NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

ANALYSIS OF SATELLITE COMMUNICATION AS A METHOD TO MEET INFORMATION EXCHANGE REQUIREMENTS FOR THE ENHANCED COMPANY CONCEPT

by

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September 2008

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REPORT DOCUMENTATION PAGE		*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.		
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2008	**3. REPORT TYPE AND DATES COVERED** Master's Thesis
4. TITLE AND SUBTITLE Analysis of Satellite Communications as a Method to Meet Information Exchange Requirements for the Enhanced Company Concept		**5. FUNDING NUMBERS**
6. AUTHOR(S) Matthew A. Senn, James D. Turner		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.		
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited		**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

In the Global War on Terrorism and future irregular battlefields, the Marine Corps will not only fight in large-scale conventional war against sizable military forces but it will also engage adversaries that utilize smaller sized units dispersed asymmetrically over vast geographical locations. To address this emerging threat, the Marine Corps is developing the Enhanced Company (EC) concept, with the aim of providing the company commander with the tools necessary to make isolated decisions in an increasingly complex battlefield. In order to make timely, independent decisions and maintain information superiority these widely dispersed units will require organic access to services normally provided by higher headquarters. The Marine Corps Warfighting Laboratory is working to enhance the decision-making capabilities of the infantry company through the development of the Company Level Intelligence Center (CLIC) and the Company Level Operations Center (CLOC).

Current Marine Corps communications capabilities cannot meet the data demands of widely dispersed lower echelon units. The communications equipment organic to these units is mostly Line of Sight (LOS) technology. These systems limit the geographic dispersion of the units and are limited in data throughput capability. To allow for wider dispersion on the battlefield while providing the connectivity required for isolated decision making, these units require communications assets that are capable of operating Beyond the Line of Sight (BLOS) such as Satellite Communications (SATCOM) equipment.

This thesis will seek to analyze the use of SATCOM in support of the Enhanced Company Concept in a FOB environment. Using a Limited Objective Experiment, the authors will test if SATCOM technology is sufficient to support Information Exchange Requirements (IERs) developed in the laboratory and validated with experience. Based on the outcome of the experiments the thesis will provide recommendations regarding the use of such technology.

14. SUBJECT TERMS Distributed Operations, SATCOM, BLOS, OTH, Communications, Information Exchange Requirements, Enhanced Company, CLOC			**15. NUMBER OF PAGES** 87
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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ABSTRACT

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Current Marine Corps communications capabilities cannot meet the data demands of widely dispersed lower echelon units. The communications equipment organic to these units is mostly Line of Sight (LOS) technology. These systems limit the geographic dispersion of the units and are limited in data throughput capability. To allow for wider dispersion on the battlefield while providing the connectivity required for isolated decision making, these units require communications assets that are capable of operating Beyond the Line of Sight (BLOS) such as Satellite Communications (SATCOM) equipment.

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ACRONYMS AND ABBREVIATIONS

AES	Advanced Encryption Standard
AO	Area of Operations
AOR	Area of Responsibility
ASAS-L	All Source Analysis System-Light
BAT	Biometric Automated Toolset
BFT	Blue Force Tracker
BLOS	Beyond Line of Sight
C&S	Command and Staff
C2ID	Command and Control Integration Division
C2PC	Command and Control Personal Computer
C2	Command and Control
CAPESET	Capability Set
CASEVAC	Casualty Evacuation
CASREP	Casualty Report
CENETIX	Center for Network Innovation and Experimentation
CLOC	Company Level Operations Center
CLIC	Company Level Intelligence Center
COC	Combat Operations Center
CONOPS	Concept of Operations
CONUS	Continental United States
DAFIF	Digital Aeronautical Flight Informational File
DISA	Defense Information Systems Agency
DISN	Defense Information Systems Network
DO	Distributed Operations
EC	Enhanced Company
ECPs	Entry Control Points
EMT	Effects Management Tool
EPLRS	Enhanced Position Location Reporting System
EWS	Expeditionary Warfare School
FBCB2	Force Battle Control, Brigade and Below
FDC	Fire Direction Center
FOB	Forward Operating Base
GCE	Ground Combat Element
GEO	Geostationary
GPS	Global Positioning System
HIIDE	Hand-held Interagency Identity Detection Equipment
HQMC	Headquarters Marine Corps
HSI	Human-Systems Integration
IAS	Intelligence Analysis System
ICMP	Internet Control Message Protocol
ID	Identification
IERs	Information Exchange Requirements

