (NCT) governing the network will have the ability to control the bandwidth and power usage of participating users. This configuration will employ backward compatibility with existing SHF DAMA modems.

b. Profile 2

This is the category that the was written into the standard to "cover" the Navy's TDMA DAMA modem. This standard shares the same common control element and basic communications package as Profile 1, but also has an additional expanded communications capability. This is to allow for future mission and user needs, as well as technology insertion. There are additional capabilities beyond that of Profile 1 that are written into the second profile specification that are Navy specific.

C. PHASE III: AN/WSC-6(V)XX

Phase III of the SHF SATCOM evolution process is scheduled to begin in FY 1997. This phase will deploy the next AN/WSC-6 variant in three configurations. Configuration A is applicable to major Fleet Flagships, Battle Force/Battle Group Flagships (CV/CVNs), and major amphibious force flagships. Configuration B is applicable to selected cruisers/destroyer (Tomahawk capable platforms) selected amphibious ships, selected Combat Logistics Force (CLF) ships, and maritime prepositioning ships. Configuration C is applicable to SURTASS ships. (NRaD, 1993, p. 7) The new terminal will be a modern, modular open architecture terminal capable of providing a full spectrum of SHF SATCOM communication services. (NCCOSC, 1994, p. 4-1)

1. Standard Tactical Entry Point (STEP)

The current SHF SATCOM architecture utilizes a hub and spoke network for QUICKSAT operations. There are five QUICKSAT Satellite Communication Facilities worldwide which act as terminal entry points (gateways) or hubs. The five locations are: Northwest, Virginia; Wahiawa, Hawaii; Fort Buckner, Okinawa, Japan; Lago di Patria, Italy; and Finegayan, Guam. (SPAWAR, 1994) These five tactical entry points have unique configurations and requirements and are limited in capacity and capability. These differences often cause problems as Naval forces move from one area of operations to another. To help eliminate this problem the Navy has planned to implement the Standard Tactical Entry Point (STEP). The STEP will provide Navy and other users uniform, seamless, and transparent access to the DoD's envisioned Global Grid. It will also ensure efficient bandwidth use, indirect interoperability, no idle bandwidth, and low management overhead. (NCCOSC, 1994, p. 4-1)

2. Global Grid

Implementation of the STEP and Phase III will allow the Navy connectivity to the Global Grid envisioned by DoD, which will provide "plug and play" voice, data, imagery, and video among all services. This Worldwide DoD/Joint Communications Network will support data rates into the Giga bits per second (Gbps), utilizing Asynchronous Transfer Mode

(ATM) switching and multiplexing on a synchronous optical network that incorporates industry standards. A depiction of this Global Grid is enclosed in Figure 4. The capabilities envisioned in this concept would allow an afloat Naval Commander to carry out assignments as Naval Force Commander (NAVFOR), Joint Force Air Component Commander (JFACC), and also Commander Joint Task Force (CJTF). Additionally, when fully fielded, the Global Grid would provide for up to 150 SHF capable ships; one Fleet Flag Ship per satellite; one Flag Ship plus 12 SHF ships per Area of Responsibility (AOR); and six other SHF ships per earth terminal. (NCCOSC, 1994, p. 4-3)



Figure 4. Inter-Theater Global Grid (NCCOSC, 1994, pp. 4-3)

IV. DEFENSE SATELLITE COMMUNICATIONS SYSTEM BASICS

The Defense Satellite Communications System (DSCS) is designed to provide vital, long-haul, and high volume communications service to U.S. forces and validated non-DoD users throughout the world. The current DSCS system is composed of three segments: the control segment, the terminal segment, and the space segment. The control segment is dominated by U.S. Army operated facilities in Fort Meade, MD; Fort Detrick, MD; Fort Buckner, Okinawa; and Landstuhl, Germany. The Navy's terminal segment consists of the AN/WSC-6 and AN/TSC-93B terminals, which were discussed in Chapter III. The DSCS SHF SATCOM space segment consists of the Department of Defense (DoD) DSCS satellite constellation. This constellation has evolved through three different variants (DSCS I, DSCS II, and DSCS III) since the Advanced Research Projects Agency (ARPA) undertook an effort to provide an operational military communication satellite in April 1960. (Martin, 1991, p. 95)

A. DEFENSE SATELLITE COMMUNICATIONS SYSTEM I

1. Initial Defense Communication Satellite Program (IDCSP)

The Defense Satellite Communications System I (DSCS I) program was originally called the Initial Defense Communication Satellite Program (IDCSP). An artist's

rendering of the DSCS I/IDCSP is depicted in Figure 5. The IDCSP program began in 1962 when the Advent program, which was the program ARPA began in 1960, was cancelled. The Titan III-C rocket was selected as the IDCSP launch vehicle, and the first successful launch of the IDCSP into a subsynchronous orbit was completed in June 1966. Additional satellites were launched in 1967 and 1968, placing 26 of 34 satellites launched successfully into orbit. (Martin, 1991, pp. 95-96)

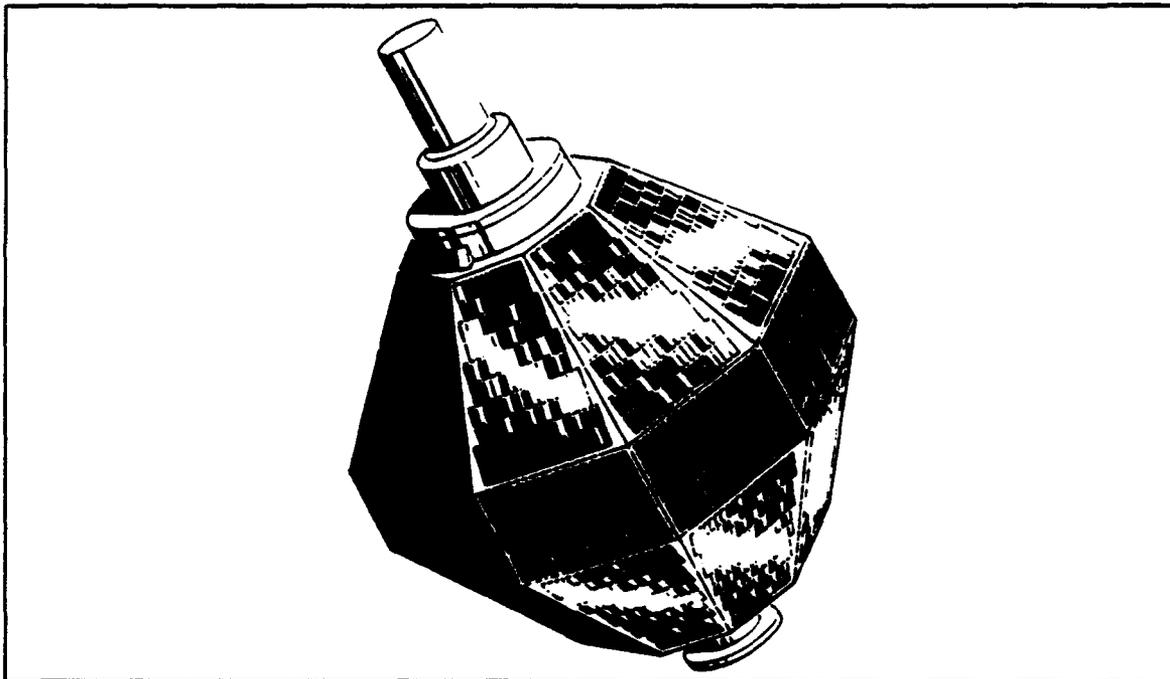


Figure 5. Defense Satellite Communication System I (DSCS I) /Initial Defense Communication Satellite Program (IDCSP) [Martin, 1991, p. 95]

2. Satellite Operations

The IDCSP was a very simple, spin-stabilized, subsynchronous satellite, with neither a stationkeeping or altitude control capability. The design engineers of the satellite (Ford Aerospace and Communications Corporation) determined no command systems were to be included in the constellation, as command system failures had led to the termination of the Advent program and terminated operations of the Courier and Telstar 1 satellites. Additionally, the randomness of the individual satellite orbits provided for automatic replacement of failed satellites with acceptable outages. (Martin, 1991, p. 95) Satellite design details and specifications are included in Appendix D.

In 1967, the war in Vietnam led to the IDCSP being used as an operational communication link for high-speed, digital data transmission from Vietnam to Washington, D.C., via Hawaii. (Martin, 1991, p. 96) The system was declared operational in 1968, and the name of the program was again changed to Initial Defense Satellite Communication System (IDSCS). Though the name was never "officially" changed to DSCS I, it has come to be known as this amongst satellite communications experts. The overall reliability of the DSCS I program was much beyond the original expectations of the designing engineers. The actual Mean Time Before Failure (MTBF) achieved was more than double the design life of three

years. The last DSCS I satellite was removed from service in 1977. (Martin, 1991, p. 96)

B. DEFENSE SATELLITE COMMUNICATIONS SYSTEM II

The experiences of the DSCS I/IDCSP program demonstrated that satellite communications could satisfy certain DoD needs, therefore, in June 1968 efforts for developing a more advanced SATCOM capability began. TRW was the primary contractor for Program 777, hence the satellites were initially called 777 satellites. The name of the satellite has since been changed to DSCS II, and the capabilities of this system are significantly different from the IDCSP satellites. (Martin, 1991, p. 100)

1. Technology Advancements

The DSCS II satellite was designed so that it was compatible with modified IDCSP ground terminals as well as new terminals specifically built for Phase II of DoD's SATCOM capability. Unlike the IDCSP, the DSCS II satellites have a command subsystem, attitude control and stationkeeping capability, and multiple communication channels with multiple access capability.

Another developmental advancement of the DSCS II was the dual spin configuration, which allowed the two parabolic reflectors and two horn antennas to always point at the earth.

The satellite is composed of two sections: the outer section (which includes the cylindrical solar array and equipment

platform), and the inner section (which houses all the communications equipment and antenna). The outer section was designed to spin to stabilize the satellite, while a motor and bearing assembly effectively isolates the inner section by despinning it. This despinning action is what allows the antennas to always point at the earth. (Martin, 1991, p. 100) An artist's rendering of the DSCS II is depicted in Figure 6.

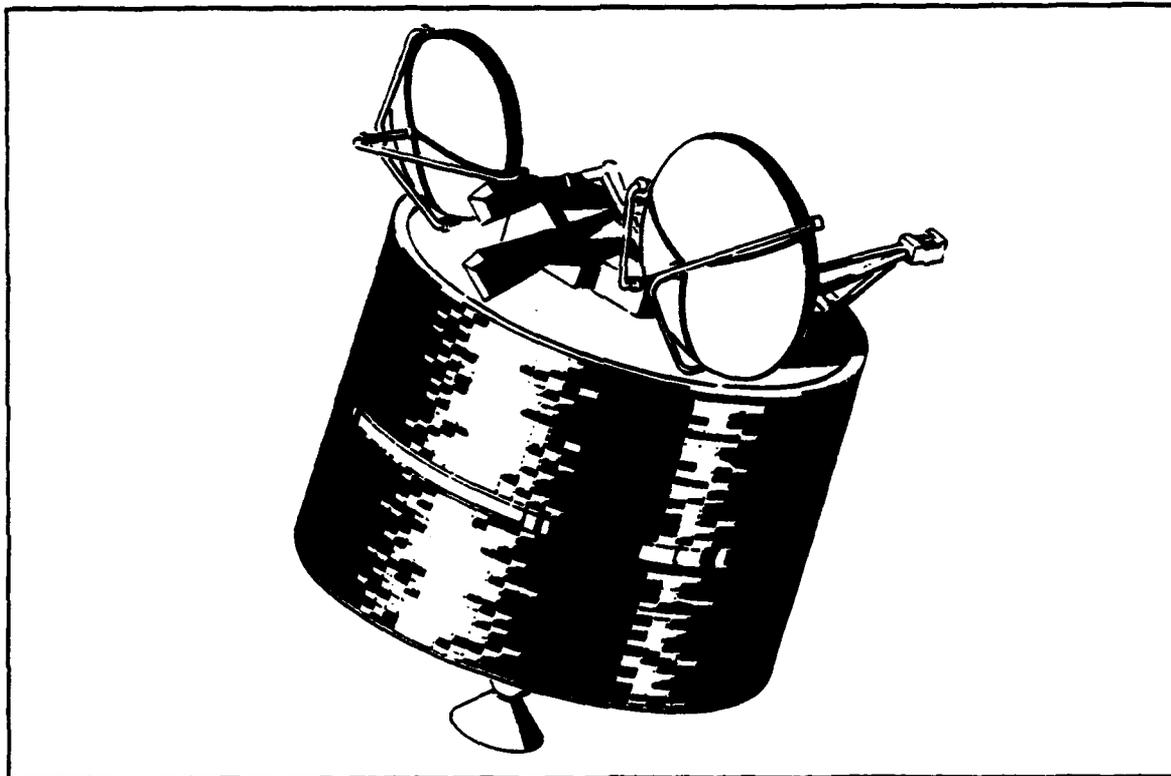


Figure 6. Defense Satellite Communication System II (DSCS II) [Martin, 1991, p. 100]

2. Satellite Operations

The first pair of DSCS II satellites were launched by a Titan III-C rocket in November 1971. Of the 16 DSCS II "birds" launched between November 1977 and October 1982, 12 achieved the designed synchronous orbit and provided service for some time. The first 14 DSCS II birds were launched in pairs. The 15th and 16th DSCS II satellites were launched in tandem with DSCS III birds. The launch platform for these launches was the Titan 34-D.

The last 10 DSCS II satellites were modified so that one narrowbeam antenna is "defocused" to provide area coverage of nominally six degrees of bandwidth. These satellites were launched to establish and maintain an orbital system of four active and two spare satellites. The last four satellites were upgraded to include 40 Watt Traveling Wave Tubes (TWTs) instead of the originally installed 20 Watt TWTs. (Martin, 1991, p. 102)

3. Communication Subsystems

The DSCS II satellite has a communication subsystem comprised of four channels. This subsystem includes redundant, sophisticated combinations of tunnel diode preamplifiers, single-frequency conversion, tunnel diode amplifiers (TDAs), and driver and high power TWTs. (Martin, 1991, p. 102)

a. Channel 1

Channel 1 transmits in the 7250 to 7375 MHz frequency range. Both the receive and transmit antennas provide earth coverage.

b. Channel 2

Channel 2 transmits in the 7400 to 7450 MHz frequency range. The transmit antenna provides earth coverage. The receive antenna provides narrowbeam or earth coverage (on satellites 7-16).

c. Channel 3

Channel 3 transmits in the 7490 to 7675 MHz frequency range. The transmission and receive antennas of satellites 1 through 6 both provide narrowbeam coverage. Upgrades to satellites 7 through 16 allow for either narrowbeam or earth coverage on the transmission and receive antennas.

d. Channel 4

Channel 4 transmits in the 7700 to 7750 MHz range. The receive antenna provides earth coverage. The transmit antenna provides narrowbeam or earth coverage (on satellites 7-16).¹ [Martin, 1991, pp. 101-102]

¹ Additional technical specifications on the DSCS II satellite are enclosed in Appendix D.

4. Constellation Life Cycle Management

The designed life cycle of the DSCS II satellites was five years. Due to inadvertant over-engineering of the solar arrays (caused by an error in the model used to help design the solar arrays), the actual life expectancy of a DSCS II bird has averaged approximately 12 years. (Williams, 1994) As the older satellites become degraded, they are replaced with another satellite to act as the "primary" communications satellite. The degraded satellite then assumes the role of a "back-up" system. Once the constellation is so degraded that it is no longer useful, it is maneuvered out of the synchronous orbit with the stationkeeping thrusters. The last DSCS II satellite acting as a "primary" communication satellite was replaced with a DSCS III bird in March 1994. (Williams, 1994)

C. DEFENSE SATELLITE COMMUNICATIONS SYSTEM III

As the DSCS system has evolved, there has been a significant increase in both the number and variety of terminals. The system that was originally planned for long-distance communications between major military locations was now being adapted to be used by GMF users needing transportable terminals, or mounted on ships to provide SHF communications connectivity to deployed Naval forces. The Defense Satellite Communications System III (DSCS III) was

developed to operate in this diverse environment. (Martin, 1991, p. 111)

1. Program Inception

Design studies and breadboard systems of certain components of the DSCS III satellite were being conducted by General Electric Astro Space in 1976. The major advancement that was requiring the most study was the development of the Multi-Beam Antenna (MBA). Final development of the DSCS III qualification model and two flight models began in 1977. The first of these three DSCS III Block A satellites was launched in October with a DSCS II bird. The program plan of DSCS III is to establish and maintain an orbital constellation of at least five active and two spare satellites. (Martin, 1991, p. 113)

2. Satellite Components

The DSCS III satellite has a rectangular body approximately six feet x six feet x 10 feet. Attached to the main body of the satellite are two solar arrays, which deploy from the north and south faces of the satellite to an overall length of 38 feet. All support subsystems except the solar arrays are contained within the body. See Figure 7 for an artist's rendering of the DSCS III antenna.

3. Primary Communication Subsystem

There are eight antennas on the primary communication subsystem of the constellation that can be configured in

various ways to six transponders. The eight antennas include: one 45-inch receive MBA, two 28-inch transmit MBAs, one 33-inch gimbaled dish antenna (GDA) for transmission, and four horn antennas (two for receive and two for transmission). (Martin, 1991, p. 111)

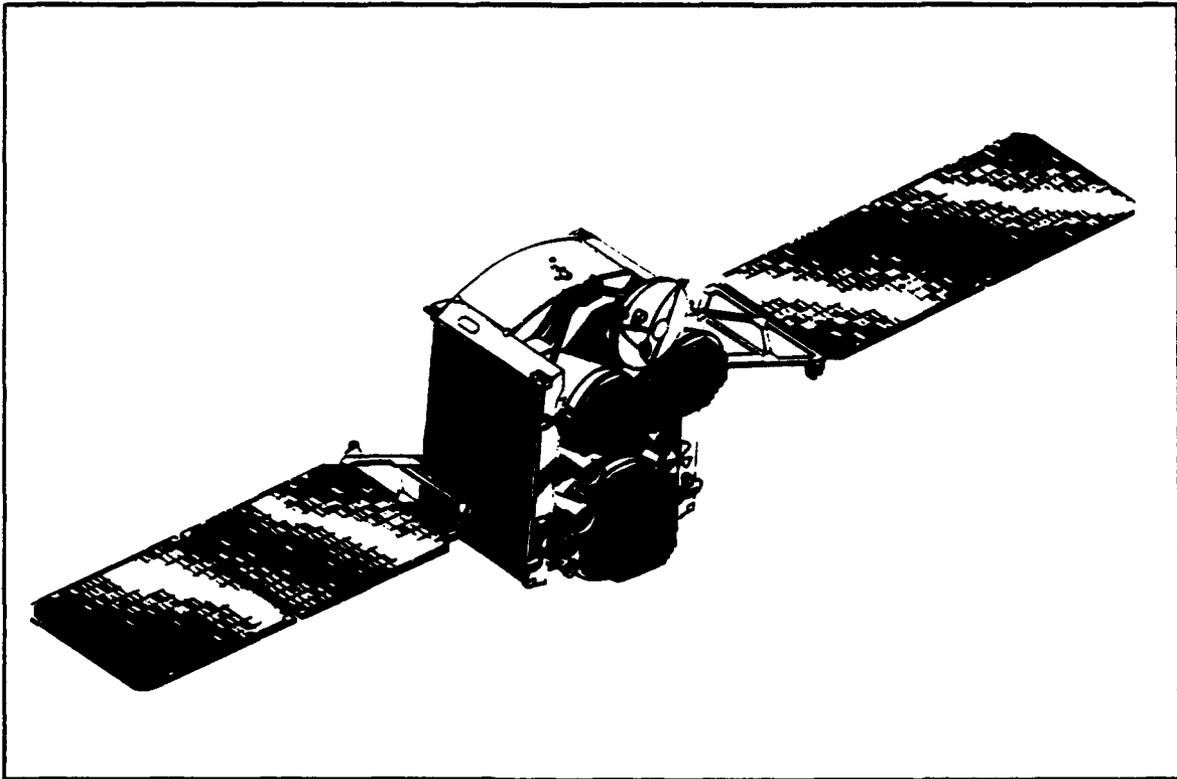


Figure 7. Defense Satellite Communications System III (DSCS III) [Martin, 1991, p. 111]

The six transponders on the satellite are unique in that they have their own limiter, mixer, and transmitter. This feature allows the transponders to be configured to be used with either Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA) transmissions. Additionally, the transponders can be configured to choose

between receiving antenna, transmitting antenna, and transponder gain level. (Martin, 1991, p. 111) The 45-inch receive MBA can form a beam of variable size, shape and location by means of a beam forming network that controls the amplitudes and phases of each of the individual 61 beams. Four of the six transponders can be connected to this antenna. The MBA also has the ability to form nulls in selected areas/directions to counter jamming. (Martin, 1991, p. 111) The two receive horn antennas are earth coverage antennas.