IP	Internet Protocol
IPL	Imagery Product Library
IOS	Intelligence Operations Server
ISR	Intelligence, Surveillance and Reconnaissance
IOWs	Intelligence Operations Workstations
Kbps	Kilobits per second
LAN	Local Area Network
LOE	Limited Objective Experiment
LOS	Line of Sight
MAGTF	Marine Air-Ground Task Force
MEF	Marine Expeditionary Force
Mbps	Megabits per second
MCCDC	Marine Corps Combat Development Command
MCSC	Marine Corps Systems Command
MCTOG	Marine Corps Tactics and Operations Group
MCTSSA	Marine Corps Tactical Systems Support Activity
MCWL	Marine Corps Warfighting Lab
MIDB	Modernized Integrated Database
MSC	Main Support Component
MSR	Main Supply Route
NPS	Naval Postgraduate School
NRL	Naval Research Laboratory
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OPTEMPO	Operational Tempo
OTH	Over The Horizon
P2P	Point-to-Point
RF	Radio Frequency
RFI	Request for Information
SATCOM	Satellite Communications
SITREP	Situation Report
SNMP	Simple Network Management Protocol
SOF	Special Operations Forces
SOP	Standard Operating Procedures
TCP	Transmission Control Protocol
T/E	Table of Equipment
T/O	Table of Organization
TTPs	Tactics, Techniques and Procedures
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UUNS	Urgent Universal Needs Statements
VMF	Variable Message Format
VTC	Video Teleconference
WAN	Wide Area Network

ACKNOWLEDGMENTS

The authors would like to thank the following individuals:

For their guidance and insight:
Dr. Bordetsky, NPS
Mr. Welch, NPS
LtCol Oros, NPS

For the technical support and on the job training:
Donovan Dinger, Swe-Dish
Michael Clement, NPS CENETIX Lab
Maj Cornell, MCTSSA
Eric Gay, MCTSSA

For their theoretical input, support and discussion:
Maj Browne, MCWL
The Officers of 1/7, 29 Palms
LtCol Buzby, MCTOG

And of course, our families for their consistent and unflagging support during all of our Marine Corps career endeavors.

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I. INTRODUCTION

A. BACKGROUND

Traditionally, the Marine Corps brings Defense Information Systems Network (DISN) services into a theater via satellite terminals located at Marine Expeditionary Force (MEF) and Major Subordinate Command (MSC) headquarters. Various terrestrial based transmission terminals then distribute these services to the subordinate Marine forces in the Area of Responsibility (AOR). Lower echelon units tend to use low bandwidth terrestrial systems for reach back to higher headquarters. Since the Gulf War, bandwidth requirements have grown exponentially at all levels of organization, including at lower echelon units such as infantry battalions and companies; the Defense Information Systems Agency (DISA) claims that at the peak of Operation Iraqi Freedom "3 Gbps of satellite bandwidth was being provided to the theater . . . 30 times the bandwidth made available during [Desert Storm]."[1] Current urban and asymmetric operations in Iraq and Afghanistan have served to further increase the demand for bandwidth. In order to meet this increase in demand, the Marines have distributed terminals designed to handle large traffic loads as well as satellite communications services, typically organic equipment at the regiment or higher echelons, as far down as battalion-sized units. Marine Corps units identifying a capability gap in communications at the lower echelons have submitted numerous Urgent Universal Needs Statements (UUNSs) to expedite a solution to the problem. Efforts are currently underway at Headquarters Marine Corps (HQMC), Marine Corps Combat Development Command (MCCDC), and Marine Corps Systems Command (MCSC) to research and procure solutions to meet the bandwidth shortfall for battalion-sized units and below operating using current tactics, techniques and procedures.

Since 1963, when MCO 3120.3, formalized the Marine Air-Ground Task Force (MAGTF) the Corps has structured its forces using a scalable and balanced air-ground,

[1] Leland Joe and Isaac Porche III, *Future Army Bandwidth and Capabilities* (Santa Monica, CA: Rand Corporation, 2004).

combined arms task organization.[2] This modular breakdown into ground, air, and support elements has provided great utility in organizing and deploying appropriately sized forces for conventional conflicts throughout history. Based on lessons learned from past and current conflicts and a forecast increase in the number of future asymmetric battlefields, the Marine Corps is developing concepts to fight an elusive adversary who utilizes small, vastly distributed units to engage in localized yet very violent actions and who makes every attempt to avoid a conventional massed force on force battle. The Marine Corps describes these types of threats as "hybrid challenges"[3]; challenges that will require new ways of deploying and better trained and equipped small unit leaders. As part of the effort to expand abilities to operate in a more dispersed environment the Marine Corps is developing a concept labeled *Enhanced Companies* (EC). This new concept focuses on company size and below units dispersed in urban terrain or at such distances that limit conventional support capability of higher or adjacent units. These units will rely, more than ever, on the spirit of commander's intent and increased autonomous decision support capability to execute key, isolated actions that may have strategic impact. To make informed and timely decisions, these dispersed forces will require the capability to organically gather and process information typically passed from higher. These units will not be able to count on the already overtaxed, smaller bandwidth, and distance/terrain limited information exchange technologies that exist on today's battlefield to provide that data.

Special-operations Forces (SOF) unit deployments are autonomous in nature and are inherently able to respond to both symmetric and asymmetric threats. Most SOF units deploy at great distances from adjacent and higher units. Those units are often called "disadvantaged users" in part due to the complex terrain they deploy to, their requirement for mobility as well as their limited capability to haul or power large pieces of communications equipment. However, SOF units are still able to execute their mission effectively because they are equipped with technology that adequately supports

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[2] Edwin H. Simmons. *The United States Marines: A History, Fourth Edition* (Annapolis, Maryland: Naval Institute Press, 2003).

[3]USMC, *USMC Vision & Strategy 2025*, http://www.marines.mil/units/hqmc/cmc/Documents/MCVS2025%2030%20June.pdf (accessed 17 September 2008).

their information exchange requirements. SOF and dispersed USMC units will never execute the same mission set, however, the manner in which each type of unit deploys to execute its particular mission and the inherent communications requirements an Enhanced Company and its platoons will encounter are comparable. Both types of units may be operated beyond the range of normally deployed equipment or in environments where that equipment may not be effective and therefore must substitute alternate technology for traditional methods of communication. SOF has successfully translated this dispersed type deployment directly into requirements documents to procure SATCOM equipment that provides the necessary links and bandwidths. The success SOF have enjoyed as a "disadvantaged user" may serve as a model for capabilities in support of Enhanced Companies, if not an initial vector for Marine Corps planners.

This thesis will analyze the utility of satellite communications in support of the Enhanced Company concept by validating forecast information exchange requirements for a dispersed Marine infantry company and then conducting a Limited Objective Experiment (LOE) using SATCOM technology to measure the effectiveness with which the technology meets the validated Information Exchange Requirements (IERs). It will attempt to determine the best location for satellite terminals within the MAGTF structure at units higher, lower and adjacent to the infantry company. The thesis will also suggest which capabilities these terminals should have in order to meet the IERs of these units based on these experiments.

B. OBJECTIVES

The primary objective of this research is to determine if the use of SATCOM is a viable solution as an information exchange technology for use in the USMC Enhanced Company concept of deployment.

A secondary objective includes the validation of proposed USMC EC IERs through interviews with USMC infantry units with recent combat deployment experience in order to help determine which IERs and decision-making applications the dispersed unit will actually use. This objective helps lead the way towards establishing Standard

Operating Procedures (SOPs) and Tactics, Techniques and Procedures (TTPs) that future communication network architects can use to define capability sets for technology to meet those requirements.

The subject of this thesis is extremely narrow; as compared to the intricacies involved in developing an entire architecture that supports the EC concept. However, this work will not only provide a possible answer for future communication architects but will also serve as a starting point for developing joint information exchange technologies that will enable future network-centric warfare concepts.

C. RESEARCH QUESTIONS

The primary research question of this thesis seeks to determine if the IERs developed by the Naval Research Laboratory for the Marine Corps Warfighting Laboratory are valid and if so, the authors will seek to determine whether a particular SATCOM technology is satisfactory for information exchange by an Enhanced Company. Given a list of requirements and technologies, the authors will provide a recommendation as to the appropriate echelon in the Ground Combat Element (GCE) of the MAGTF for deployment of those technologies.

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this thesis will include:

The analysis of information exchange requirements associated with the Marine Corps Enhanced Company to include those exchange requirements essential for Intelligence, Maneuver, Logistics, Command and Control (C2), and Fire Support.

The analysis of a current SATCOM technology to determine if it can support the information exchange requirements mentioned above.

Field experiments at the Marine Corps Tactical Systems Support Activity (MCTSSA), located at Camp Pendleton, California.

Face to face interviews conducted with a combat experienced infantry battalion / company currently undergoing pre-deployment training.