The two 28-inch transmit MBA have the same capabilities as the receive MBA, with the exception of nulling. There are also only 19 individual beams on these antennas, which may be connected to four transponders. The remaining two transponders are always connected to the two transmit earth coverage horn antennas. Three transponders may be switched to the 33-inch GDA, which generates a single beam with high EIRP. (Martin, 1991, pp. 111-112)

4. Secondary Communication Subsystem

The secondary communication subsystem on the DSCS III satellite is the AFSATCOM single channel transponder (SCT). The SCT supplements dedicated AFSATCOM spacecraft for command and control communications from the national command authorities (NCA) and appropriate commanders to the nuclear capable and support forces. There are two crossed dipole UHF antennas (one for transmission, and one receive) associated

with the SCT, but it can also be connected to the X-band earth coverage or MBA receiving antennas. The SCT demodulates the received UHF uplink and remodulates it for transmission. There is also a message store capability inherent to the SCT system for repeated transmissions. Due to the strategic nature of the requirements passed on this transponder, the X-band uplink has anti-jamming protection. (Martin, 1991, p. 111)

5. Launch Vehicle Considerations

Originally the Air Force planned to launch the DSCS III satellites in pairs from the space shuttle, and two were launched on the 51-J classified space shuttle mission in October 1985. As was mentioned previously, a DSCS III was paired with an earlier DSCS II model for launch on the less powerful Titan 34-D rocket. Only the shuttle or a Titan 4 rocket could launch two DSCS IIIs at the same time. After the Challenger accident, it was determined the remaining DSCS III birds would be launched individually on Atlas-2 rockets. (Chien, 1994, p. 107) Subsequent changes to the space shuttle's cargo bay after the Challenger accident altered the dimensions of the bay such that DSCS III satellites will no longer fit. (Williams, 1994)

The change in launch vehicles made it necessary to develop a bipropellant apogee motor stage to deliver the satellite to synchronous orbit. The Integrated Apogee Boost

Subsystem (IABS) was the result of these efforts, and it was retrofitted into several already built satellites, which were classified as DSCS III-Bs.

Eight DSCS III's of variant A/B have been launched since October of 1982. The launch dates of the remaining six satellites are tentatively scheduled as follows: A-3 in May 1995, B-7 in May 1998, B-6 in FY 99, B-8 in FY 00, B-11 in FY 02, and B-13 in FY 03. (Williams, 1994) These satellites are currently stored in the Martin Marietta Astrospce warehouse in Valley Forge.

D. MODIFICATION OF CURRENT PLATFORM VERSUS DEFENSE SATELLITE COMMUNICATIONS SYSTEM FOLLOW-ON

The need for an improved DSCS capability or DSCS follow-on program is being driven by the increased use of satellites by the armed forces. This increased use is substantiated by the fact that during the Gulf War, a pair of DSCS III and DSCS II satellites transmitted more military satellite communications traffic than was sent between the United States and Europe during the entire Cold War. (Chien, 1994, p. 116) A representation of DSCS traffic usage during the Gulf War is shown in Figure 8.

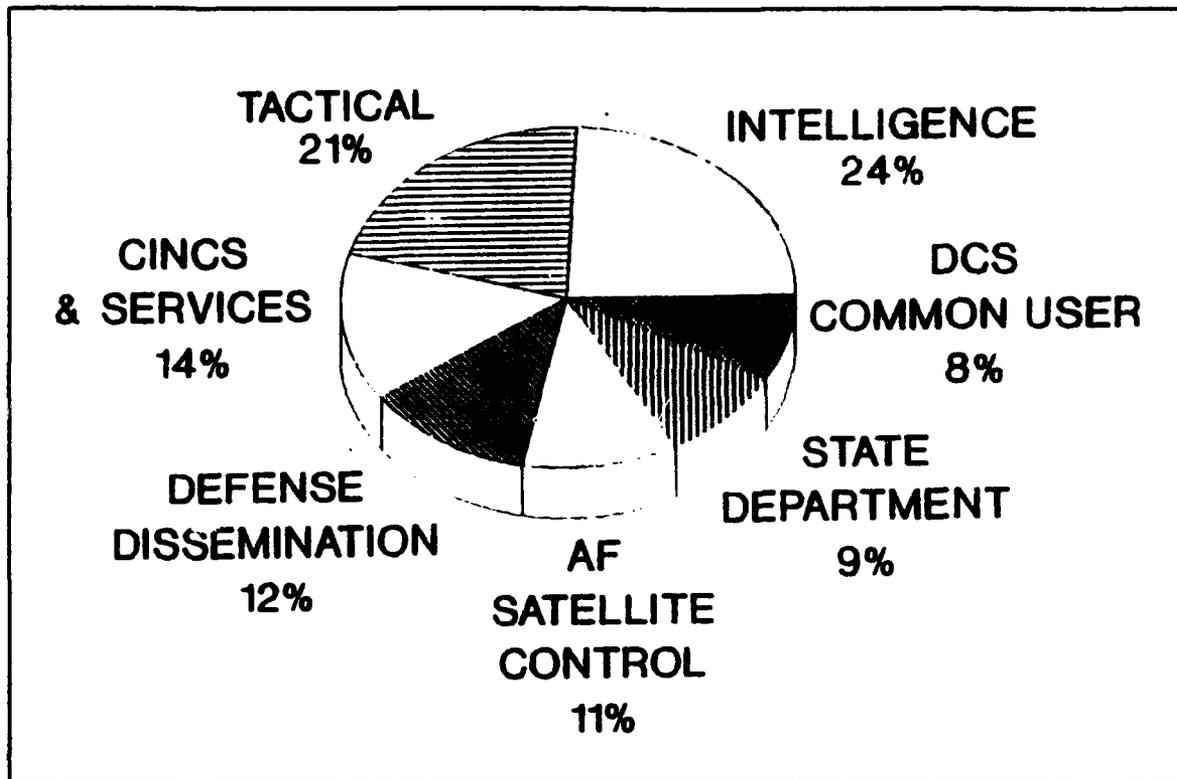


Figure 8. DSCS Usage (Williams, 1994)

1. Political Impact

There are currently several staff efforts being conducted by the Air Force, DISA, and other Federally Funded Research and Development Centers (FFRDCs) concerning the feasibility of modifying four of the existing six DSCS satellites versus beginning a new DSCS follow-on program. The political "tug-of war" behind these efforts dates back to 1989. Portions of a Government Accounting Office (GAO) Report documenting the Congressional/DoD actions with regard to

MILSATCOM are enclosed in Appendix E. (GAO, 1993, pp. 1-5) Recent guidance with regard to SHF SATCOM from the Office of the Assistant Secretary Of Defense for Command, Control, Communications and Intelligence (ASDC³I) listed the following for FY 1996 Program Objective Memorandum (POM) Planning:

- Fund the DSCS III program sufficient to maintain a five satellite, plus residual, constellation through FY 1996 (including Beam Forming Network [BFN] modifications on the last four satellites).
- Determine if cost effective opportunities exist to offload long haul DSCS requirements to commercial SATCOM or fiber optic cable which would allow transition to a four satellite plus residual operational constellation.
- Identify decision phase points for transition to a follow-on system to DSCS III. The system is to utilize industry-developed commercial satellite buses, recommend innovative cost and acquisition streamlining opportunities for the systems, and possibly identify opportunities for international cooperation. (ASDC³I, 14 January 1994, pp. 1-2)

a. Government Accounting Office (GAO) Findings

The initial time frame scheduled for the decision to determine whether to replenish the current DSCS constellations or transition to a new platform was 1994. The accompanying acquisition plan and first launch date were to follow in 1995 and 2002 respectively. Figure 9 shows DoD's (USAF) actual and planned launch dates, and expected operational periods for DSCS III satellites between 1991 and 2007. In order to support the DoD's requirement of five fully operational satellites (East/West Atlantic, East/West Pacific, and Indian Ocean) at all times, replenishment or replacement

of current and programmed launches would be required in 2002, which coincides with the initially planned launch date of the platform that would result from the replenish or transition decision. (GAO, 1993, p. 10) The shaded area on Figure 9 is what the GAO claims is a period of "excessive satellites in orbit."

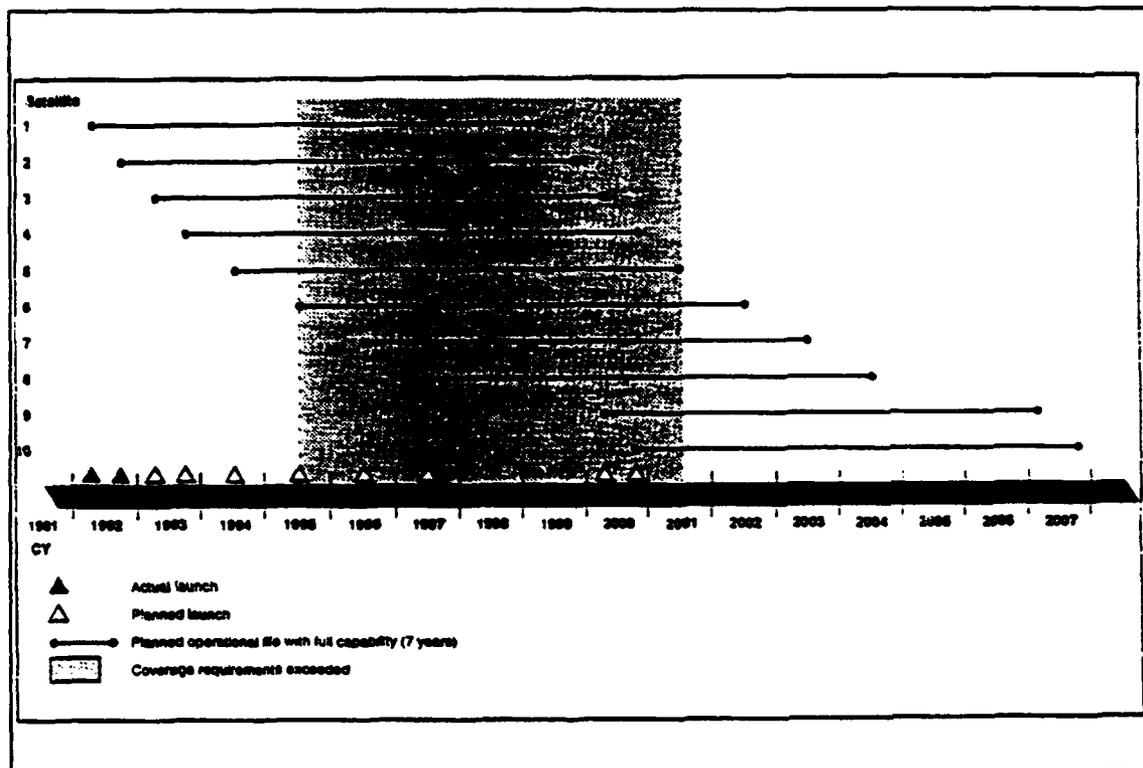


Figure 9. DoD Plans for DSCS Constellation (GAO, 1993, p. 10)

In order to avoid "excessive satellites in orbit," and allow DoD time to provide future technology enhancement (dual common bus) for future satellite systems, GAO has recommended a modified DSCS III launch schedule. This schedule, shown in Figure 10, delays launching satellite 6 until 1998. This plan not only supports DoD's requirement of

5 operational satellites at all times, but it also extends the life of the constellation from 2002 to 2005. This plan eliminates "excessive satellites in orbit" and could allow for future technologies to be developed before follow-on systems are required, since ARPA representatives estimate that they can provide a dual common bus capability by 2003. (GAO, pp. 9-11)

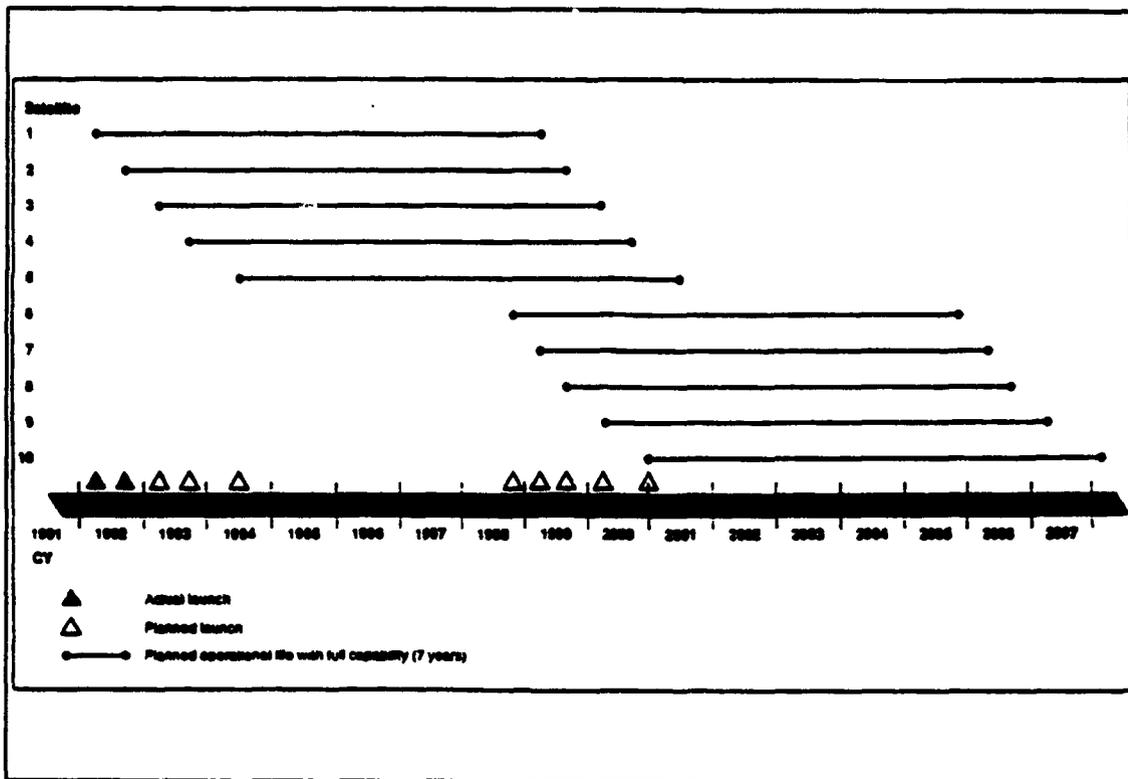


Figure 10. Revisions to DoD Plans for DSCS Constellation (GAO, 1993, p. 11)

2. Modification to Current Platform

Fiscal year 1995 money has already been approved by Congress for a modification to the communication capabilities of four of the six remaining DSCS III satellites. This is

primarily to adjust the technical capabilities of the constellation's six transponders from the current strategic configuration to a more tactical application. Of the six transponders on the DSCS III birds currently in orbit, four are configured for a strategic capability (i.e., designed to work with larger 40 and 60 foot ground terminals), and two are designed to work with tactical size terminals. This modification to the transponders was initially scheduled to be done concurrently with a programmed improvement to the Integrated Apogee Boost Subsystem (IABS), but delays in appropriations/allocation of funding has prevented this from happening. (Williams, 1994)

a. Procedural Changes In Addition to Modification

Modifications to the DSCS transponders or implementation of seven foot antennas on ships does not alleviate the power limitation problems the Navy experiences, but utilizing a standard tactical entry port (STEP) gateway significantly improves the situation. Figure 11 demonstrates the comparison of the power requirements of both the shipboard [AN/WSC-6A(V)2] and GMF [AN/TSC-93] user with and without the tactical entry port gateway. While the power requirement of the satellite transponder remains basically the same (18.4% versus 19.2%), the power requirement of the user is significantly reduced. As a result, less complicated shipboard or mobile systems are necessary.

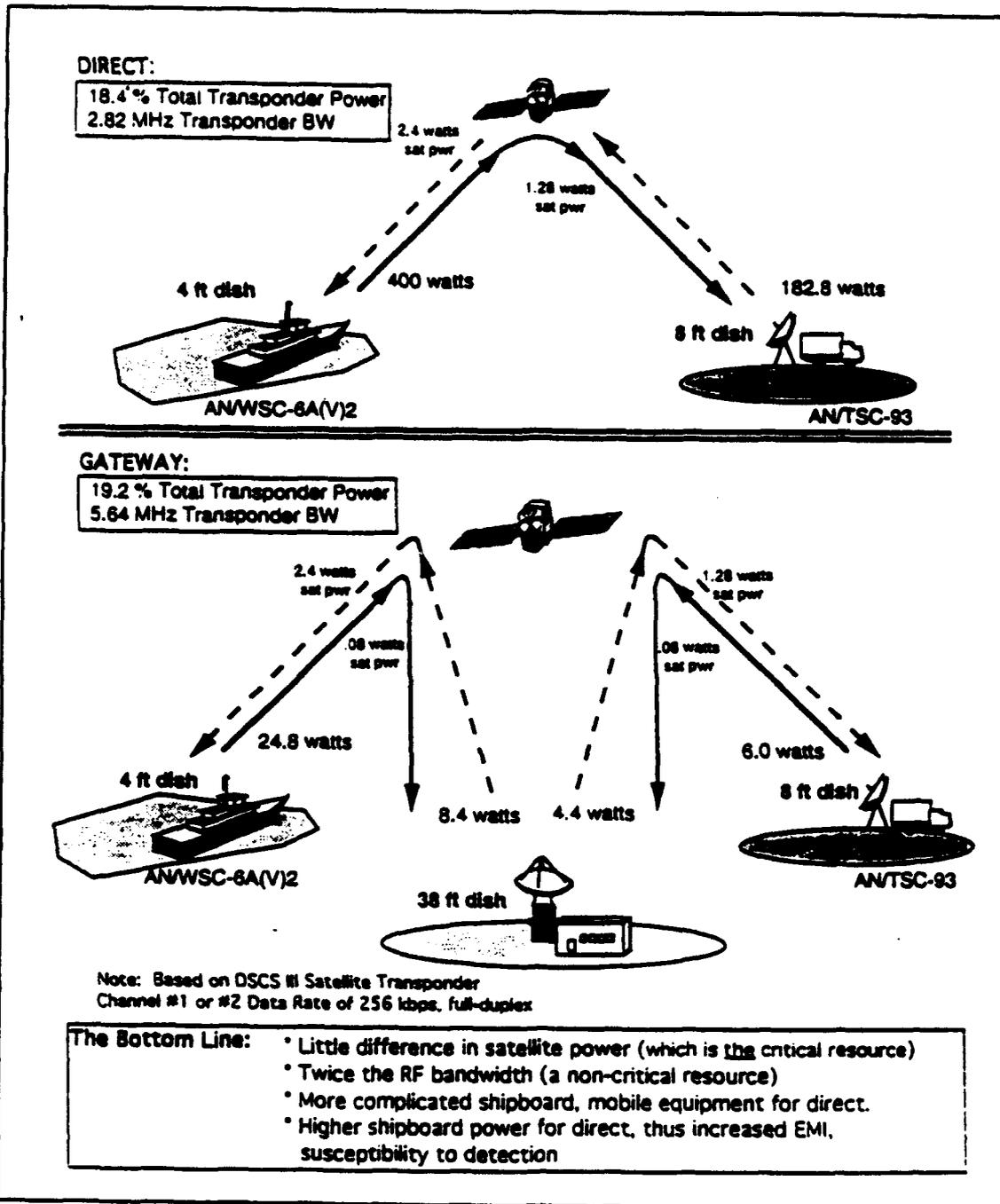


Figure 11. Tactical Entry Port Gateway vs. Direct Connectivity (SPAWAR, 1994)

b. Additional Modifications

Experience has shown DSCS II birds will last approximately twice as long as the DSCS IIIs due to the over-engineering of the solar arrays mentioned earlier. DSCS IIIs will degrade significantly after ten years due to a gradual breakdown of the solar arrays. Minority opinions within the satellite communities of DoD feel the money approved for the communication modifications would be better spent on improving the efficiency of the solar arrays and North-South, East-West station keeping thrusters. Improvements in these areas would increase the longevity of the satellite, which is a beneficial factor during times of decreased funding for new programs. (Williams, 1994)

3. Possible DSCS Follow-On Programs

The guidance recommendations from ASDC³I for future SATCOM systems have yielded three possible DSCS follow-on programs. These programs are the Direct Broadcast Satellite (DBS) system, the International Military Satellite (INMILSAT), and the Multi-Beam Multi-Mission Broadband Antenna (MMBA).

a. Direct Broadcast Satellite (DBS) System

The Fixed-Satellite Service (FSS) and Broadcast Satellite Service (BSS) were established by the International Telecommunications Union (ITU) in 1963 as distinct radio services. In 1971, specific frequency bands were allocated by

the ITU for each type of system. As a result, the FSS was improved to support all types of communications between satellites and large ground terminals, and the BSS was geared to support transmission of television signals from central terminals to moderately sized community reception terminals or small individual reception units. The later application corresponds to direct broadcast, meaning direct from satellite to the home, in contrast to distribution via cable systems or rebroadcasts from terrestrial receivers/transmitters. The first satellites to demonstrate high-power broadcast to simple community and home receivers were the Applications Technology Sensor (ATS) 6 [developed by the National Aeronautics and Space Administration {NASA}], Communications Technology Satellite (CTS) [known as Hermes in Canada], and the Japanese Broadcasting Satellite in 1974, 1976, and 1978, respectively. Versions of these systems utilized antennas as small as two feet in diameter. (Martin, 1991, p. 194)

In 1981 the Federal Communications Commission (FCC) began formulating a direct broadcast policy. Studies by the FCC concluded that such systems are in the public interest and should be allowed to develop with minimum regulation. While the FCC was making this determination, low-power and medium-power DBS systems were developing.

(1) *Low-power DBS.* Low-power DBS systems receive 4 GHz FSS downlink (D/L) signals from Canadian and U.S. satellites that are intended for distribution of network television to affiliate local broadcasting stations, and distribution of various types of television programming to cable television systems. Reception of the 4 GHz signals is actually an interception of signals intended for other class receivers, but this reception/interception was recognized by Congress as a legal action in 1984 (when limited to private use in the home). Current estimates gauge that three million homes are equipped with a low-power DBS capability using a receiver that costs as little as \$1000, and an antenna as small as six feet in diameter. (Martin, 1991, p. 194)

(2) *Medium-Power DBS.* The medium-power DBS system operates in a similar manner to the Low-Power DBS system. The medium-power DBS allows for interception of U.S. and Canadian signals being transmitted in the 12 GHz range. Since medium-power DBS is a more recent development, the number of homes with receivers is only approximately 50,000. The antenna diameters for medium-power DBS may be as small as four feet and the receiver prices as low as \$500. (Martin, 1991, p. 194)

(3) *High-Power DBS.* High-power DBS refers to reception of signals transmitted by high-power BSS satellites intended for home reception. High-power systems are designed such that receivers will cost from \$300 to \$600 and use two to

three foot antennas. The first application for a high-power DBS system was filed by the Satellite Television Corporation (STC), a subsidiary of Comsat Corporation (the U.S. signatory for INMARSAT and INTELSAT), in 1980. Numerous applications for permits to begin efforts in high-power DBS systems were submitted to the FCC for approval between 1982 and 1990, but the only DBS constellation in orbit is the Hughes DBS-I. The DBS-II is scheduled to be launched in late 1994, but it is unlikely that any additional high-power DBS satellites will be launched by other companies, due to cost estimates ranging between \$200 and \$800 million for system establishment (i.e., to get at least two satellites into orbit and in use). [Baciocco, 1994; Martin, 1991, p. 195]

(4) *Military Applications.* Military Applications of the DBS system would leverage off commercial sector technology advancements in the DBS service arena and replace the current private user in the home with joint service subscribers. The DBS system could be utilized on a "Pay-Per-View" basis, with the information being passed to the subscribing unit through the "User-Pull/Intelligent-Push" concept. Services that could possibly be made available to the user via DBS could include: "Free" or "Basic Service" consisting of Cable News Network (CNN) [intelligence to the foxhole] and a directory of available services; "Subscriber Service" (Intelligence Push) could consist of a theater

tailored information package (e.g., Intelligence Summaries or Theater Airfield Terminal Forecasts); and a "Pay-Per-View" (User-Pull) service could include targeting imagery, Tomahawk Mission Data Updates (MDUs), Tactical Environmental Support System (TESS), Streamlined Automated Logistics Transmission System (SALTS), education and training films, and Armed Forces Radio Television System (AFRTS) broadcasts. [CNO, 1994, p. 4]

Direct Broadcast Satellite systems fall under the MILSATCOM architecture described in JCS Memorandum of Policy 37 (MOP 37) [CJCS MOP 37, 1992]. Decision Opportunity Two of the MILSATCOM Architecture and Roadmap Study, scheduled for release in June 1994, should result in an acquisition decision for the DBS program. Issues associated with the current DBS system that could affect its military application are: worldwide coverage, information management and transmission frequency. The current customers using DBS are television viewers located on land, hence the DBS birds utilize shaped, focused beams pointing only to land masses, and there is no maritime coverage (this is a particular concern to the Navy). Information management procedures/doctrine would have to be developed to prevent "information overload" that could be caused by "Intelligent-Push." Additionally, the decision on whether the transmission frequency of DBS should be in the commercial or military band needs to be made. (Baciocco, 1994)

b. International Military Satellite (INTMILSAT)

A memorandum of understanding between the U.S., United Kingdom (U.K.), and France was signed in 1992 to investigate the feasibility of developing an International Military Satellite (INTMILSAT) communications capability. This effort began in 1991, when a high ranking official of France wrote a letter to Deputy Secretary of Defense Atwood suggesting that the United States and France explore development of a bilateral satellite communication system. Mr. Atwood then invited the United Kingdom to join in on this effort, since all three countries would need some sort of SATCOM replacement system in operation by 2005. It was determined that all three countries would conduct independent two year studies to more closely review the proposed effort, keeping in mind the unique requirements of each country and the combined requirements of all three countries.² (Cook, May 1994)

In order for France and the U.K. to conduct the study, the U.S. provided them with a sanitized description of the Core and General Purpose Functional and Performance Requirements for DoD, International and Commercial-Based Satellite Communication Service Networks. France and the U.K. provided equivalent documents to the U.S. for study to

² The U.S. has a separate MILSATCOM capability for UHF, SHF and EHF, while France and the U.K. only have one system, EHF.

determine if the project is both operationally and cost effective from two perspectives: how the INTMILSAT program will benefit each individual country, and how it will benefit a combination of all three countries. The companies conducting the study for the U.S. are the Loral Corporation, Hughes, TRW, and Martin Marietta. The actual funding for the contractors' investigation of INTMILSAT expired in April 1994, but the report the contractors will submit containing the findings of the study is not due until December 1994. (Williams, 1994; Cook, 1994)

The next step in the development of the INTMILSAT program will be an independent governmental study of the program, which will probably be done by DISA MSO and the Advanced Programs Division of the MILSATCOM Program Office (MCX). This study will be conducted from January to April of 1995. This study will make a recommendation to the ASDC3I on whether or not to sign a letter of intent with France and the U.K. on INTMILSAT. Signing a letter of intent would basically begin the Concept Exploration phase of the defense acquisition process. Additionally, a Program Manager would be selected and a INTMILSAT Program Office would be established. The remaining actions would be similar to those of a program preparing for a Defense Acquisition Board One (DAB-1) review. (Cook, 1994)

**c. Multi-Beam Multi-Mission Broadband Antenna
(MMBA)**

The "Advanced Technology Development Planning Guidance" letter, from the Office of the Chief of Naval Operations (CNO), called for research and development to begin on a program that could alleviate the antenna proliferation problem experienced on ships, while enabling simultaneous communication of data from multiple sources, both fixed and mobile. (CNO Letter, 28 May 1992) The ensuing research and development effort was named the Multi-Beam Multi-Mission Broadband Antenna (MMBA) program.

As demonstrated in Operation Desert Storm, data is essential to support mission planning and situation assessment. Joint Task Force commands located on ships currently require several antennas to acquire data from reconnaissance, surveillance, planning and intelligence systems to accomplish signal intelligence assessment, disseminate indications and warning, evaluate enemy Order of Battle, perform Battle Damage Assessment, and develop coordinated strike plans. (MMBA OPNAV N-6, 1994)

Current shipboard communication links (DSCS, FLTSAT, and COMSAT) use separate, dedicated parabolic dish antennas that can support only a single, full duplex link at any time. It is possible to upgrade parabolic dish antennas to operate in more than one frequency spectrum, but parabolic antennas cannot be modified to track, acquire, and communicate simultaneously with multiple platforms. Continuing to install separate antenna systems is not a practical way to provide additional communications capabilities, because of the space,

weight, moment and electromagnetic interference constraints aboard Navy ships. (MMBA OPNAV N-6, 1994)

The MMBA is currently under study by the Applied Physics Laboratories, based on a Mission Needs Statement generated by Navy Space Systems Division (OPNAV N-63) of the CNO's Space and Electronic Warfare Directorate. The proposed MMBA system would utilize a phased array communications system. Applications of phased array radar technology would make communications harder to jam, intercept, and exploit. Additionally, satellite connectivity could be maintained on CV/CVNs when the ship suddenly "turns into the wind" to conduct flight operations. The MMBA would operate on the same ships and in the same environment as existing systems, and since it would be a replacement for existing assets, no additional maintenance personnel are expected.

V. NETWORK SECURITY

A. INTRODUCTION

The current Defense Satellite Communication System (DSCS) service request process, as detailed in CJCS Memorandum of Policy 37 (MOP 37), begins with the prospective CINC, Service, or Defense Agency user's justification for satellite connectivity. Figure 12 depicts an overview of the MILSATCOM service request flow. Routine requests for DSCS service are sent to the Joint MILSATCOM Panel Administrator (JMPA), who then coordinates the results of a technical assessment that is conducted by the DSCS System Manager. The technical assessment decides if or how a requirement can be satisfied and offers alternative connectivity means when DSCS service is not available. After reviewing the technical assessment, the JMPA makes a recommendation for approval or disapproval to the CJCS, who has the final authority in determining DSCS access. The JMPA then notifies the user of the panel results and enters all approved DSCS requirements into the Integrated SATCOM Data Base (ISDB). Urgent requests for DSCS service are submitted directly to the Joint Staff/Joint Communications Satellite Center (JCSC). [DISA MSO DSCS Program Plan, 1993, p. 2-23]

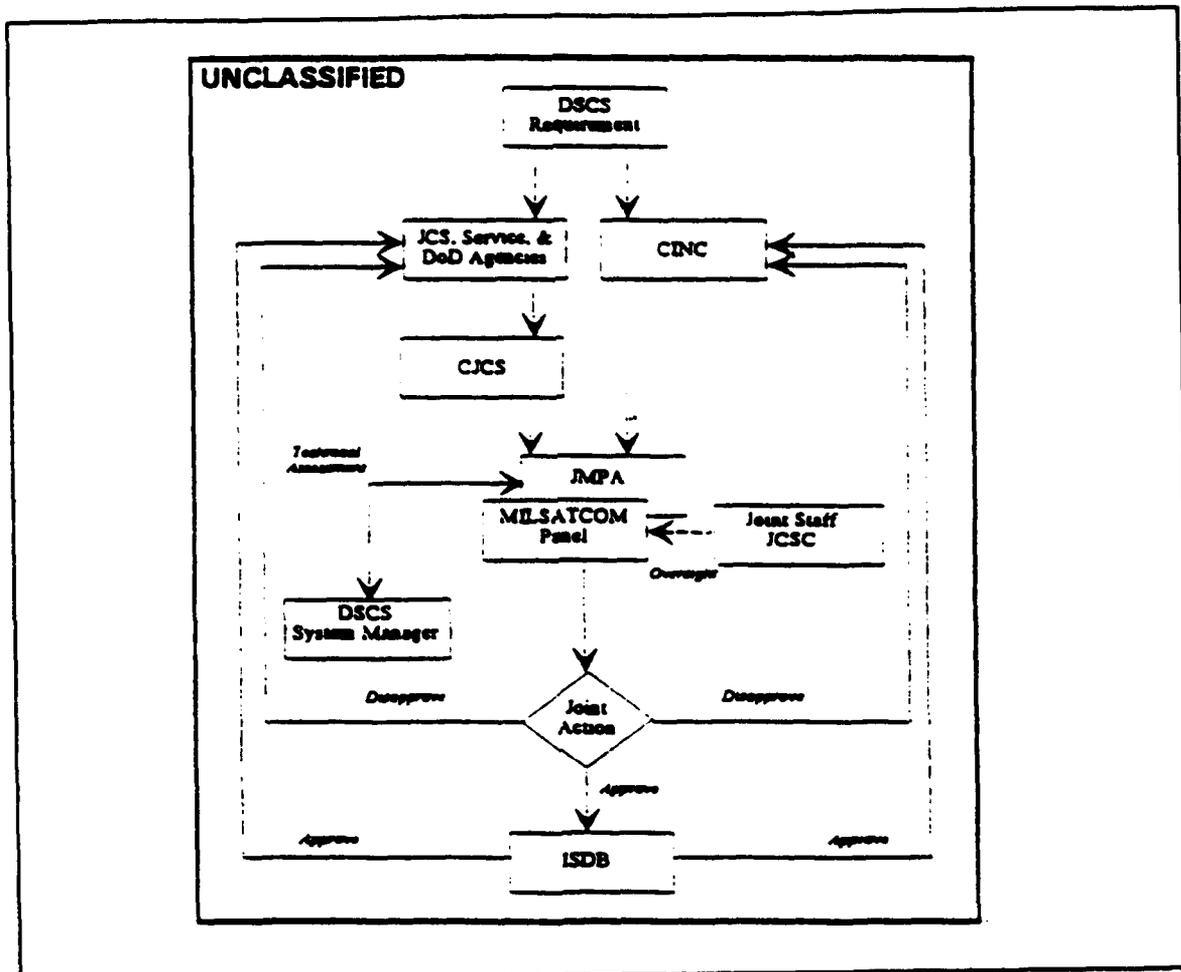


Figure 12. DSCS Requirements Processing (DISA MSO Program Plan, 1993, p. 2-23)

Memorandum of Policy 37 (MOP 37) defines the ISDB as a data base that will indicate the degree to which requirements can be satisfied with current or programmed systems. (CJCS MOP 37, 1992, p. 5) The accuracy of the communications requirements that are maintained in the database are somewhat questionable, as it sometimes takes up to two years for requirements to appear in the ISDB. (Clair, 05 April 1994).

Currently, if a MILSATCOM user puts in a request for DSCS access from point A to point B, there is no verification process to see if the two points requesting MILSATCOM connectivity are capable of conducting communications over existing terrestrial land lines with end-to-end encryption. The existing process grants access to DSCS after it has been determined that the request is valid via the procedure shown in Figure 12. (Guiar, 1994) The inability to offload long haul fixed-site to fixed-site DSCS users to terrestrial fiber optic cable has created a significant overloading of the DSCS system. Not only has it overloaded the system, but the bandwidth that can be provided to the fixed-site user on terrestrial fiber optic cables far exceeds anything that currently exists on SATCOM. The only additional piece of equipment that would be necessary to conduct secure communications over established land lines is an National Security Agency (NSA) approved encryption device. One of the approved devices that is capable of handling this requirement is the Network Encryption System (NES).

B. APPLICATION OF THE NETWORK ENCRYPTION SYSTEM (NES)

The increased proliferation and sophistication of networked computer systems coupled with the threat posed by computer hackers and the ability of foreign governments to access networked data have lead to a need for a truly advanced data protection capability. A similar requirement previously

existed in voice communications, but has been completed and implemented in the form of the STU-III Secure Telephone. The original manufacturer of the STU-III, Motorola Inc., saw the need for an advanced flexible network security device for data protection. In coordination with the United States Government under the National Security Agency's (NSA) Commercial Communications Security (COMSEC) Endorsement Program (CCEP), Motorola developed the Network Encryption System (NES) in 1989. The NES is endorsed by NSA for "use by U.S. Government departments and agencies and their contractors to secure U.S. Government information classified TOP SECRET and below." (NSA, 1991)

C. SYSTEM COMPONENTS

Data confidentiality, data integrity, peer identification/authentication and mandatory/discretionary access control services are provided by an internal design structure based on a security kernel with an open architecture. According to the International Organization for Standardization and the International Electrotechnical Committee (ISO/IEC), an open system is a system that complies with the requirements of a given set of universally accepted standards for communication and interacting with other open systems. (Egge, 1993, p. 24) The open architecture of the NES allows the system to support a variety of commercially available Versa Module Eurocard (VME) Input/Output (I/O)

processor boards and loadable application software. The customer determines the specifications of their NES, and Motorola then factory-configures the system with the appropriate I/O boards. The NES is then delivered to the user ready for the installation of software dependent on the customer's particular needs. (Motorola Performance Specifications) These features offered by the open architecture ensure that the NES is not a system that will be obsolete the day it is delivered. The security device is capable of being upgraded to incorporate advancement in technology in both hardware and software, in a reasonable timeframe. (Motorola White Paper, 1993)

The NES Security Platform is software configured using a configuration disc created at the NES Product Server (NPS). The configuration disc contains not only the application software, but the Identity-Based Access Control (IBAC) tables, static routing tables, as well as other configuration information. The IBAC tables identify hosts on the local and remote RED (clear/unencrypted) Local Area Networks (LANs) that are authorized communications permission. The Network Administrator uses the NPS computer, an IBM compatible PC running a set of customized software functions, to establish an NES domain. Once the domain has been created, configuration discs are built for each NES in the domain. The configuration disc built by the NPS is designed to support 32 RED side host addresses, 4000 Remote host addresses and 1000

NES devices. (Wade, 02 August 1993, p. 1) The authorization provided by the IBAC tables is called Discretionary Access Control (DAC). Once these hosts have been properly verified on the IBAC tables, the host NES will establish a connection with the remote NES and a "handshake" occurs. This "handshake" provides Mandatory Access Control (MAC) authentication by both NES devices and creates a Traffic Encryption Key (TEK). The TEK formation is a four phase "FIREFLY" exchange between a pair of NES units. The security kernel produces a cryptographic checksum which is written to the disk and binds the contents of the disk to the NES Platform. (Giest, 1993) The MACs are provided by NSA generated key material. The TEK is used to encrypt/decrypt datagrams sent from one RED LAN to another. Without a verified DAC check, communication between hosts is not allowed, and the datagrams assigned to the attempted communication are discarded. (Wade, 02 August 1993, p. 1)

1. Keying Mechanism/External Components

The keying mechanism for the NES Security Platform is the KSD-64A, which is supplied by the NSA Electronic Key Management System (EKMS). The KSD-64A, which contains a non-forgable certificate and NES identity and security classification, is loaded at the front panel of the NES. This key may be either an Operational Key, or a Seed Key, which has the ability to receive Operational Keys electronically.

(Motorola Performance Specifications, 1993) This ability to provide automatic electronic key management meets the NSA Secure Data Network System (SDNS) standards. This set of standards is modeled after the STU-III secure telephone, but is designed for data transmission instead of voice. This feature of the NES lowers costs and eliminates the manpower required to run a key management system. The importance of this is demonstrated by the ease and speed with which keys are automatically created, their crypto periods measured and finally the traffic keys are destroyed after access rights to the network connection have been "approved." This is in contrast to the burden encountered by CMS (Classified Material System) custodians while following the strict procedures and doctrine required to maintain communications security. In addition, the credentials used by the NES are distributed and updated in a manner identical to the STU-III, therefore there is no new training requirement for COMSEC personnel to learn in order to implement the system. (Motorola White Paper, 1993)

The remaining components contained in the front panel of the NES unit are: key port, 16-character display, floppy disc, power switch fuse battery compartment, and LED status indicator. These components are shown in Figure 13. (Motorola Performance Specifications, 1993)

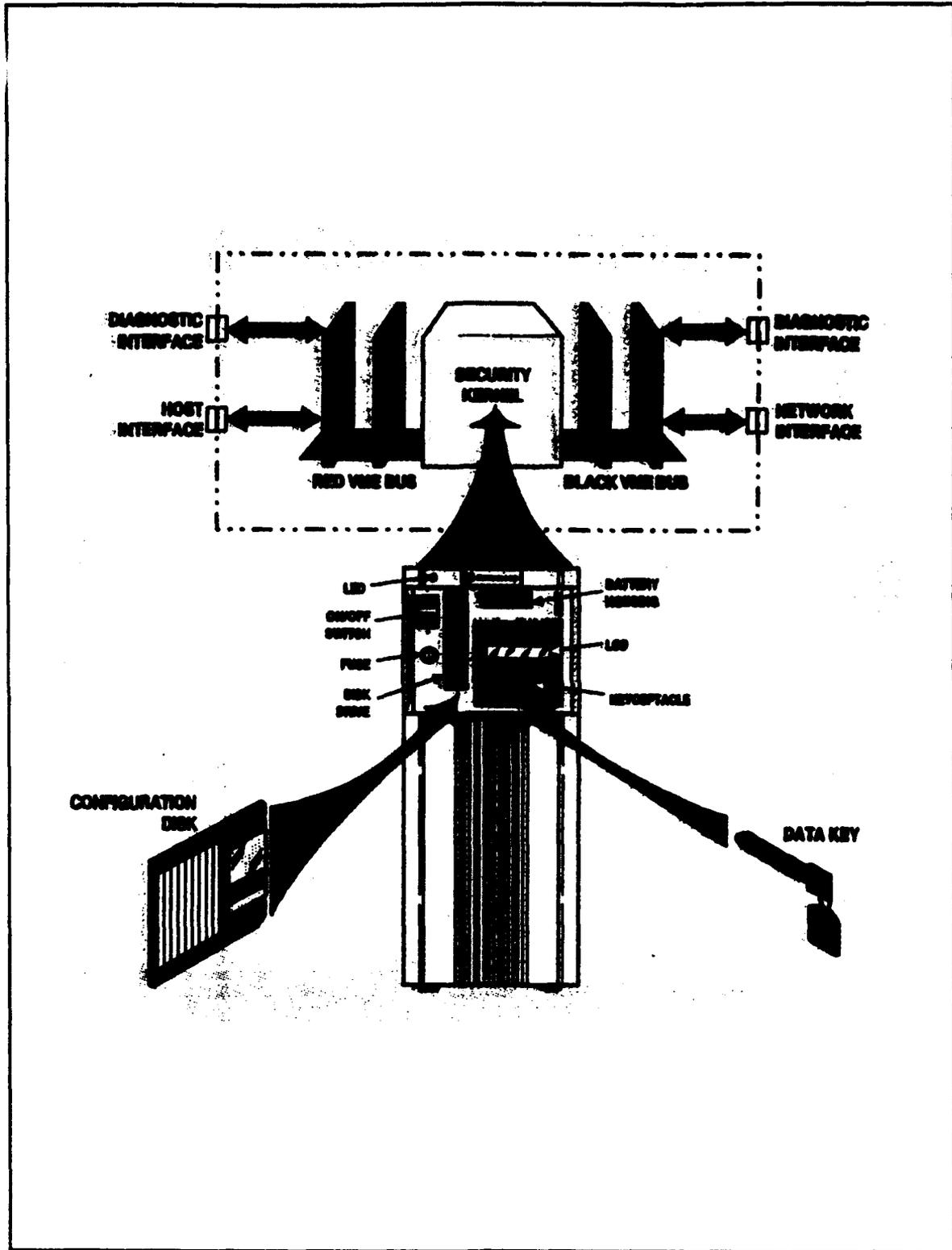


Figure 13. NES External Components

2. Internal Components

The internal components include: Security Kernel, RED (Clear/Unencrypted) and BLACK (Secure/Encrypted) I/O processor boards, diagnostic and communications interfaces, floppy disk drive, RED and BLACK power supplies and the security panel. (Motorola Performance Specifications, 1993) The security kernel contains the keying algorithms and COMSEC security mechanisms endorsed by the NSA, and it provides a separate RED and BLACK VME bus interface to the RED and BLACK I/O processor boards. The RED and BLACK I/O processor boards run the application software loaded from the floppy disc during the start-up process. The floppy disc not only loads the application software, but also the IBAC tables, static routing tables and other configuration data. (Motorola Performance Specifications, 1993)

3. Datagram Flow

The only devices (NES units) that can communicate are those which appear in the IBAC tables. There is a strict process that must be completed for a datagram to flow from one NES to another. In order to exchange data, the NESs must have the same address pairs in their address tables and be keyed at the same security level. Figure 14 demonstrates the datagram flow that occurs between two NESs.

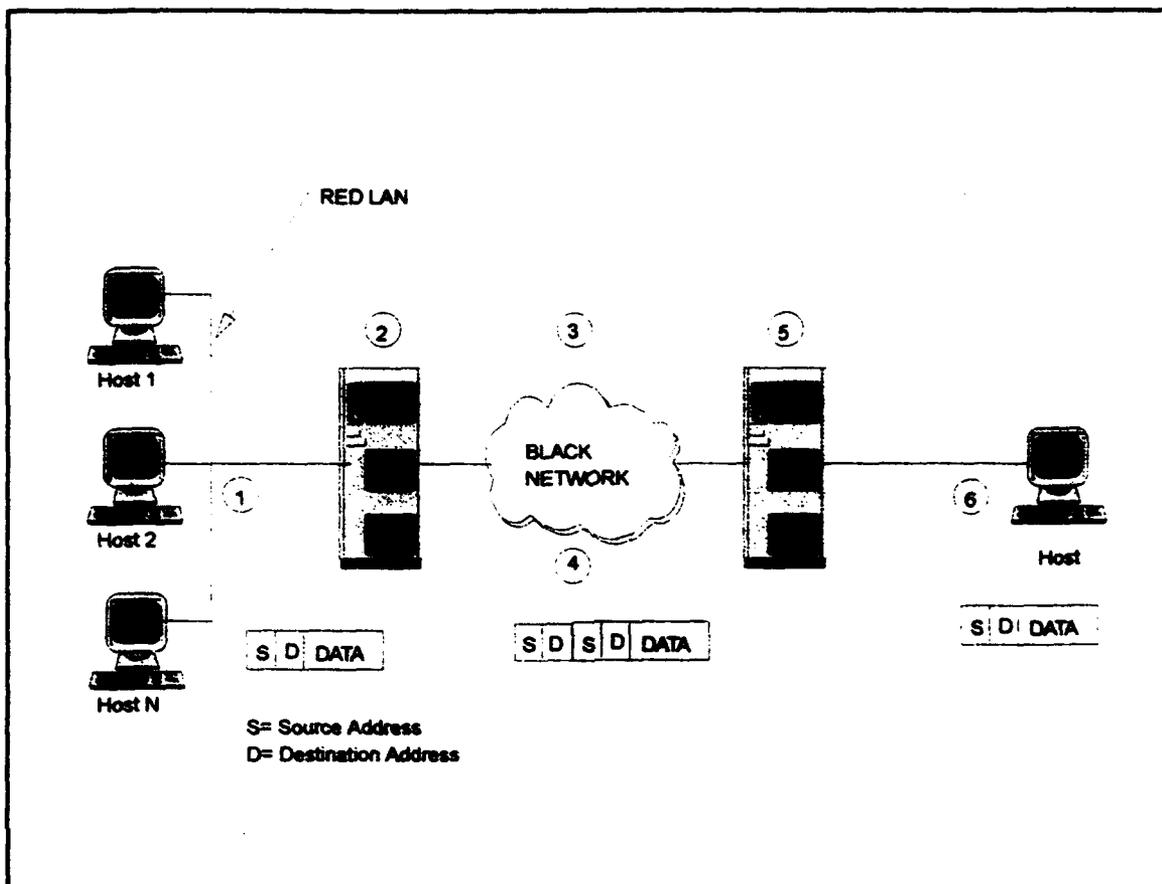


Figure 14. Datagram Flow

The outgoing datagram in Figure 14 arrives at the NES (1) and a DAC check is conducted by the host security platform to ensure the destination NES is a valid member of the network (2). If the check is valid, the four-phase FIREFLY exchange and key establishment occur (3). Data packets are then encrypted and "encapsulated" within a new data packet with the source and destination addresses of the NESs that are communicating (4). The addressing information travels in the clear so it can be routed across a variety of networks. The

destination NES decrypts the datagram and checks for integrity (5) and then delivers the datagram to the destination host (6). (Motorola Performance Specifications, 1993)

D. THROUGHPUT ANALYSIS

Throughput is an expression of channel efficiency calculated by determining the amount of useful data that is put through a data communication link. The "useful" data is data that is directly useful to the computer or data terminal equipment (DTE), the remaining data is "unuseful" data, which may take the form of overhead bits. On a specific circuit, throughput varies with the following: raw data rate, error rate and the type of error encountered (whether burst or random), type of error detection and correction system used, message handling time, and the block or frame length. (Freeman, 1991, p. 773)

In throughput tests conducted by Motorola to determine the maximum amount of packets per second the NES server was able to process with no packet loss, throughput (measured in bits per second) was defined as the maximum steady state rate at which the NES could process 802.3/Ethernet data frames of a given size. Packet throughput (measured in packets per second) can then be calculated by dividing the data throughput values by the given 802.3/Ethernet data frame size. (Wade, 19 August 1993, p. 3)

1. Throughput Test Procedures

Packets used for both the throughput and latency tests were generated by a LANalyzer, and all test results were collected after the NES Security Platform had performed the "FIREFLY handshake" and a TEK had been created and installed. The packets generated ranged in size from 0 to 1400 bytes. Table I shows the packet size on both the RED and Black networks. The value indicated in the Data Field column is the actual data area of the Internet Protocol (IP) datagram. The RED Packet Size column represents the actual IP datagram (data + header), and the Black Packet Size is the encrypted RED Packet with the Protected Security Protocol header plus the clear header and the IP header. (Wade, 19 August 1993, pp. 4-9)

Table I. RED AND BLACK DATA PACKET SIZE IN BYTES

| Data Field Values | RED Packet Size | BLACK Packet Size |
|-------------------|-----------------|-------------------|
| 0 | 60 | 108 |
| 64 | 98 | 146 |
| 128 | 162 | 210 |
| 256 | 290 | 338 |
| 384 | 418 | 466 |
| 512 | 546 | 594 |
| 1024 | 1058 | 1106 |
| 1400 | 1434 | 1482 |

Figure 15 shows the throughput test configuration. The "Sniffer" was used to determine the quality of the packets being sent over the network (i.e., to check if packets had become fragmented or not during transmission). To do this, 30,000 packets of a particular size were generated by the LANalyzer with a specific interframe gap rate to the input of the RED host NES.

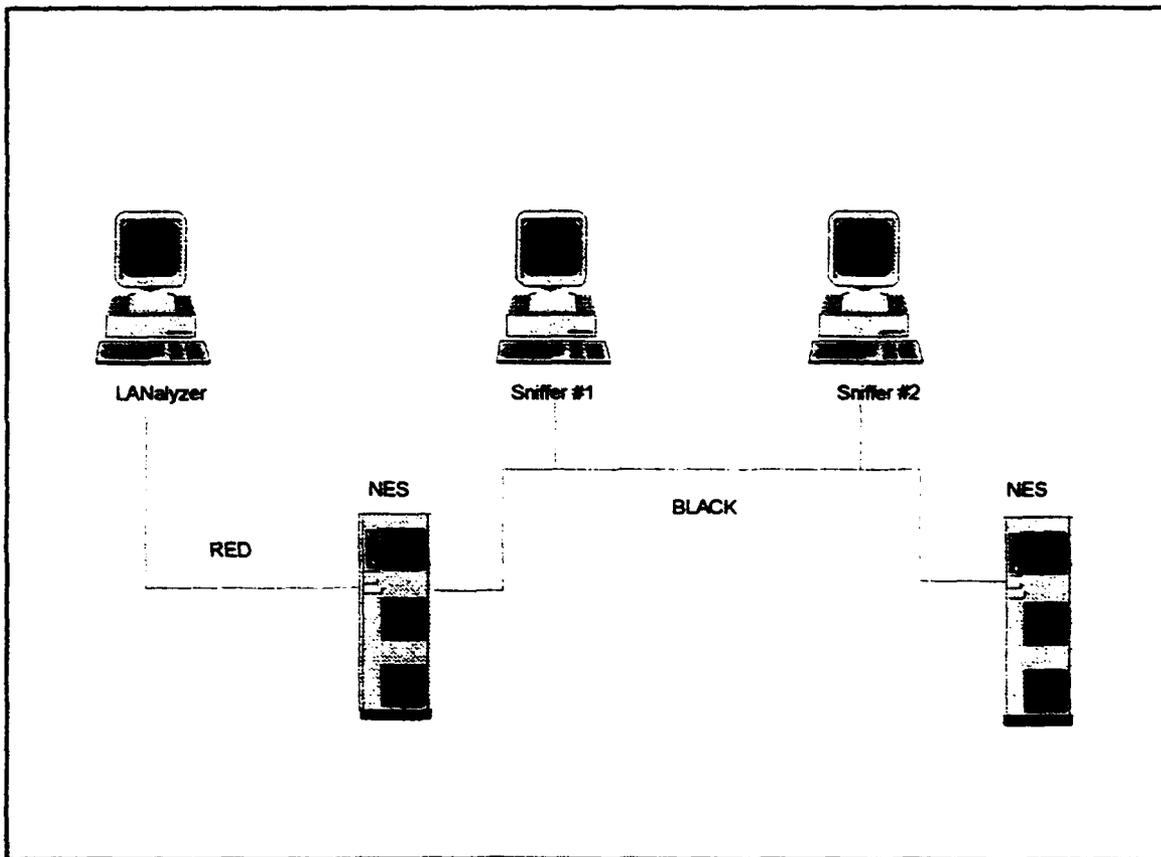


Figure 15. Throughput Configuration

The packets were encrypted by the NES Security Server, then the BLACK side packets were captured by a "Sniffer". To establish a constant load, the RED side packet count was compared to the BLACK side count. If the counts were equal, the interframe gap was reduced until they were no longer equivalent. The last value where no packets were lost due to packet discarding by the NES Security Server was then set as the interframe gap. The second "Sniffer" in the configuration was used to capture packets on the BLACK side beginning around the 20,000 packet mark. The number obtained by "Sniffer #2" was then compared to "Sniffer #1". The test results were based on the number of packets captured in the buffer during a one second interval. These packets were counted and rounded down to the nearest whole packet. The count results recorded were the throughput rate and are shown in Figure 16 (Throughput in Packets per Second) and Figure 17 (Throughput in Bits per Second). (Wade, 19 August 1993, pp. 4-9)

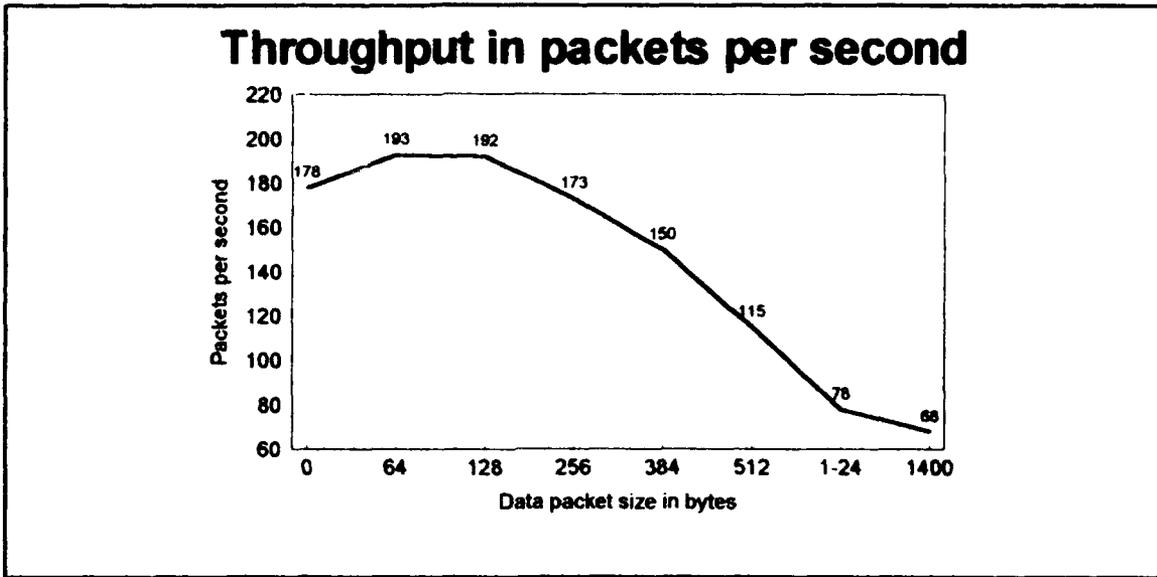


Figure 16. Throughput in Packets per Second (Wade, 1993, p. 7)

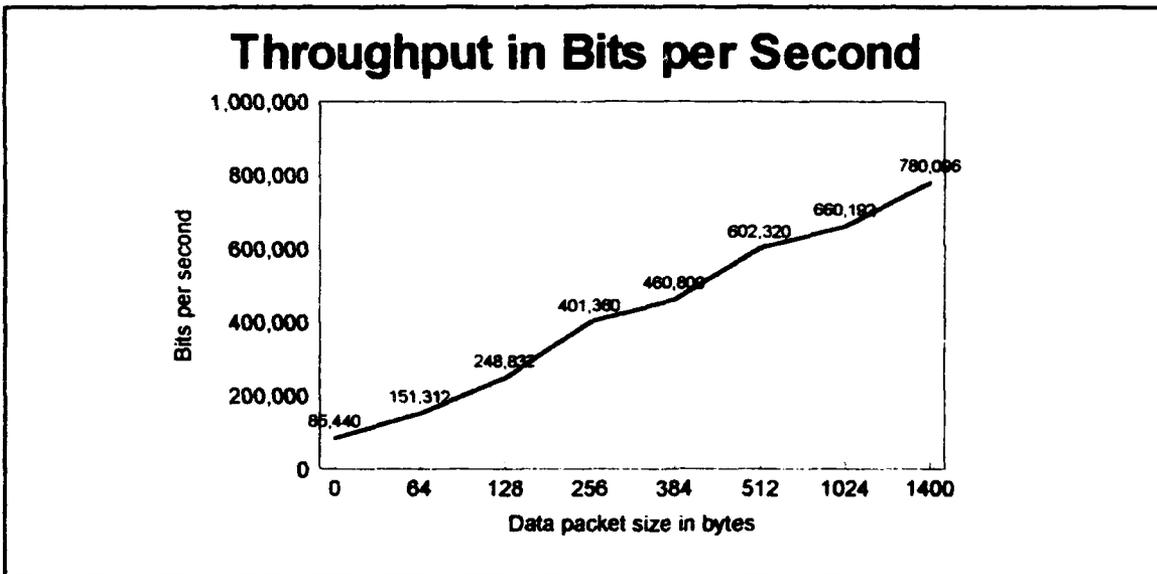


Figure 17. Throughput in Bits per Second (Wade, 1993, p. 7)

Throughput was computed as follows: Transfer Rate of Information Bits (TRIB) = Throughput. The TRIB is the number of information bits that are accepted on receive end divided by the amount of time required for the information to be accepted. (Giest, November 1993) Given data packet size in bytes and throughput in packets per second from Figure 16, the times required for the packets of various sizes to be accepted were calculated and are enclosed in Appendix F.

E. LATENCY ANALYSIS

The objective of the latency test was to determine the processing delay through the NES server. This test was also conducted with packets of varying sizes, with the outcome measured in milliseconds.

1. Latency Test Procedures

The test configuration of the NES Latency test is shown in Figure 18. The normal procedure to determine latency would be to timestamp the inbound and outbound packets, then taking the difference between the two to be the latency. This procedure is what is used when calculating latency on unencrypted or clear links. Since in the NES latency test all network devices were on the same physical network, the inbound (plain text) and outbound (encrypted) packets could be captured by a "Sniffer".

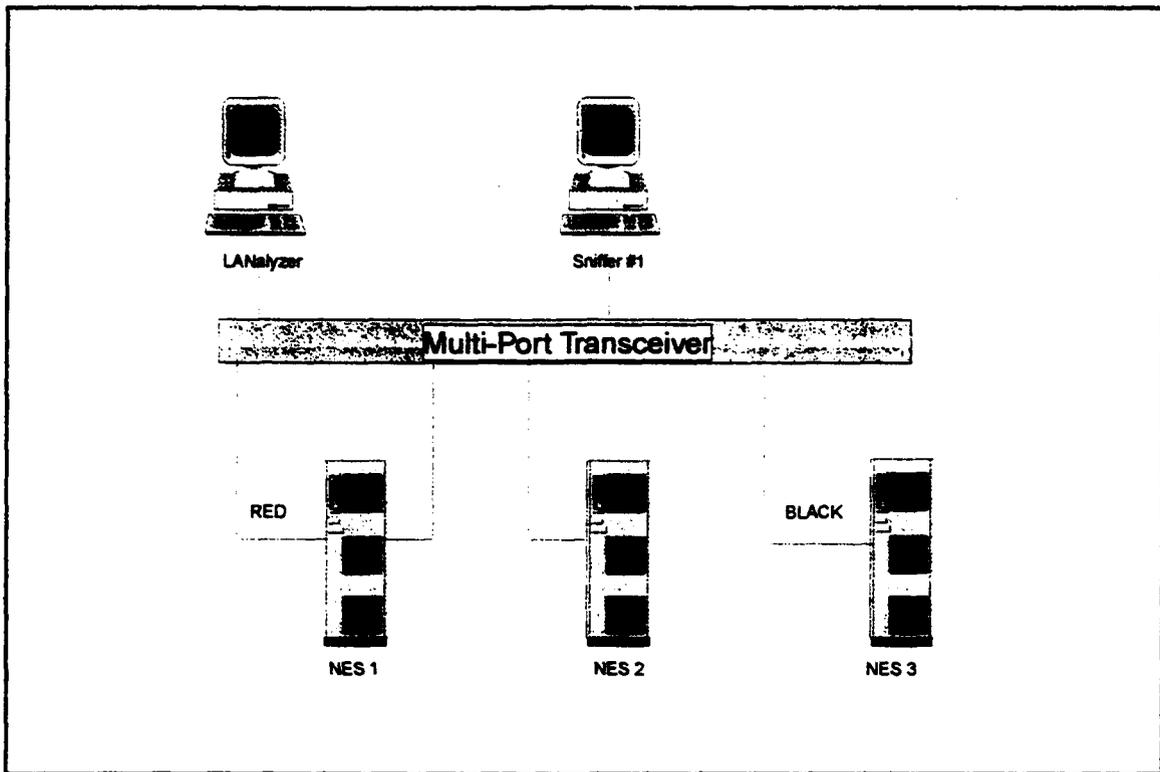


Figure 18. Latency Configuration (Wade, 1993, p.6)

The LANalyzer sent a series of 125 packets from NES 1 to NES 2 to place a constant load on the box. This was followed by 1 packet sent between NES 1 and NES 3. This packet was captured on both the RED and BLACK side by the "Sniffer" and the latency was the difference between the capture timestamp. (Wade, 19 August 1993, p. 5) The measured latency values for the varying packet sizes are attached in Figure 19.

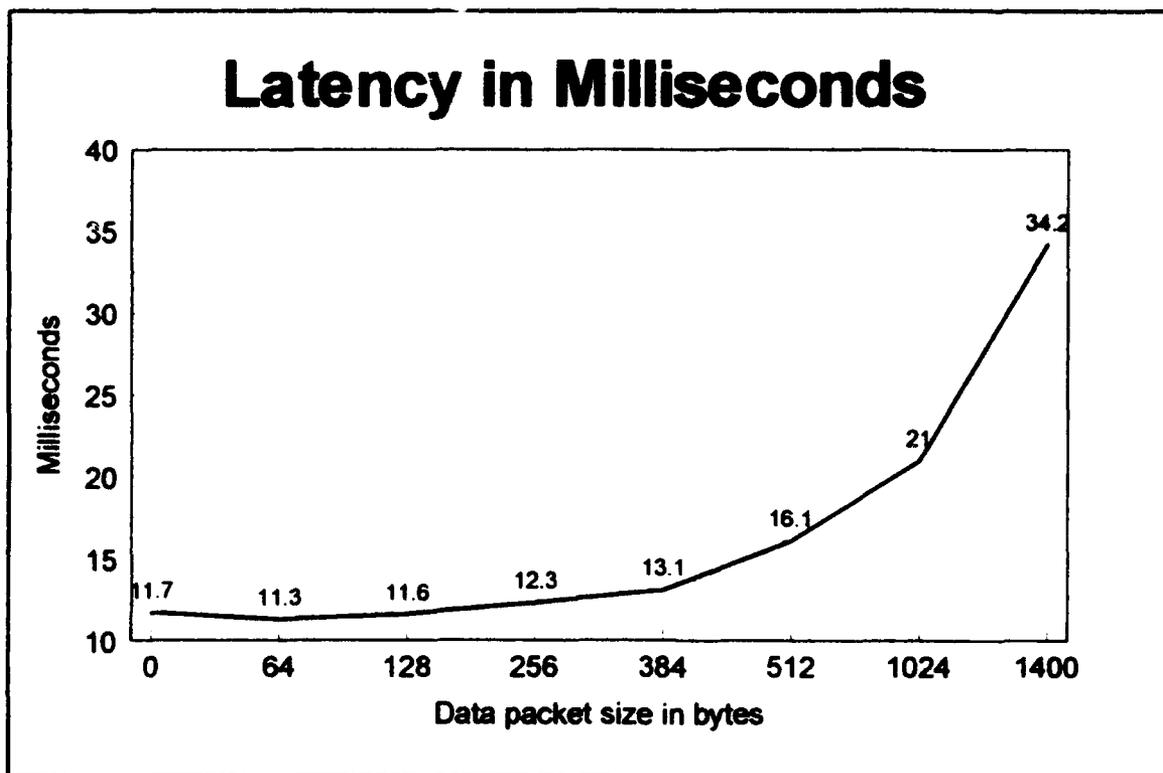


Figure 19. Latency in Milliseconds (Wade, 1993, p. 8)

F. LIMITATIONS/SOLUTIONS

As previously mentioned, the Network Administrator uses the NPS computer to establish an NES domain. After the domain is created, configuration discs are built for each NES in the domain. Currently the NES configuration disc is built to support 32 RED side hosts, 4000 Remote host addresses and 1000 NES devices. (Wade, 02 August 1993, p. 1) It has been found that 32 RED side host addresses is not sufficient in all NES applications. Three methods have been identified to solve the 32 host limitation, however Motorola has certain misgivings for each. The three methods to solve the limitation are: (1)

Increase the IBAC table for local hosts to 64 addresses, (2) Support IP bridging using RED side routers and having no requirement for DAC checks on discrete hosts addresses, and (3) Use address masking to provide a method of performing the DAC checks on a range of addresses. (Wade, 02 August 1993, pp. 1-4)

1. Increasing IBAC Table to 64 Hosts

Motorola has determined that increasing the IBAC tables from 32 to 64 hosts is a very easy problem to fix, however they see it only as an interim step. Exactly what the effects of supporting 64 hosts on the RED side will have on performance is unknown.

2. IP Bridging

The use of IP routers on the RED side of the NES would allow the RED network to be more dynamic because DAC checks would be performed only on the local routers Ethernet address and the distant router or host Ethernet address. The RED network is more dynamic in that response to addition/deletion would be done on a local level and decrease the workload of the Network Administrator.

The drawbacks to this are that network security and performance may suffer as a result. Since there are no DAC checks performed on a host's network address, any host attached to the networks serviced by the router may have access to the security services provided by the NES. The use

of IP bridging and RED routers could possibly increase the number of RED hosts, thereby significantly increasing the traffic on the RED side and decreased performance could result.

3. Address Masking

Address masking could provide the Network Administrator the ability to configure the NES to perform DAC checks on a range of addresses and/or a set of discrete address entries (64). This application would pose no threat to security; however, as the number of hosts increases so does the traffic load on the RED LAN, and degraded performance could result. All in all, degraded performance is the result with additional traffic load for all three options.

G. APPLICATIONS OF THE NES

The NES has been successfully demonstrated its ability to provide E³ (End-to-End Encryption) in a tactical strategic environment (both land-based and ship-to-shore) over terrestrial and satellite-based networks. The NES successfully demonstrated its use in providing secure packet encryption from shore-based LANs to ship-based LANs through SHF gateways during the Secure Tactical Data Network-4 (STDN) demonstration conducted in September of 1993. It also demonstrated that the NES can provide connectivity and security from tactical sites to fixed sites through existing networks such as the Defense Simulation Internet (DSI), and

also on future networks such as AT&T's bandwidth on demand satellite network. (DISA Volume 2, October 1993, p. 48) Additional DoD organizations using the NES are: the Army's Reserve Component Automation System (RCA) is in the deployment phase across the country; the Air Force's Headquarters System Replacement Program (HSRP) is being installed in the Pentagon by the 7th Communications Group; and the Office Automation & Secure Information System (OASIS) is being installed in the Pentagon for the Office of the Secretary of Defense (OSD). (Motorola White Paper, 1993)

B. CONCLUSIONS

In summary, the Network Encryption System appears to be the secure network system solution for the future. Motorola has taken its lessons learned in the secure voice communications business and applied them to the secure data transmission. As a result, Motorola has produced a product with excellent flexibility, as demonstrated by the NES's Open Architecture, and a long application expectancy. Additionally, the lower life cycle costs of the NES due to modernized EKMS, adaptability to recognized standards and interservice and worldwide interoperability make the NES a very attractive security device in these days of increasing operational requirements and decreasing dollars for defense.

CHAPTER VI. UTILIZATION OF COMMERCIAL SATELLITES

There is currently an on-going argument between Congress, military operators/communicators, and defense contractors as to whether the expense of a Defense Satellite Communications System (DSCS) follow-on program is necessary, economically feasible, and/or worth it. Supporters of the commercial satellite (COMSAT) option feel commercial satellite services can provide for the military's SHF needs. Military supporters point to the need for survivability and jam-resistance as their main argument in support of the DSCS follow-on constellation program. The middle-ground attitude is that commercial satellite services should be utilized for "surge" capacity, while at the same time there is always a need for some protected SHF capability.

Congressional direction (beginning in 1989) mandated that the Department of Defense (DoD) conduct a study of the Integrated SATCOM Database (ISDB)³ and develop a comprehensive plan, defining all SATCOM requirements and potential solutions to meet the requirements. (GAO, 1993, pp. 1-5) This direction was the impetus for the Commercial Satellite Communications Initiative (CSCI).

³ The ISDB was preceded by the User Requirements Database (URDB), which was established in the mid-1970s to document communication frequency requirements. The name was changed to ISDB approximately three years ago.

A. COMMERCIAL SATELLITE COMMUNICATIONS INITIATIVE (CSCI)

The CSCI was a study completed in January 1994 by defense contractors to determine COMSAT systems capabilities. The contractors were issued requirements documented in the Integrated SATCOM Database (ISDB) and asked to provide a detailed analysis of their SATCOM systems abilities to fulfill the General Purpose and Core Requirements (as defined in Chapter I) of the DoD user. It was known at the onset of the study that due to commercial satellite systems inability to satisfy Hard Core Requirements (as defined in Chapter I) MILSTAR was currently the only means available for communications requiring that level of protection. The findings of the CSCI were that commercial satellite systems could satisfy all General Purpose requirements, but could only handle Core requirements that did not require an anti-jam (A/J) capability. (Giar, 1994)

B. AEROSPACE/MSO STUDY

The MILSATCOM Systems Office (MSO) of DISA conducted an additional study from August to December 1993, known as the Aerospace/MSO Study, to determine the capability of current and programmed DoD satellite assets to handle the General Purpose, Core and Hard Core requirements of DoD users. The baseline configuration of satellite systems available used for study purposes was as follows: four MILSTAR II satellites,

five DSCS III-B satellites, eight UFO satellites (six with EHF) and terminal equipment as planned for all systems. The study was conducted on two independent scenarios set in 2003 where wartime SATCOM throughput requirements are 1061 Mbps.⁴ The first scenario was a peacetime environment, and the second was that of a combined major regional conflict (CMRC) in Southwest Asia and Korea. Additional assumptions of the study were: UHF communications requiring protection were migrated to EHF, and appropriate fixed-to-fixed site requirements were candidates for unprotected/protected optical fiber paths. (DISA MSO, 1994, pp. 2-5)

Findings of the Aerospace/MSO study were that DSCS III and MILSTAR II can't satisfy the remaining protected requirements as documented on the ISDB, even after migrating 50% of candidate requirements to commercial fiber optic lines. DISA MSO also stated that upgrades to the DSCS satellite system are needed to increase protected service for SHF communications. Figures 20 and 21 show a graphical representation of the inability of the UHF, SHF and EHF systems depicted in the study to meet user requirements. Additionally, the graphs show the underutilization of commercial satellite systems in both peacetime and CMRC scenarios.

⁴ 1061 Mbps was determined to be the future throughput requirement after off-loading 50% of current DSCS users (who are fixed site-to-fixed site users) to terrestrial optical fiber, and then using the ISDB as a prediction tool.

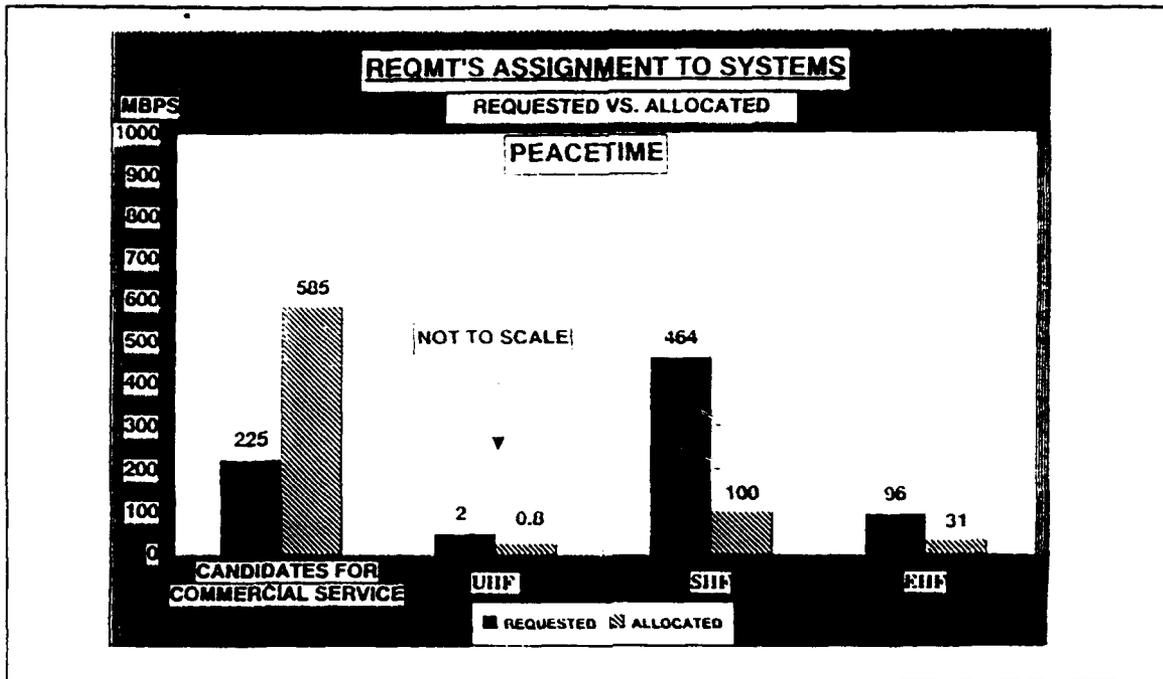


Figure 20. Peacetime Requirement Assignment (DISA MSO, 1994, p. 10)

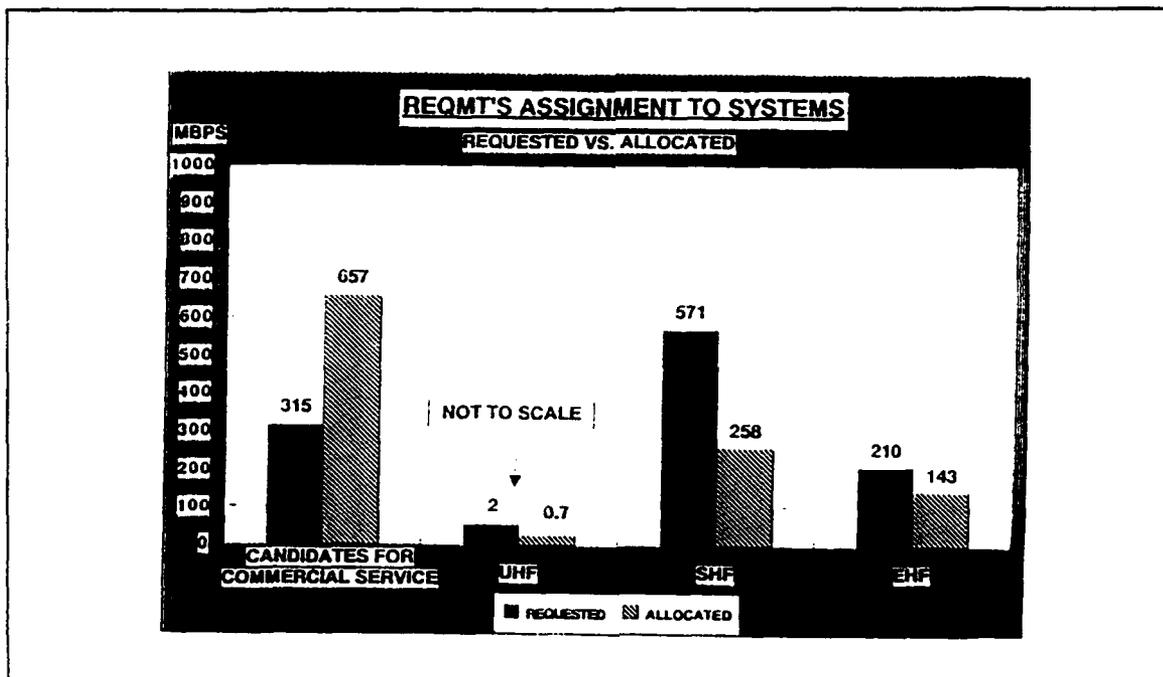


Figure 21. CMRC Requirements Assignment (DISA MSO, 1994, p. 11)

C. INTEGRATED SATCOM DATABASE (ISDB) PROBLEMS

Using the ISDB as a frequency allocation prediction tool to help build communication systems of the future is causing problems. This problem is substantiated by the comments of Mr. Bill Harding, Director of Space and Nuclear C³, at the March 1994 MILSATCOM Users' Conference. Mr. Harding stated

...the ISDB process is not working the way it should be. Users put in for requirements on what they think can be met vice what they need. Thus, people in D.C. are basing studies on faulty information in the ISDB. Users need to realize this and put in for what they actually require vice what they think they can get. (McCollum, 1994, p. 3)

Additional problems with the ISDB are documented in an excerpt from an interview with Mr. Bill Clair, Senior Project Engineer, DISA MSO Communications Architecture Directorate.⁵

...the problems with the ISDB are due to the fact that it (the ISDB) is being utilized in an extended application (i.e., other than it was initially designed for as described in MOP 37). Using the ISDB as a requirements prediction tool is like trying to predict the capabilities you want your personal computer (PC) to have 10 years from now. For instance, you give the designer of your computer system the following "grey" requirements for your system that you want to have designed and be fully functional for the next 20 years: data fusion, multi-media, virtual reality, etc... The applications that the ISDB is being used for today is like saying 10 years from now you want to operate a communications system with a specific frequency, a specific crypto, a specific keying mechanism, etc... The requirements specified in the ISDB are too narrow to apply to tomorrow's systems...it has no applicability. Trying to apply the ISDB as a bandwidth allocation prediction tool is very similar to the PC example, and keep in mind that PCs have only been around for about 13 years. But on the other hand, the ISDB is really the only requirement prediction tool we currently

⁵ Bill Clair, Commander USN (retired), served as Head of Navy Satellite Communications Branch (N631), Navy Space Systems Division, prior to holding his current position.

have, so we use it, and the way we are using it now is not working. (Clair, 5 April 1994)

Due to problem areas like these, MOP 37 will undergo a major revision beginning in June 1994. The goals of revising the current Military Satellite Communications Systems document will be to readdress and more strictly define areas that have caused confusion and problems. The revision was also directed by the DoD Inspector General U.S. Space Command Inspection Report which made the following recommendation.

...the Chairman of the Joint Chiefs of Staff, in coordination with the Defense Space Council, revise MOP 37, "MILSATCOM Systems," and MJCS-11-88, "MILSATCOM Command and Control Operations Concept," to further clarify responsibilities for MILSATCOM systems between the U.S. Space Command, the Defense Information Systems Agency, and the the Military Services. (DoD IG Report, October 1993, p. 21)

D. COMMERCIAL SATELLITE USAGE DURING THE GULF WAR

Commercial satellites provided valuable complementary capacity to the MILSATCOM systems being used during Desert Shield/Desert Storm.⁶ The primary commercial satellite systems used by the United States during the Gulf War were International Maritime Satellite Organization (INMARSAT) and International Telecommunications Satellite Consortium (INTELSAT) satellites. INTELSAT provided about half of the out-of-theater SHF capacity and some 20% of the total SHF

⁶ Military Satellites utilized during Desert Shield/Desert Storm included DSCS II, DSCS III, LEASAT, FLTSAT, GAPFILLER, TACSAT, and the United Kingdom's SKYNET.

capacity. INMARSAT supported major naval task forces, sealift, and some ground unit commanders. In particular, it supported extensive unclassified and some classified traffic (secured with STU-III) for the Military Sealift Command and provided connectivity to allied Navy and merchant ships. Due to the short supply of TACSAT capacity, INMARSAT also supported sealift and battle group commanders. (Wentz, 1992, p. 13)

During the height of the air and ground war (January-March 1991) INMARSAT reported a 50% growth in Gulf traffic, a period when commercial shipping would have been expected to give the area a wide berth. INTELSAT also reported substantial traffic increases during the Gulf War, although the bulk of this growth was attributed to television traffic when Cable News Network (CNN) took to the space waves and became a worldwide household name. (Anson and Cummings, 1992, pp. 125-126)

1. Legal Issues Associated with Use of INMARSAT

Article 3(3) of the INMARSAT Convention states that the INMARSAT Organization "shall act exclusively for peaceful purposes." (INMARSAT, p. 1) The interpretation of "peaceful purposes" created problems with regard to how U.S. forces were going to use INMARSAT during the Gulf War. The Judge Advocate General (JAG) for the CNO stated that "peaceful purposes" does not exclude military activities so long as those activities are consistent with the United Nations charter.

It is under this interpretation that INMARSAT has long approved the installation of Ship Earth Stations (SESS) aboard warships. (JAG, 1991, p. 1) The application of such SESS under armed conflict created further questions, as the United Kingdom and Iraq used SESS in the Falklands and Iran-Iraq wars, respectively. In a December 1987 legal opinion and March 1988 policy directive, the INMARSAT Legal Advisor stated that in instances of armed conflict, "the SES shall only be used for distress and safety communications or other purposes recognized by international humanitarian law." (JAG, 1991, p. 1) These statements did not take into account the effect of United Nations Security Council (UNSC) Resolutions.

In 1990, UNSC Resolution 678 authorized states to use "all necessary means" to uphold and implement all previous UNSC resolutions on the subject and "to restore international peace and security in the area." Through this resolution, the JAG determined that Navy units may use INMARSAT in support of armed conflict consistent with UNSC resolutions. (JAG, 1991, p. 1) This statement still left some question as to whether the actions of individual Naval units were actually operating within the bounds of UNSC resolutions. To finally eliminate any question as to how INMARSAT could be used by U.S. forces operating in the Pacific Region, USCINCPAC issued an INMARSAT Policy. This policy stated that INMARSAT may be used in peacetime for military exercises and routine operations, and during armed conflict use is permissible for distress, safety

and humanitarian purposes (e.g., searching for or collecting shipwrecked or wounded personnel, or alerting search and rescue ships or aircraft). Additionally, use of INMARSAT is authorized when acting under the authority of a UNSC resolution. (USCINCPAC, 1993, p. 2)

E. INMARSAT OPERATIONS

The Navy has been extremely satisfied with the capabilities and services provided to them by the use of the INMARSAT system. Figure 22 shows the how the Navy's usage of INMARSAT has increased significantly since 1989, not only in the number of shipboard terminals that are in the fleet, but also in the number of minutes being used. As 4 April 1994, 203 Navy ships have INMARSAT systems installed. Existing funding allocations will allow for 300 single channel INMARSAT A terminals to be fielded, and 250 of these terminals will be eventually be upgraded to an INMARSAT B capability. The capacity of the circuit provided by this system is the INMARSAT standard data rate of 9.6 kbps. (Hartung, April 1994)

Currently, wide bandwidth INMARSAT terminals are being used extensively on USS Blue Ridge (LCC-19), USS Mount Whitney (LCC-20), USS Theodore Roosevelt (CVN-71) and USS George Washington (CVN-73) to demonstrate advanced technology capabilities. Some of these capabilities include video-conferencing (VTC), distribution of primary imagery directly to ships from collection assets, and packetized

transfer of large database information. (Ricketts, 1994; Hartung, 1994)

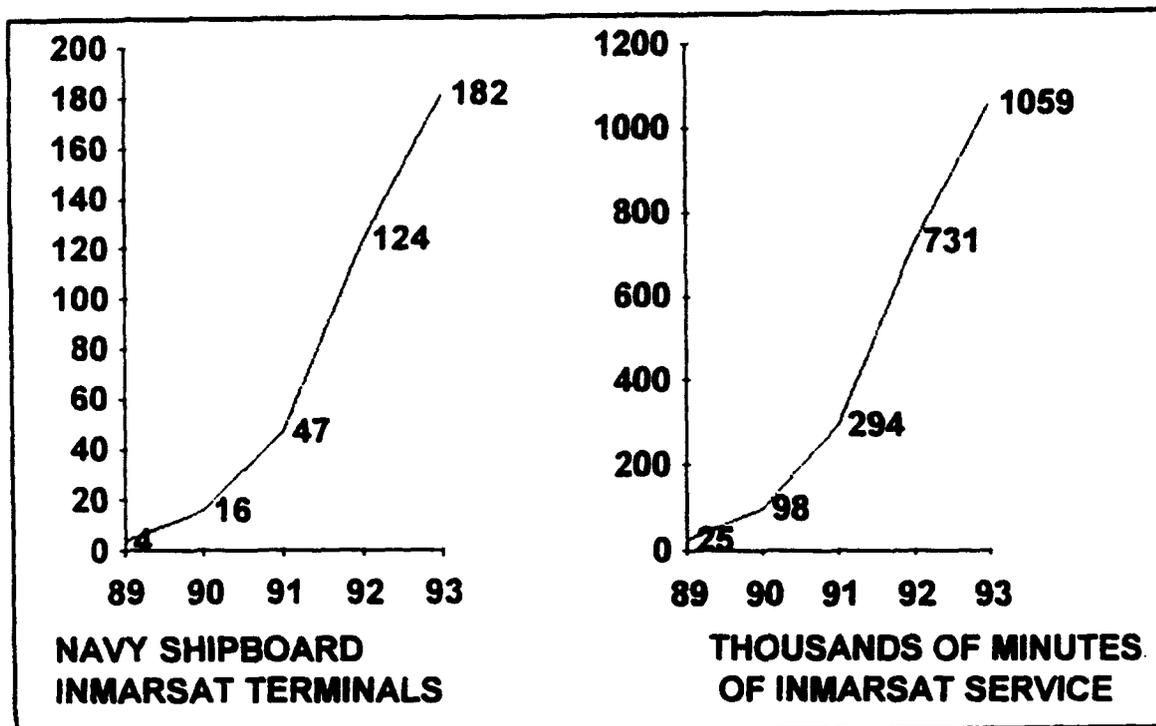


Figure 22. Navy Use of INMARSAT (Hartung, 1994)

1. INMARSAT A/B

The INMARSAT A terminal utilizes an analog system. Due to advancements in commercial communications technology, INMARSAT A is scheduled to be phased out and replaced with INMARSAT B, which is digital, beginning in 1996. The last ships that will have INMARSAT A installed onboard are the Arleigh Burke (DDG-51) class destroyers. The reason the Navy's newest ships are having a soon to be retired system installed onboard is that a class B INMARSAT terminal has not

yet been approved by the INMARSAT council as a standard terminal, so it is not currently available for installation. Once those terminals are available, they will begin to be installed. Due to the rapid decommissioning of numerous ships, the total number of INMARSAT "B" ships that will be in service between 1996 and 2000 is 250, which is less than the original fielding mark of 300 ships. (Hartung, 1994)

As previously mentioned, the majority of INMARSAT A installations provide only a single channel capability, therefore regardless of how efficient a ship is utilizing a single channel terminal, only one telephone call can be made at a time. Due to the need of more telephones, multi-channel INMARSAT A units are being installed on CV/CVNs, large amphibious ships and Fleet Flagships. These platforms will be provided with four circuits instead of just one. Of the four INMARSAT lines the multi-channel arrangement provides, two will be the high data rate (64 kbps) and two will be standard data rate (9.6 kbps). Upgrades to single channel users INMARSAT A systems would allow for high data rate communications at 56 kbps. (Hartung, 1994)

2. INMARSAT M

As INMARSAT usage has grown, two questions have arisen from the users: (1) How can current traffic charges be reduced? (2) How can more telephone circuits be added to the ship? Costs will be discussed in subsequent sections. The

development of a new INMARSAT M system was the direct result of the second question. The INMARSAT M system will provide four INMARSAT M lines (4.8 Kbps per phone), which would plug into what is normally (or previously) one high data rate line. The end result is a net gain of 3 telephones. This capability is scheduled to be demonstrated on USS Theodore Roosevelt in June 1994. (Hartung, 1994) A variation of the INMARSAT M system will be installed on Mine Counter Measure Ships and Patrol Craft to provide them some means of utilizing INMARSAT communications. (OPNAV, 1994, p. 5)

3. INTELSAT

Simultaneous efforts are being conducted with INTELSAT systems to provide advanced alternate means of communication and intelligence to the afloat commander. The current data rate transmission capability of 150 kbps is not fast enough for imagery to be transmitted to ships. Not only does the information tie up the communications net, as it would take between 3 and 5 hours to transmit, but it is important to get the information there quickly, as it is time critical. As a result of this, global beams on INTELSAT are currently being used concurrent with exercise Challenge Athena, where a T-1 telephone line was run into USS George Washington and a "half T-1" was run out of the ship. This increased data rate into the ship provided imagery in minutes vice hours. The reason for the higher data rate into the ship was to support the

"warrior pull" concept, where the afloat commander has the option of drawing information he wants from a large selection being provided on the circuit. The "half T-1" out of the ships would allow for an additional 20 phones to be run off the ship. These telephone lines would be capable of supporting Secret and General Service VTC, telemedicine and public affairs photographs. Challenge Athena is an exercise that has received \$3.5 million from Congress to explore the INMARSAT/INTELSAT usage requirements and utilization of an aircraft carrier as it prepares for (going through the "work-up" process) deployment, and when it is actually deployed for a six month period. A similar study is being conducted on USS Mount Whitney to determine the "user-pull" requirements of an afloat Joint Task Force Commander (CJTF). (Hartung, 1994)

F. INMARSAT COSTS

The Navy is paying INMARSAT \$146,000.00 per month to lease a 36 MHz transponder 24 hours a day to provide service to ships that is just like picking up a commercial telephone. The charge for using INMARSAT is based completely upon call duration. Whenever a ship places a call and the dialed number "answers" the call, the clock is started. Whenever the "talkers" hang up, the clock stops. Each individual ship only pays for the amount of service they use. The payment for usage is made from each ship's operating target (OPTAR) funds. If a ship never places a call, no usage fee is charged for

system utilization. The Navy currently pays \$6.25 per minute for the service, which is prorated into 10 second increments, with a 30 second minimum. The normal tariff rate for usage of INMARSAT is \$10.00 per minute, but due to a Volume Subscriber Plan (VSP), DoD only pays \$6.25 for a 9.6 kbps line. The commercial tariff charge for the upgraded 56 kbps line is \$18.00 per minute; whether the Navy will receive a high volume discount rate has yet to be determined. (SPAWAR, 1994, p. 3; Ricketts, 1994)

For shore originated calls, the shore originator is charged for the call at a rate determined by the shore user's local telephone service provider, and this charge appears on the originator's telephone bill. As far as the local telephone company is concerned this is simply a long distance phone call made to one of four area codes. These area codes correspond to the four ocean regions as defined by the INMARSAT network: Atlantic East, Atlantic West, Indian and Pacific. Most typically, users are charged at a rate that approximates \$10 per minute. (SPAWAR, 1994, p. 3)

In addition to ship to shore and shore to ship calls, INMARSAT provides a ship to ship service. This service works in exactly the same manner as all other INMARSAT calls, except the path is a double hop from ship to satellite to earth station and from earth station to satellite to ship. Due to this, the call is charged as two calls at \$6.25, or \$12.50 per minute. (SPAWAR, 1994, p. 3)

1. Additional Costs for INMARSAT A

An INMARSAT A terminal costs approximately \$25,000 to procure and \$16,000 to install, except overseas where there is an additional \$ 6,000 to 10,000 charge from the INMARSAT host nation. The 56 Kbps upgrade costs an additional \$19,000 for the hardware and \$2,000 more to install. (Ricketts, 1994) The single channel INMARSAT capability utilizes a 1.2 meter satellite antenna.

2. Additional Costs for INMARSAT B

Anticipated costs for the INMARSAT B terminal range between \$30,000 and \$35,000. This terminal is expected to be ready for installation around 1995-96. Installation costs should range between \$6,000 and \$8,000. The implementation of the INMARSAT B package should be a change conducted in a shipyard availability since INMARSAT A terminal parts are completely removed and replaced by those for the digital variant.

3. Multi-Channel Terminal Costs

The costs of expanding a ship's capability in the four channel arena, including the 56 kbps upgrade, is estimated to be \$315,000. The four channel terminal utilizes a 2.4 meter satellite dish and 56 kbps satellite modem. (SPAWAR, 1994, pp. 4-10)

4. COMSAT Proposals

The United States representative in the INMARSAT organization is the COMSAT Corporation. COMSAT has suggested leasing out-of-band channels to the Navy at a bulk rate. The tariff rate for usage of these channels is to be determined. Ships would get these channels on a first come, first served basis. However, if the ship can't operate on this out-of-band channel due to system configuration or geographical location, they can always revert to the in-band channels to make calls at the regular rate. COMSAT currently has a monthly 56 kbps lease program available that would permit the Navy to lease a 56 kbps circuit, available on demand, for a flat fee of \$45,000 per month. The drawback with this is that the ships utilizing this service have to be high volume users in order for it to be economically feasible. INMARSAT has recently approved several new versions of this 56 kbps service, based primarily on Navy interest, but COMSAT has not published new tariffs based on these developments. It is anticipated that the new tariffs will offer shorter term versions of the current monthly package. (SPAWAR, 1994, p. 11)

G. DSCS COST COMPARISON

The average life cycle cost of one DSCS III satellite is \$140 million. (Drozd, 1994) This figure was determined by adding up all of the programmatic, research and development, production, and operation and maintenance costs for the 14

DSCS III satellites and associated IABS and BFN modifications and then dividing by 14. An additional \$55 million must be included for the average cost for the Atlas II Centaur rocket used as the launch platform. (Drozd, 1994) These two costs are then added together and divided by 10, the expected life of the satellite. An additional \$5 million dollars is paid to Martin Marietta annually for engineering support, anomaly resolution and system trend analysis. (Drozd, 1994) Therefore, the total annual operational cost of one DSCS III satellite, excluding ground station or user terminal costs, is \$24.5 million in FY 93 dollars. No time phased costs were available, therefore discounting was not taken into account. Table II contains the figures used to arrive at the \$24.5 million estimate. (Drozd, 1994)

It must be remembered that this cost is for DSCS usage by all DoD organizations. Figure 8 (previously presented in Chapter IV) demonstrates how DSCS was utilized by various DoD organizations during Desert Shield/Desert Storm, but it does not show usage by each individual service. Figures for individual service usage of DSCS were not available to the author due to administrative problems and the classification of this thesis. It is difficult to determine percentage of use by service due to issues concerning power and capacity. While the Navy's power allocation on DSCS III satellites is 50% of the power on Channel 1 and the maximum throughput capacity is 512 kbits, the DSCS usage percentages by service

are not consistent due to the variance in transponder size. (Baciocco, 1994) Figure 11 (previously presented in Chapter IV) demonstrates the different power requirements of four foot, eight foot and 38 foot dish antennas. Additionally, the DSCS III satellites have been over-engineered, which will cause actual operating lifetimes to extend. This in turn will cause the average annual operational cost of a DSCS III satellite to fall, while INMARSAT charges remain constant.

The Navy's used 1,059,000 minutes of INMARSAT service in 1993. (Rasmussen, 1994) The total cost for the Navy to utilize INMARSAT in 1993, including terminals, is \$10,494,750. Table III contains the figures used to arrive at the \$10,494,750 million estimate. (Hartung, 1994) The other services usage of INMARSAT in 1993 were as follows: Army units - 171,448 minutes; Air Force units - 55,520 minutes; Marine Corps - usage included in Navy figure of 1,059,000 minutes. (Rasmussen, 1994) The services were charged the Defense Commercial Communication Office (DECCO) discount rate of \$6.25 per minute of usage. Military Sealift Command (MSC) used INMARSAT for 360,000 minutes of voice traffic and 750,000 minutes of data transmission. Military Sealift Command units were charged \$8.00 per minute for voice traffic and \$4.00 per minute for data transmissions. (Rasmussen, 1994) The rates MSC units were charged for INMARSAT usage are different from the rates charged the military organizations of DoD due to some participating MSC units not being included in the DECCO

contract with COMSAT. The total amount paid by DoD organizations to COMSAT Mobile Communications for INMARSAT service (excluding terminal costs) in 1993 was \$13,917,300. (Rasmussen, 1994) Navy and MSC units were responsible for \$12,498,750 of the total charge, demonstrating their dependence on INMARSAT due to the lack of land line connectivity during at sea operations.

No direct comparison can be made between DSCS III and INMARSAT costs due to the fact that the costs for DSCS III are based on a quantity average and INMARSAT costs are calculated on a time basis. The quantity average is determined by dividing the total programmatic costs for the DSCS III program by the quantity of satellites produced. The time-based calculation is determined by calculating the time of service usage and multiplying by the service charge. It must also be remembered that quality of the service provided by DSCS III satellites and INMARSAT are not the same, as DSCS III satellites provide some anti-jam capability but INMARSAT provided none.

Table II. DSCS III COST BREAKDOWN (Drodz, 1994)

| | |
|-------------------------------------------------------------------------------------------------------------------|-----------------------|
| DSCS III Satellite Program Costs | \$1.96 Billion |
| Total # of DSCS III Satellites Produced | 14 |
| Individual DSCS III Satellite Cost = Program Costs/Total # Produced | \$140 Million |
| Total Cost per Atlas II Centaur Launch Vehicle | \$55 Million |
| Single Satellite in Orbit Cost = Individual Cost + Launch Vehicle Cost | \$195 Million |
| Design Life of DSCS III Satellite | 10 Years |
| Annual Orbiting Costs For One DSCS III = Single Satellite Orbiting Cost/ Divided by Design Life of DSCS III | \$19.5 Million |
| Annual Engineering Support Costs Paid to Martin Marietta | \$5 Million |
| Total Annual Operating Cost of One DSCS III Satellite, Excluding Ground Station of Terminals | \$24.5 Million |

Table III. INMARSAT COST BREAKDOWN (Hartung, 1994)

| | |
|------------------------------------------------------------------------------|--------------------------|
| Monthly Transponder Rental Fee | \$168K |
| Annual Rental Fee = Monthly Fee x 12 | \$2,016,000 |
| Minutes of Usage in 1993 | 1,059,000 Minutes |
| Charge per Minute | \$6.25 |
| Usage Fee = Minutes Used x Charge per Minute | \$6,618,750 |
| INMARSAT A Terminal Costs | \$62 K |
| # of INMARSAT A Terminals Scheduled for Procurement | 300 |
| Estimated Design Life of Terminals | 10 Years |
| Total Terminal Costs = (Cost per Terminal x # of Terminals) / Design Life | \$1,860,000 |
| Total INMARSAT Costs = Transponder Costs + Usage Fees + Terminal Costs | \$10,494,750 |

H. REPRESENTATIVE FLEET USAGE OF INMARSAT

INMARSAT terminals are primarily used for mission support (i.e., non-tactical) whether it be to maintain crew morale, obtain current logistics support information, or to aid in the completion of operational planning. The breakdown of one aircraft carrier's calls over a three month deployed period showed that 15% of the calls were for unclassified information related to the Streamlined Automated Logistics Transmission System (SALTS, defined in Appendix B); 25% of the calls were made by the crew by means of prepaid calling card calls; and the remaining 60% were for daily operations of the ship (e.g., STU-III, direct dial, etc...). [Ricketts, 1994]

The average SALTS call completed during this three month survey was 2.8 minutes. Analysis of the costs associated with SALTS calls shows that 60% of the total cost comes from only 18% of the calls, suggesting these were extremely long calls. The throughput speed of data transmission experienced was in the range of 2.4 to 9.6 kbps. If the "long" SALTS calls had been completed on a 56 kbps circuit rather than a 9.6 kbps single channel circuit, the call transmission time could have been cut dramatically. For example, a 12.8 minute call on a 9.6 kbps line corresponds to a 2.5 minute call on a 56 kbps line. For simplification of the model comparison, the "average" 56 kbps call session would require 3 minutes. Using the \$6.25 per minute fee for 9.6 kbps and \$11.90 per minute for 56 kbps, the average savings per SALTS session by using a

56 kbps circuit is \$45 per session. The standard operating procedure for the carrier was to conduct two SALTS sessions per day, therefore the saving would be \$90 per day. (SPAWAR, 1994, p. 12)

Recalling that the cost incurred by the Navy to upgrade a ship's INMARSAT system to a 56 kbps capability is approximately \$22,000, it would take 233.33 days to recoup the investment for the upgrade. Two hundred and thirty-three days is approximately 1.2 deployments. It appears that the potential savings provided by the 56 kbps circuit is an excellent way to reduce traffic charges and more efficiently use the INMARSAT system.

VII. CONCLUSIONS AND RECOMMENDATIONS

The Navy's SHF SATCOM program, like all military programs, is experiencing the far reaching effects of the fall of the Soviet Union. The re-evaluation of our National Military Strategy, and our strategic shift from global and theater warfare to crisis operations and low intensity conflicts has altered the emphasis of the factors driving development of future MILSATCOM systems. Before Desert Shield/Desert Storm and before the end of the "Cold War" the factors driving advancement of MILSATCOM systems in order of emphasis were: responsiveness, coverage, protection, capacity and cost. The demise of the once powerful "Soviet Bear" has caused the emphasis on these factors to become: cost, capacity, coverage, responsiveness and protection.

Congress wants the MILSATCOM architecture to include as many commercial systems as much as possible, referring to how successfully they were employed during Desert Shield/Desert Storm. Additionally, political pressure seems to be steering future development of MILSATCOM systems in the direction of cheaper, more capable, less protected systems.

This is a dangerous trend; recovering from such practices, if established, could be much more costly than if the proper systems were developed and implemented. Former ideas of fighting a European land battle and taking advantage of

existing telecommunications networks and systems in NATO countries no longer are valid. It must be remembered that Iraq did not jam U.S. and coalition satellite communications; and even if they did, the location conducting the jamming could have been targeted and eliminated. Crisis operations, low intensity conflicts, and humanitarian operations are more likely to occur in "third world" countries where telecommunications systems capable of supporting the C⁴I requirements of our commanders do not exist. This is what should be remembered while decisions are being made regarding future MILSATCOM systems.

The revision of MOP 37, scheduled to begin in June 1994, will attempt to more closely define the applications of the ISDB and determine a way to make the ISDB more of an accurate reflection of what DoD's frequency requirements really are. If this can not be done, then research dollars should be spent on ways to design something new which could more realistically be used as a bandwidth allocation prediction tool. The pressure calling for increased utilization of commercial satellite assets may affect the revision of MOP 37. Areas of the document that could potentially be influenced by political pressure are the definitions for general purpose, core and hard core requirements. Restructuring of these definitions could make commercial SATCOM systems more applicable in the MILSATCOM architecture.

It appears that the DSCS requirements screening process is beginning to shift fixed-site-to-fixed-site users to terrestrial optical fiber lines instead of DSCS satellites, based on the study completed by MSO/Aerospace. Not only would this free up channels on DSCS, but the fixed-site users would no longer face power limitations and would gain bandwidth as a result.

The first recommendation is to significantly increase training efforts in the area of SHF SATCOM. The Navy made great advances in command and control under the leadership of Vice Admiral Tuttle. He really "got the ball rolling" as far as development of advanced communications systems goes. The Chief of Naval Operations Space and Electronic Warfare Directorate (N-6) produced a document entitled Sonata in 1992, which stated:

...DoD no longer is driving research and development. In 1962, the U.S. Navy was responsible for over 50 percent of the nation's research and development expenditures on electronics. Thirty years later, Navy is less than five percent. (CNO SEW, 1992, p. 48)

Since the Navy is no longer the leader in production, design, sales, and distribution of electronics, we have to focus our efforts on training. Ground and maritime forces, carrier battle groups, amphibious readiness groups, and Fleet Flagships are experiencing problems while "in-chopping" from one CINC area of responsibility (AOR) to another. Comments from CINCCENT cite lack of training, documentation, standardization of hardware and software for these problems.

(Baciocco, 1994) The Chief of Naval Technical Training has also received a requirement for SHF SATCOM training and has requested implementation of various degrees of training programs for potential SHF SATCOM users. These users range from division officers and department heads to surface communications systems operators. (CNO, 01 April 1994, p. 1)

New systems fielded without sufficient documentation and user training are a major problem. As a case in point, QUICKSAT was initially only supposed to be an interim program to support five ships, but now there are 13 ships with QUICKSAT. The thought process for meeting training requirements was through on the job training (OJT). (Martin, 1994) Training methods began to improve slightly when the installing activity trained up the ships crews on how to operate the new equipment. It was initially thought that this technique would work, but within about two years everyone who had been trained by the installers had rotated. An additional two years later the operational effectiveness of the systems operators was significantly decreased from what it should have been. The ships' capabilities were deficient due to a loss of "corporate knowledge" on how to operate the equipment. Further problems were encountered as the communications equipment began to be cross decked from returning ship to deploying ship due to a lack of equipment.

NAVELEX Portsmouth (now called NISE East) is putting together a three volume training handbook as a baseline to help begin bridging the training gap. Volume one of the handbook is an executive summary, aimed for use by commanding officers. The second set of volumes (a multi-volume set) is a by-component description of all the items currently in the Navy's SHF inventory. The third volume is a ship-specific systems diagram book, which can be used by the operators for training purposes or to help troubleshoot problems while on deployment. NISE East has also put together a five week users course for more hands-on training. Current training schedules from NISE East anticipate providing eight more courses per year. This may paint an optimistic picture for SHF SATCOM training programs, but Fleet Flagships with pre-QUICKSAT (Phase 0) using the OM-55 modem will soon have no training support, as the operator/maintainer course in Norfolk has been cancelled. (Martin, 1994)

Future training programs need to be developed so the sailor going through the "A school" training pipeline learns all the theory, fundamentals, and actually gets to operate a prototype system; this should be similar to the way the Navy trains nuclear pipeline training. This way, when the sailor goes to the ship, he/she can adapt to the actual onboard system and can bridge that gap by using onboard training aids like the volume three handbook provided by NISE East. Another established training method which the Navy's nuclear program

has proven effective is utilization of two to three week schools for crews after deployments, emphasizing problems experienced during the deployment. Establishment of a remedial course in Norfolk and San Diego to sharpen fleet operator skills 10 to 12 months after they have reported to their ship could also complete this requirement. The bottom line is that the sailor needs to be trained for a Navy enlisted code (NEC) as a SHF SATCOM operator instead of a WSC-6 technician. The program needs to train for an open architecture vice a systems architecture. This idea could also adapt to a joint environment by training operators as SATCOM technicians and have them become familiar with more than one SATCOM system. Efforts are currently being made to move the Navy's SATCOM pipeline training to Fort Gordon to co-locate with the Army's DSCS training center. The Navy personnel would attend separate specific courses from the Army personnel, but they would be able to take advantage of the Army's operating facilities and be exposed to the Army's training. (Martin, 1994)

Additional emphasis must be placed on the responsibility of the newly formed Afloat Training Group (ATG) to train the fleet operators. The ATG also needs to develop training plans and methods to better support the combat systems and communications training programs. But once again the problem with getting these types of programs started is money. Funding for development of the curriculum isn't necessarily

the problem; the problem is getting the billets for the instructors, because it involves permanent change of station (PCS) orders.

The final recommendation is to develop the future SATCOM architecture as a mix of MILSATCOM systems and commercial systems. The reason both systems are necessary is quite simple, protection and savings. Commercial systems can't provide the antijam capability required for specific core and hard core communications, and MILSATCOM systems are too expensive to operate as the sole system. This "middle ground" attitude emerging within the SHF SATCOM community seems to indicate that commercial satellite services will be used for "surge" capacity. The only problem with this idea is defining what "surge" means. What kinds of communications requirements constitute surge? Video teleconferencing? Tomahawk mission data updates (MDUs)? Closer inspection of increased message traffic during Desert Shield/Desert Storm showed that much of the "surge" was nothing more than multiple copies of the same message being sent. Definitions of "surge" must be provided, because communications that are required once daily in condition three operations may become four and five times daily in condition one or two operations. Also, communications that fall into the "surge" category must be strictly defined; otherwise these communications that "require a miracle" to establish will become daily routine to the commander who becomes accustomed to operating with it.

Commercial SHF SATCOM systems should continue to be used for development of future capabilities, as they are now in the Secure Tactical Data Network demonstrations and Ulchi Focus Lens exercises. Great pains need to be taken, though, to eliminate C-band interference and self-jamming problems, as this is what caused HMS Sheffield to be sunk by an Argentine launched Etendard/Exocet missile during the Falklands War in May 1982. The British SHF satellite communications system (SCOT) blocked out detection of the Etendard/Exocet radar and caused the subsequent loss of 20 British sailors and a Type 42 guided-missile destroyer. (Woodward, 1992, pp. 1-22)

APPENDIX A. ACRONYMS

| | |
|---------------------|----------------------------------------------------------------------------------------|
| ACU | - Antenna Control Unit |
| AFCEA | - Armed Forces Communications and Electronics Association |
| AFRTS | - Armed Forces Radio Television System |
| ARP | - Address Resolution Protocol |
| ARPA | - Advanced Research Projects Agency |
| ACS | - Advanced Communications Systems |
| AJ | - Anti-Jam |
| ANDVT | - Advanced Narrowband Digital Voice Terminal |
| AOR | - Area of Responsibility |
| ASDC ³ I | - Assistant Secretary of Defense for Command, Control, Communications and Intelligence |
| ATG | - Afloat Training Group |
| ATO | - Air Tasking Order |
| ATS | - Applications Technology Sensor |
| BFN | - Beam Forming Network |
| BLACK | - Secure/Encrypted |
| BPS | - Bits per Second |
| BPSK | - Bi-Phase Shift Keying |
| BSS | - Broadcast Satellite Service |
| CCC | - CINC Command Center |
| C ⁴ I | - Command, Control, Communications, Computers and Intelligence |
| C ⁴ IFTW | - Command, Control, Communications, Computers and Intelligence for the Warrior |

C³I - Command, Control, Communications and Intelligence
 CCEP - Commercial COMSEC Endorsement Program
 C²I - Command, Control and Intelligence
 CINC - Commander in Chief
 CINCCENT - Command in Chief Central Command
 CJCS - Chairman, Joint Chiefs of Staff
 CJTF - Commander Joint Task Force
 CLF - Combat Logistics Force
 CMRC - Combined Major Regional Conflict
 CMS - Classified Material System
 CNN - Cable News Network
 CNO - Chief of Naval Operations
 COMSEC - Communications Security
 COTS - Commercial off-the-shelf
 CTAPS - Contingency Theatre Automated Planning System
 CTS - Communications Technology Satellite
 CV - Conventionally Powered Aircraft Carrier
 CVN - Nuclear Powered Aircraft Carrier
 DAB - Defense Acquisition Board
 DAC - Discretionary Access Control
 DAMA - Demand Assigned Multiple Access
 DATS - Despun Antenna Test Satellite
 DBS - Direct Broadcast System
 DDN - Defense Data Network
 DECCO - Defense Commercial Communications Office

DISA - Defense Information Systems Agency

DISN - Defense Information Systems Network

D/L - Down Link

DLIU - Digital Line Interface Unit

DoD - Department of Defense

DSCS - Defense Satellite Communications System

DSCSOC - DSCS Operations Center

DS/DS - Desert Shield/Desert Storm

DSNet - Defense Secure Network

DSVT - Digital Subscriber Voice Terminal

DTE - Data Terminal Equipment

ECCM - Electronic Counter-Counter Measures

ECP - Engineering Change Proposal

EIRP - Effective Isotropic Radiated Power

EKMS - Electronic Key Management System

E³ - End-to-End Encryption

FAX - Facsimile

FCC - Federal Communications Commission

FDMA - Frequency Division Multiple Access

FFRDC - Federally Funded Reasearch and Development Center

FSS - Fixed Satellite Service

FTC - Fleet Training Center

FY - Fiscal Year

Gbps - Giga bits per Second

GDA - Gimbaled Dish Antenna

GENSER - General Service
 GGTS - Gravity Gradient Test Satellite
 GMF - Ground Mobile Forces
 G/T - Gain-to-Temperature
 HAC - House Appropriations Committee
 HDR - High Data Rate
 HEMP - High-Altitude Electromagnetic Pulse
 HF - High Frequency
 HMS - Her Majesty's Ship
 HPA - High Power Amplifier
 HSRP - Headquarters System Replacement Program
 IABS - Integrated Apogee Boost Subsystem
 IBAC - Identity Based Access Control
 IDCSP - Initial Defense Communications Satellite Program
 INMARSAT - International Maritime Satellite Organization
 INTELSAT - International Telecommunications Satellite Consortium
 INTMILSAT - International Military Satellite
 I/O - Input/Output
 IP - Internet Protocol
 ISDB - Integrated SATCOM Database
 ISO/IEC - International Organization for Standardization and the International Electrotechnical Committee
 ITU - Internatinal Telecommunications Union
 ITW/AA - Integrated Tactical Warning and Attack Assessment

JAG - Judge Advocate General
 JCSC - Joint Communications Satellite Center
 JFACC - Joint Force Air Component Commander
 JMCIS - Joint Maritime Command Information System
 JMPA - Joint MILSATCOM Panel Administrator
 JOTS - Joint Operational Tactical System
 JRSC - Jam Resistent Secure Communications
 K - Kelvin
 KBPS - Kbits per Second
 KSD-64A - Encryption key for NES
 LAN - Local Area Network
 LANTDIS - Atlantic Deployable Intelligence System
 LDR - Low Data Rate
 LEASAT - Leased Satellite
 LHA - Amphibious Assault Ship
 LHD - Multi-purpose Amphibious Assault Ship
 LOCC - Local Operation Control Center
 LPD - Low Probability of Detection
 LPH - Landing Platform Helicopter Dock
 LPI - Low Probability of Intercept
 LSTDM - Low Speed Time Division Multi-plexer
 MAC - Mandatory Access Control
 MARISAT - Maritime Satellite
 MBA - Multi-Beam Antenna
 MCEB - Military Communication Electronics Board
 MDU - Mission Data Update

MMBA - Multi-Beam Multi-Mission Broadband Antenna
 MMD - Mean Mission Duration
 MOP - Memorandum of Policy
 MPA - Medium Power Amplifier
 MSC - Military Sealift Command
 MSO - MILSATCOM Systems Office
 MTBF - Mean Time Between Failures
 MTTR - Mean Time To Repair
 NASA - National Aeronautics and Space Administration
 NATO - North Atlantic Treaty Organization
 NAVFOR - Naval Force Commander
 NCA - National Command Authority
 NCCOSC - Naval Command, Control and Ocean Surveillance Center
 NCT - Network Control Terminal
 NCTAMS - Naval Computer and Telecommunications Area Master Station
 NEC - Navy Enlisted Code
 NES - Network Encryption System
 NOSC - Naval Ocean System Command
 NPS - NES Product Server
 NSA - National Security Agency
 NSNF - Nonstrategic Nuclear Forces
 NT - Network Terminal
 NTCS-A - Navy Tactical Command Control System Afloat
 OASIS - Office Automation & Secure Information System
 OJT - On the Job Training

OPTAR - Operating Target
 OSD - Office of the Secretary of Defense
 OSS - Operations Support System
 PAUC - Program Acquisition Unit Costs
 PC - Personal Computer
 PCS - Permanent Change of Station
 PN - Pseudo-Noise
 POM - Program Objective Memorandum
 POTS - Plain Old Telephone System
 P³I - Pre-Planned Product Improvement
 RCAS - Reserve Component Automation System
 RED - Clear/Unencrypted
 RFI - Radio Frequency Interference
 SALTS - Streamlined Automated Logistics Transmission System
 SATCOM - Satellite Communications
 SCI - Sensitive Compartmented Information
 SCSC - System Common Signaling Channel
 SCT - Single Channel Transponder
 SDNS - Secure Data Network Systems
 SEU - Servo Electronics Unit
 SHF - Super High Frequency
 SIOP - Single Integrated Operating Plan
 SNCC - SATCOM Network Control Center
 SRWI - SATCOM Radio Wireline Interface
 STC - Satellite Television Corporation

STDN - Secure Tactical Data Network
STel - Stanford Telecommunications
STEP - Standard Tactical Entry Point
STU-III - Secure Telephone Unit Third Generation
SPAWAR - Space and Naval Warfare Systems Command
SURTASS - Surveillance Towed Array Sensor System
TDA - Tactical Decision Aids
TDA - Tunnel Diode Amplifier
TEK - Traffic Encryption Key
TESS - Tactical Environmental Support System
TRIB - Transfer Rate of Information Bits
TWT - Traveling Wave Tube
UFO - UHF Follow-On
UHF - Ultra High Frequency
U.K. - United Kingdom
UNSC - United Nations Security Council
URDB - User Requirements Database
USAF - United States Air Force
USMTF - United States Message Text Format
VIXS - Video Information Exchange System
VLSI - Very Large Scale Integrated (Circuits)
VME Board - Versa Module Eurocard Back Plane
VSP - Volume Subscriber Plan
VTC - Video-Teleconferencing
WAN - Wide Area Network
WWMCCS - Worldwide Military Command and Control System

APPENDIX B. HOST SYSTEM DESCRIPTION

The following descriptions of host systems utilized on SHF SATCOM were taken from the document SHF SATCOM BATTLE FORCE: EXECUTIVE OVERVIEW, produced by the Naval Command, Control and Ocean Surveillance Center. (NCCOSC, 1994, pp. 4-3)

CTAPS - Contingency Tactical Air Control System (TACS) Automated Planning System. Joint system (developed by USAF) used to provide planning and mission monitoring assistance and specifically for construction and review of the Air Tasking Order (ATO). The Navy is integrating the ATO functionality of CTAPS into Joint Maritime Command Information System (JMCIS).

DSNet - Defense Secure Network. Comprised of three distinct networks in the Defense Data Network (DDN). DSNet 3 is a Sensitive Compartmented Information (SCI) Top Secret network supporting the Department of Defense (DoD) Intelligence Information System (DODIIS) which is accessed by Joint Defense Intelligence Support Services (JDISS). DSNet 2 is a GENSER Top Secret network supporting the WWMCCS Intercomputer Network (WIN). DSNet 1 is a GENSER Secret network serving other service and agency users. Typical remote terminal access data rate: 9.6 kbps.

TACTERM/ANDVT - Tactical Terminal/Advanced Narrowband Digital Voice Terminal. Military operator-assisted, encrypted, and dial-up voice interface between ANDVT and STU-III users via a SATCOM Radio Wireline Interface (SRWI) located at each Naval Computer and Telecommunications Area Master Station (NCTAMS). Typical remote terminal access data rate: 2.4 kbps.

JDISS - Joint Defense Intelligence Support Services. Descendant from the Atlantic Deployable Intelligence System (LANTDIS) which provides afloat subscribers access to selected portions of the DODIIS through a consolidated theater intelligence center ashore. Typical remote terminal access data rate: 2.4 - 56 kbps.

JMCIS - Joint Maritime Command Information System. The Navy Tactical Command and Control System - Afloat (NTCS-A) [which evolved from the Joint Operational Tactical System (JOTS)] and the Operations Support System (OSS) have merged to become the Joint Maritime Command Information System (JMCIS). JMCIS is the primary afloat C²I tactical information management system with user selectable tactical decision aids (TDA) to process and display data from national, regional, and organic sensors/sources on friendly, hostile, and neutral forces. Typical remote terminal access data rate: 9.6 kbps.

JWICS - Joint Worldwide Intelligence Communications System. Eventual replacement for the DODIIS and will become the SCI component of the Defense Information System Network (DISN).

Orderwire - Mandatory operator to operator circuit used for real-time management and control of SHF SATCOM links and their hosted circuits once a SHF link is established. This complements established United States Message Text Format (USMTF) record message format Procedures. Typical remote terminal access data rate: 300 bps.

POTS - Plain Old Telephone System. Provides direct-dial unclassified access to commercial and DSN telephone networks. Both end users must use STU-IIIs for classified calls. Calls may be placed to/from the ship. Only differs from STel/STU-III system by eliminating the STel modem. A TIMEPLEX multiplexer is only used for voice compression when STU-IIIs are not used. POTS line data rate: 8 or 16 kbps.

SALTS - Streamlined Automated Logistics Transmission System. Unclassified, automated dial-in computer bulletin board system used to deliver and receive a variety of logistics, personnel, and maintenance data products thereby reducing traffic loads on tactical circuits and increasing delivery speed and accuracy. The system uses telephone connectivity such as land

line, cellular, INMARSAT, STel, and POTS. Typical remote terminal access data rate: 9.6 kbps.

STel/STU-III - Stanford Telecommunications/Secure Telephone Unit - Third Generation. Encrypted, direct-dial telephone, FAX, and PC-to-PC access using STU-IIIs employs the STel Digital Line Interface Unit (DLIU) for connection to existing shipboard analog telephone switches to accommodate multiplexer user access. Calls can be placed to/from the ship. Typical remote terminal access data rate: 2.4 kbps.

Tactical TTY - Provides traditional tactical teletype service between group communications operators for circuit coordination, message traffic, etc. Circuit/network data rate: 75 or 300 bps.

TESS-3 - Tactical Environmental Support System - Third Generation. A modular and interactive computer-based system which collects, processes, analyzes, disseminates, and displays oceanographic and meteorological data products. It can be interfaced with JMCIS via NCTS-A/NCSS Integrated Tactical Environmental System (NITES). Typical remote terminal access data rate: 2.4 or 9.6 kbps.

TRITAC/KY-68 - Direct, secure telephone connectivity (referred to as the "Bat phone") to the Pentagon Red Switch for use by CJCS, CINCs, and the National Command Authority (NCA). Formal designation of this circuit is the Digital Subscriber Voice Terminal (DSVT). Phone line data rate: 16 kbps.

VIXS - Video Information Exchange System. Provides 24 hour secure video teleconferencing (VTC) between and among the CNOs staff, fleet commanders, tactical commanders at sea, and equipped shore-based commands at the GENSER Secret level. Typical remote terminal access data rate: 112 kbps.

VVFDT - Voice, Video, Fax, and Data Terminal. Although not dedicated to a specific network or function, the system uses high data rate STU-IIIs and commercially available PCs to securely exchange large data and imagery files while permitting simultaneous secure telephone conversations. It is also capable of displaying freeze-frame video or facsimile and real-time multiple "telestrator" annotations. Remote terminal access data rate: 9.6 kbps.

WMCCS - Worldwide Military Command and Control System. Provides the means for operational direction and technical administrative support involved in the command and control of U.S. military forces plus worldwide status of forces information and E-mail capability for joint planning and coordination. It provides a multipath channel of secure

communications to transmit warning and intelligence information to the NCA and the means for the NCA to direct U.S. combatant commanders. Typical remote terminal access data rate: 2.4 - 9.6 kbps.

APPENDIX C. BLOCK DIAGRAMS

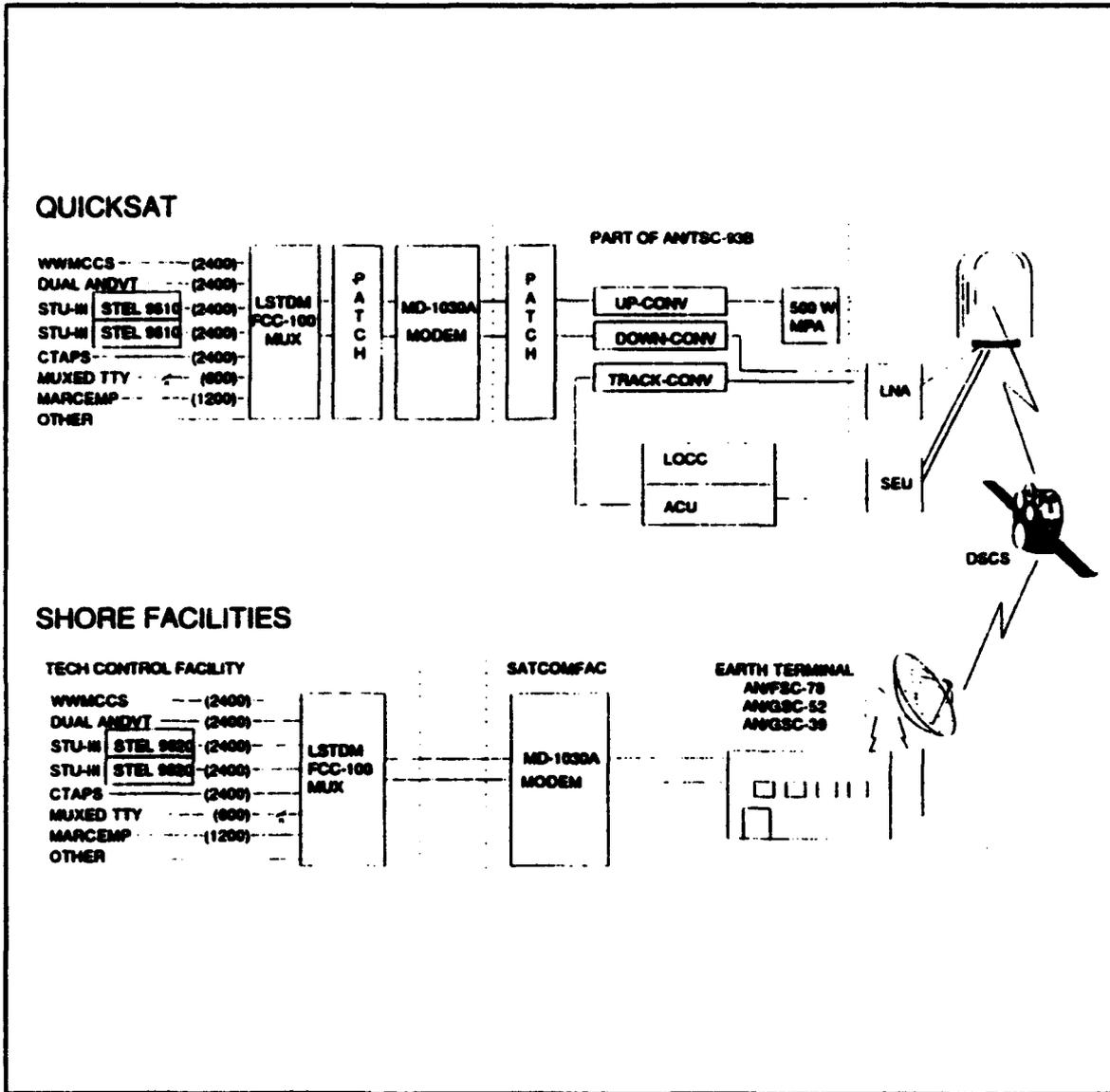


Figure 23. QUICKSAT BLOCK DIAGRAM (SPAWAR, 1994, p. 14)

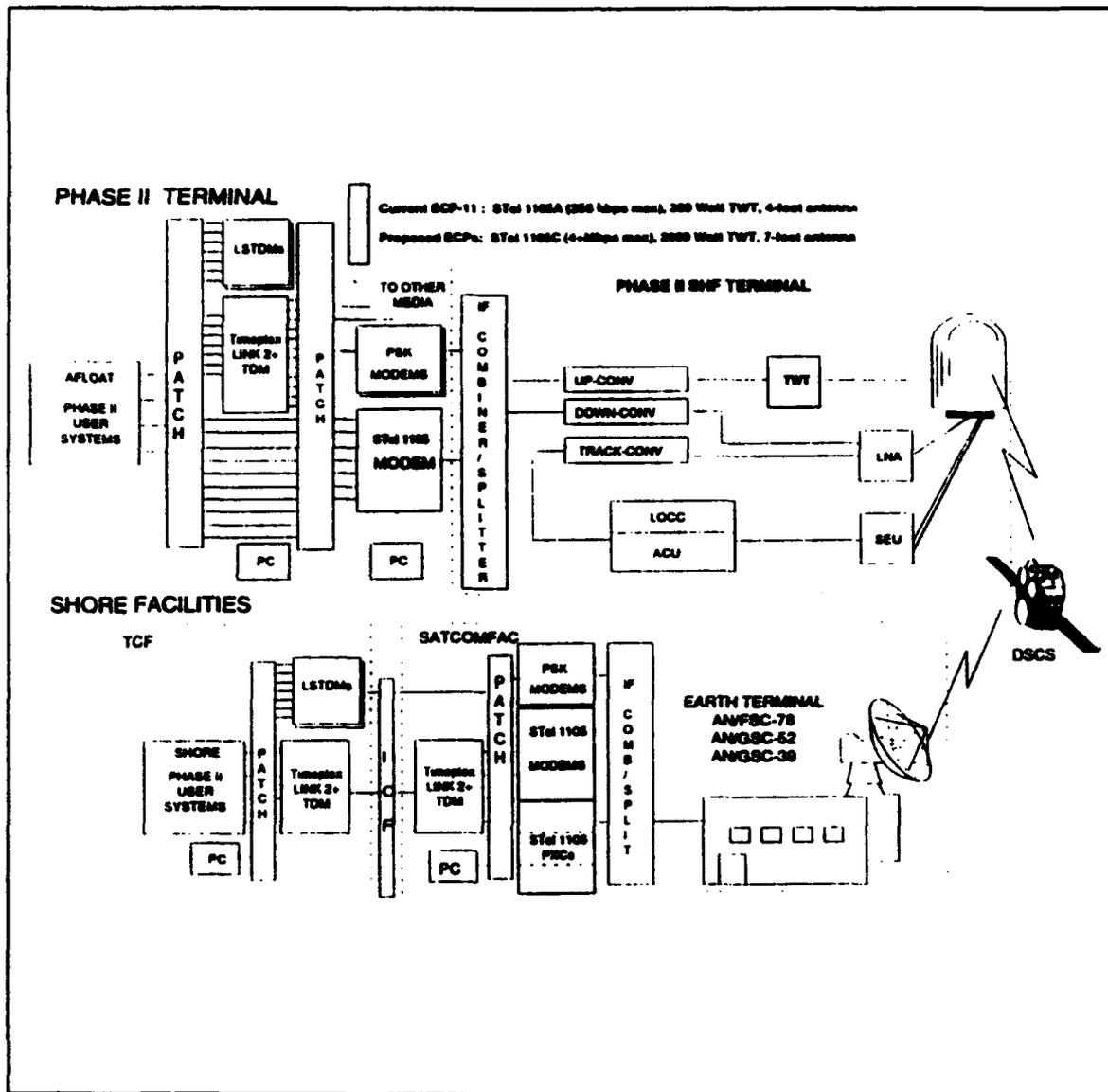


Figure 24. PHASE II BLOCK DIAGRAM (SPAWAR, 1994, p. 15)

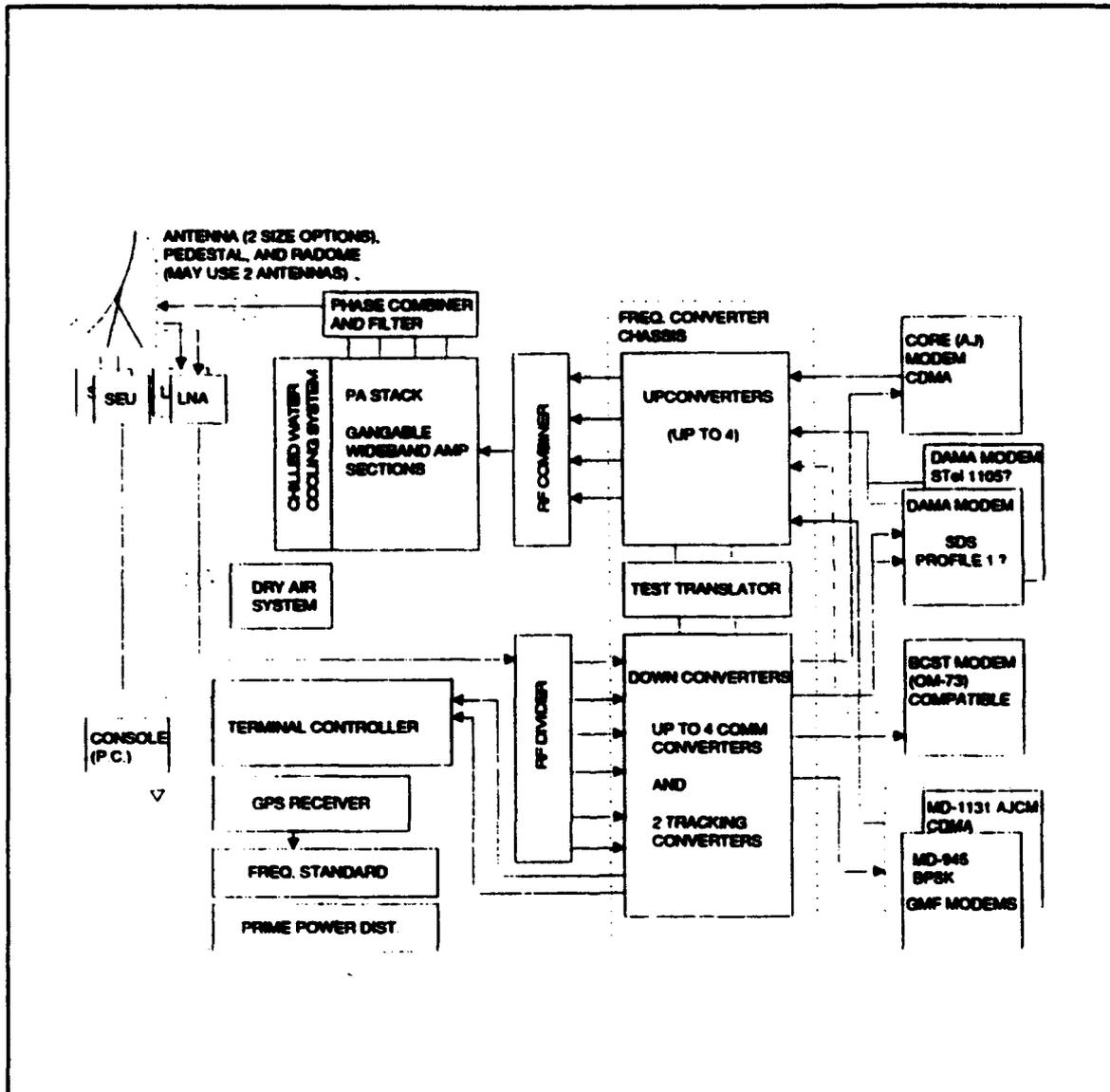


Figure 25. PHASE III BLOCK DIAGRAM (SPAWAR, 1994, p. 20)

APPENDIX D. DSCS DESIGN DETAILS AND SPECIFICATIONS

The information enclosed in this Appendix was obtained from satellite design details section of the Aerospace Corporation's *Communication Satellites 1958-1992*. (Martin, 1991, pp. 95-113)

A. DSCS I/IDCSP

1. Design Life

The design life of the DSCS I/IDCSP was required to be 1.5 years, with a three-year goal.

2. Orbit

The DSCS I/IDCSP orbits at an altitude range of approximately 17,800 to 18,700 nautical miles. The inclination is < one degree for most satellites, with approximately 30 degrees longitudinal drift per day.

3. Shape/Dimensions

The DSCS I/IDCSP is shaped like a polyhedron, 36 inches in diameter and 32 inches in height.

4. Weight

The Gravity Gradient Test Satellite (GGTS) version of the DSCS I/IDCSP weighed 104 pounds, while the Despun Antenna Test Satellite (DATS) variant weighed 150 pounds.

5. Power Source

Solar cells, approximately 40 Watts, power the DSCS I/IDCSP satellite. No batteries were contained on the constellation, therefore there was no operation during eclipse.

6. Stabilization/RPMs

The DSCS I/IDCSP was spin-stabilized at 150 rpm.

7. Configuration

The configuration of the DSCS I/IDCSP satellite was one 20-Mhz bandwidth double-conversion repeater.

8. Capacity

The capacity of the DSCS I/IDCSP satellite was up to five commercial quality two-way circuits, eleven tactical quality two-way voice circuits, or 1550 teletype. Data rates supported by the DSCS I/IDCSP were approximately 1 Mbps.

9. Transmitter

The transmitter of the DSCS I/IDCSP consisted of two TWTs (one on, one standby) that operated in the 7266.4 to 7286.4 MHz frequency range, with three watts of output and seven dBW ERP maximum.

10. Receiver

The receiver operated in the 7985.1 to 8005.1 MHz frequency range, with a noise figure of 10 dB.

11. Antenna

The DSCS I/IDCSP operated with two biconical horn antennae (one transmit, one receive), with 28 x 360 degree, 5 dB gain, circular polarization. The DATS variant antenna elements were mounted on a cylinder placed along the spin axis at one end of the satellite, which provided an additional gain of 10 dB.

B. DSCS II

1. Design Life

The design life of the DSCS II was five years, with a three year mean mission duration (MMD).

2. Orbit

The DSCS II birds orbit on a synchronous, equatorial orbit. The inclination is < three degrees.

3. Shape/Dimensions

The DSCS II satellite is shaped like a cylinder, nine feet in diameter, and six feet in height (13 feet overall).

4. Weight

The DSCS II satellite weighed 1350 pounds when launched.

5. Power Source

Solar cells and NiCd batteries provided approximately 520 Watts of power initially to the DSCS II, and 388 Watts minimum at the end of five years.

6. Stabilization/RPMs

The DSCS II satellite was spin-stabilized at 60 rpms, with 0.2 degrees antenna pointing accuracy. Hydrazine propulsion was also internalized for on-orbit use.

7. Configuration

The configuration of the DSCS II satellite was four channels with 50 to 185 MHz bandwidths, utilizing single conversion.

8. Capacity

The capacity of the DSCS II satellite was up to 1300 two-way voice circuits, or approximately 100 Mbps of digital data.

9. Transmitter

The DSCS II satellite contains two independent transmitters, one for the two earth coverage channels, and one for the two narrowbeam channels. Each transmitter has 20 Watts of output power, and satellites 13-16 have 40 Watts. The frequencies of operation are: 7250 to 7375 MHz, 7400 to 7450 MHz, 7490 to 7675 Mhz and 7700 to 7750 MHz. Earth coverage is specific at ≥ 7.5 degrees of earth terminal elevation angle. Narrowbeam and area coverage are anywhere within beamwidth.

a. ERP per Transmitter: Satellites 1 to 6

The ERP values provided for transmitter were as follows: 28 dBW was provided for earth coverage, 43 dBW for

one narrowbeam antenna, and 40 dBW for each of two narrowbeam antennas.

b. ERP per Transmitter: Satellites 7 to 12

The ERP provided for transmitters were as follows: 28 dBW was provided for earth coverage, 43 dBW for the narrowbeam antenna, 31 dBW for the area coverage antenna, and 40/28 dBW using both narrowbeam and area coverage (50% of power to each) antennas.

c. ERP per Transmitter: Satellites 13 to 16

The ERP provided for transmitters were as follows: 31 dBW was provided for earth coverage, 46 dBW for the narrowbeam antenna, 34 dBW for the area coverage antenna, and 40/33 dBW using both narrowbeam and area coverage (75% of power to area coverage) antennas.

10. Receiver

The receiver operated in the 7900 to 7950 MHz, 7975 to 8100 MHz, 8125 to 8175 MHz, 8215 to 8400 MHz frequency range, with a noise figure of 7 dB. The receiver also had tunnel diode preamplifiers and limiter/amplifiers.

11. Antenna

The DSCS II satellites have two earth coverage horn antennas (one to transmit and one to receive), which provide 16.8 dB gain at edge of earth; two narrowbeam parabola antennas, 44 inches in diameter, that provide a 2.5 degree beamwidth with 36.5 dB gain on axis, and they are steerable to

± 10 degrees of each axis. On satellites seven to 16, one antenna has been defocused to a 6 degree beamwidth for area coverage. All antennas are mounted on a despun platform and are circularly polarized.

C. DSCS III

1. Design Life

The design life of the DSCS III is 10 years. The mean mission duration (MMD) is expected to be seven years.

2. Orbit

The DSCS III satellite orbits in a synchronous equatorial orbit. Onboard thrusters allow the constellation a North-South, East-West stationkeeping capability with ± 0.1 degree of station.

3. Shape/Dimensions

The DSCS III has a rectangular body, approximately 6 feet x 6 feet x 10 feet. When the solar arrays are deployed, the overall wingspan is approximately 38 feet.

4. Weight

Satellites one through three weighed 2475 pounds once placed in orbit. The design weight was increased to 2580 pounds beginning with satellite number four.

5. Power Source

Sun-tracking solar arrays and NiCd batteries power the DSCS III satellite. The arrays and batteries provide 1240

Watts of power to the bird at the time it is placed in orbit. This capability degrades to approximately 930 Watts after ten years.

6. Stabilization/RPMs

The DSCS III is three-axis-stabilized using reaction wheels. This technology provides 0.08 degree accuracy in pitch and roll correction, 0.8 degree correction for yaw, and 0.2 degree antenna pointing accuracy.

7. Configuration

The configuration of the DSCS III satellites one through seven is as follows: Channel 1 - 60 MHz (7975-8035), Channel 2 - 60 MHz (8060-8120), Channel 3 - 85 MHz (8145-8230), Channel 4 - 60 (8255-8315), Channel 5 - 60 MHz (8340-8400), and Channel 6 - 50 MHz (7900-7950). Satellites eight through 14 are provided a total of 30 MHz more bandwidth is as follows: Channel 1 - 50 MHz, Channel 2 - 75 MHz, Channel 3 - 85 MHz, Channel 4 - 85, Channel 5 - 60 MHz, and Channel 6 - 50 MHz.

8. Transmitter

The DSCS III birds have six transponders that can be configured to serve as transmitting antennas. The capabilities of the six channels are as follows.

a. Channels 1 and 2

Channels 1 and 2 have two 40 Watt TWTs (one operational and one spare). The effective isotropic radiated

power (EIRP) per channel is 40 dBW for the narrow coverage, multi-beam antenna (MBA). The EIRP/channel for the earth coverage MBA is 29 dBW and 44 dBW for the gimbaled dish antenna (GDA).

b. Channels 3 and 4

Channels 3 and 4 have two 10 Watt TWTs (one operational, and one spare). Beginning with satellite 4, the 10 Watt TWT is gradually being replaced with a 10 Watt transistor amplifier. This will improved to a 16 Watt transistor amplifier for the last seven DSCS III satellites. The EIRP/channel amounts are as follows: 34 dBW for the narrow-beam MBA, 23 dBW for the earth coverage MBA, 25 dBW for the horn antenna, and 37.5 dBW for the GDA.

c. Channels 5 and 6

Channels 5 and 6 have two 10 Watt TWTs (one operational, one spare), and these are gradually being replaced by a 10 Watt transistor amplifier beginning with satellite 4. The EIRP/channel for the horn antenna is 25 dBW.

d. Single Channel Transponder (SCT)

This is a UHF transponder of approximately 70 Watts, with a minimum EIRP of 21.3 dBW. The EIRP depends on the MBA configuration.

9. Receiver

The six transponders can also be configured to operate as receive antennas. Channels 1 to 6 have gain-to-temperature

(G/T) ratios of 1 dB per degree kelvin (K) for the narrow coverage MBA, -16 dB/K for the earth coverage MBA, and -14 dB/K. The SCT has a G/T of -24.5 dB/K minimum.

10. Antenna

All antennas on the DSCS III antenna are circularly polarized. The constellation has one 45-inch receive MBA, two 28-inch transmit MBAs, one 33-inch gimbaled dish transmission antenna, two transmission horn antennas, two receive horn antennas, one transmit UHF crossed dipole antenna, and one receive UHF crossed dipole antenna.

a. Receive MBA

The 45-inch receive MBA has 61 narrow coverage beams, which are defined for a one degree cone.

b. Transmit MBAs

The two 28-inch aperture transmit MBAs have 19 narrow coverage beams, which are defined for a one degree cone.

c. Transmit GDA

The 33-inch, parabolic, transmit GDA is steerable with a tree degree beamwidth.

d. Horn Antennas

Both the pair of transmit and receive horn antennas have earth coverage capability.

e. UHF Antenna

The transmit and receive UHF crossed dipole antennas used for AFSATCOM have approximately 4 dB of gain at the edge of coverage.

**APPENDIX E. EXCERPTS FROM GOVERNMENT ACCOUNTING OFFICE
(GAO) REPORT GAO-NSTAD-93-216.**

The following paragraphs are direct quotations taken from Government Accounting Office (GAO) Report (GAO-NSTAD-93-216). [GAO, 1993, pp. 1-5]

In August 1989, the House Appropriations Committee (HAC) expressed concern that DoD's satellite communications architecture was in a state of disarray. It directed DoD to provide a comprehensive plan, defining all satellite communications requirements and potential solutions to meet the requirements within realistic resource levels. In October 1990, during deliberations on the fiscal year 1991 defense appropriations bill, the conference committee expressed dissatisfaction with the plan that DoD had provided in March 1990. The committee was concerned about the lack of a comprehensive architecture and directed DoD to submit a 'clear and affordable plan' with the fiscal year 1992 defense budget request.

In November 1991, DoD published its military satellite communications architecture study - the plan that the Congress had directed DoD to submit with its fiscal year 1992 budget request. The study identified 12 alternatives that outlined various communication approaches that ranged from using all commercial to all military satellite systems. The estimated life-cycle costs of these alternatives ranged from \$16 billion

for the all-commercial approach to \$58 billion for the most expensive all-military approach. From among the 12 alternatives, DoD selected an all-military approach consisting of existing systems, which it called the baseline architecture. This alternative had an estimated life-cycle cost of about \$55 billion.

The alternative DoD selected was the second-highest-cost alternative. The study stated that the baseline was the alternative for the 1990s primarily because of high mission supportability and low to moderate programmatic and system transition risk. The baseline architecture consists of major ongoing programs including MILSTAR, DSCS, and the Ultra-High Frequency Follow-On (UFO) systems. It consists of (1) plans for technology insertion to upgrade or replace these satellite systems at the end of their operational lives and (2) continued leasing of commercial satellite communication services to satisfy requirements that are unmet by military systems, including plans to increase the use of commercial systems for general purpose communications.

In October 1992, the conference committee report on the fiscal year 1993 defense authorization bill expressed additional concern about DoD's space investment strategy. It noted that (1) the declining defense budget will inevitably increase pressure to constrain or reduce spending on space programs and (2) increased efficiency and decreased costs will likely be necessary to sustain current systems and

capabilities and will certainly be required to afford new systems. Accordingly, the conferees directed the Secretary of Defense to develop a comprehensive acquisition strategy, aimed at reducing costs and increasing efficiencies for developing, fielding, and operating DoD space programs.

Congressional concern over the need for cost reductions and greater efficiencies may become even more important because DoD projects that its satellite communications capacity requirements will increase by 50 percent between 1992 and 1997. These requirements are measured in terms of throughput - the number of bits of information that can be passed through the satellites per second. In 1992, DoD's total requirements were one billion bits per second, whereas by 1997 its requirements are projected to be about 1.5 billion bits per second.

Considering the conflicting relationship between declining defense budgets and increasing satellite communication requirements, DoD is developing new cost estimates and alternatives for military communication satellites as part of the Secretary of Defense's ongoing "bottom-up" review of major defense programs. The review is to be completed by the end of July 1993 and is to provide guidance for upcoming acquisition decisions.

APPENDIX F. THROUGHPUT CALCULATIONS

A. THROUGHPUT IN PACKETS PER SECOND AND BITS PER SECOND

TRIB = Transfer Rate of Information Bits ~ Throughput

$$\text{TRIB} = \frac{\text{\# of information bits accepted on receive end}}{\text{time required to be accepted}}$$

The following data was provided by Motorola NES Customer Support Engineer, INFOSEC Systems Section, Olan J. Wade.

(Wade, 1993, pp. 4-9)

| Data Packet Size in Bytes | Throughput in Packets/Sec |
|----------------------------------|----------------------------------|
| 0 | 178 |
| 64 | 193 |
| 128 | 192 |
| 256 | 173 |
| 384 | 150 |
| 512 | 115 |
| 1024 | 78 |
| 1400 | 68 |

| Data Packet Size in Bytes | Throughput in Bits/Sec |
|---------------------------|------------------------|
| 0 | 85440 |
| 64 | 151312 |
| 128 | 248832 |
| 256 | 401360 |
| 384 | 460800 |
| 512 | 602320 |
| 1024 | 660192 |
| 1400 | 780096 |

*Note: 1 Byte = 8 bits

B. THROUGHPUT ANALYSIS (BITS PER SECOND)

Given: Data packet size in bytes and throughput in bits per second.

Find: Time y in μsec required for packet to be accepted.

1. **64 Byte Packet**

$$(64 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 151312 \text{ bits/sec}$$

$$y = (512 \text{ bits/packet}) \times (1 \text{ sec}/151312 \text{ bits})$$

$$y = 3.384 \mu\text{sec per 64 byte packet}$$

2. **128 Byte Packet**

$$(128 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 248832 \text{ bits/sec}$$

$$y = (1024 \text{ bits/packet}) \times (1 \text{ sec}/248832 \text{ bits})$$

$$y = 4.115 \mu\text{sec per 128 byte packet}$$

3. 256 Byte Packet

$$(256 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 401360 \text{ bits/sec}$$

$$y = (2048 \text{ bits/packet}) \times (1 \text{ sec}/401360 \text{ bits})$$

$$y = 5.103 \text{ } \mu\text{sec per 256 byte packet}$$

4. 384 Byte Packet

$$(384 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 460800 \text{ bits/sec}$$

$$y = (3072 \text{ bits/packet}) \times (1 \text{ sec}/460800 \text{ bits})$$

$$y = 6.667 \text{ } \mu\text{sec per 384 byte packet}$$

5. 512 Byte Packet

$$(512 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 502320 \text{ bits/sec}$$

$$y = (4096 \text{ bits/packet}) \times (1 \text{ sec}/502320 \text{ bits})$$

$$y = 8.154 \text{ } \mu\text{sec per 512 byte packet}$$

6. 1024 Byte Packet

$$(1024 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 660192 \text{ bits/sec}$$

$$y = (8192 \text{ bits/packet}) \times (1 \text{ sec}/660192 \text{ bits})$$

$$y = 12.409 \text{ } \mu\text{sec per 1024 byte packet}$$

7. 1400 Byte Packet

$$(1400 \text{ bytes} \times 8 \text{ bits/byte}) \div (y \text{ sec}) = 780096 \text{ bits/sec}$$

$$y = (11200 \text{ bits/packet}) \times (1 \text{ sec}/780096 \text{ bits})$$

$$y = 14.357 \text{ } \mu\text{sec per 1400 byte packet}$$

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