E. METHODOLOGY

In July of 2006, the Warfighter Human Systems Integration Laboratory at the U.S. Naval Research Laboratory (NRL) in Washington D.C. provided an assessment to the Marine Corps Warfighting Laboratory (MCWL) regarding a proposed optimal mix of devices for infantry companies and below operating in a Distributed Operations mode.[4] As part of the assessment, the NRL developed an information exchange list for each included node. The main objective of this thesis is to validate the list provided in the assessment by interviewing Communications, Intelligence and Operations Officers from Marine infantry units that have deployed in support of current contingencies around the world. The experiences of units that have deployed in real-world environments and in a manner similar to those conceptualized by the Marine Corps Tactics and Operations Group (MCTOG) for the Enhanced Company will provide a check to the laboratory developed IERs and perhaps serve as a basis for doctrinal information exchange requirements for EC deployments.

The authors will conduct field experimentation using a single current commercial technology with metrics designed to evaluate the utility of SATCOM to meet information exchange requirements in an Enhanced Company environment. Equipment performance will be measured to determine if that particular technology will have adequate bandwidth, be useable by those that will be utilizing the technology to communicate, and will meet the portability requirements consistent with widely dispersed and mobile units.

F. ORGANIZATION OF THESIS

This paper is divided into fivechapters as follows:

Chapter I consists of the Introduction, which provides a general overview of the background, purpose and methodologies associated with this research.

Chapter II will cover the currently published EC IERs, according to MCWL, and will vet that list by using input garnered from interviews with combat unit leadership.

[4] Coyne, et al., *Final Report: Company and Below Command and Control Information Exchange Study* (Washington D.C.: Naval Research Laboratory, 2006).

Chapter III contains information regarding the Limited Objective Experiments conducted in support of the thesis.

Chapter IV consists of an analysis of the data generated in the experiment outlined in Chapter III as well as the utility of that experiment.

Chapter V will provide conclusions regarding the findings of this thesis. It will also provide recommendations as to the feasibility of using SATCOM in the Enhanced Company Level Operations Center as well as recommendations regarding for further research and actions that will further support the objectives of this thesis.

II. ANALYSIS OF INFORMATION EXCHANGE REQUIREMENTS

A. OVERVIEW OF INFORMATION EXCHANGE REQUIREMENTS

The following sections explain the method used to generate a list IERs in support of the Limited Objective Experiment explained later in the thesis.

1. Background of Naval Research Laboratory Report for MCWL Experiment

a. Purpose of Report

In 2006, the MCWL Technology Division tasked the Human-Systems Integration (HSI) Laboratory, part of the NRL, with providing a human factors-based assessment of the optimal mix of communications modalities and technology at each communication node (point where information flows into and out of)[5]. The goal of the MCWL study was to identify the optimal set of communication modalities and gear for Distributed Operations (DO) equipped units. When first developed, the DO concept of deployment sought to permit small units to operate at distances beyond support from adjacent and higher command elements. In this regard, MCWL identified the primary technical limitation preventing traditionally deployed Marine units from adopting the DO mode is the range of their communications gear and the increase in communications burden that DO places on the small unit leaders. The Distributed Operations moniker used for the concepts being researched in 2006 has recently given way to similar concepts with different names.

The final report includes a DO communications task analysis, the information exchange list per node and the list of modes per exchange. For the purposes of this thesis, the authors will focus on the list of information exchanges

[5] Coyne, et al., *Final Report: Company and Below Command and Control Information Exchange Study* (Washington D.C.: Naval Research Laboratory, 2006).

where the company is a node and use that list as an experimental baseline for IERs for an Enhanced Company, operating in a Forward Operating Base (FOB) environment.

The content of the information exchange list and task analysis detail the common or significant communications likely to occur within an infantry company. The specific chains of communication detailed in this list are based upon an understanding of the likely concept of operations (CONOPS) for a company, or elements of a company operation in a DO mode, acquired through discussions and exchanges with other MCWL staff who were directly responsible for the experimentation and development of the DO concept.[6] Although not specifically developed as a comprehensive list for an Enhanced Company in a FOB environment this list is adequate as a starting point for developing a list of IERs. However, based on the fact that the list was developed in a laboratory environment, the IERs included need to be validated with real world experience to define what capabilities an Enhanced Company will rely on to complete its mission. The task analysis was organized by critical functions, with the primary function areas being Intelligence, Maneuver, Fire Support, Command and Control, and Logistics.

b. Company Critical Tasks

The purpose of any information exchange is to help rapidly and decisively execute critical tasks. The following is a list of those tasks deemed critical to mission success by the NRL report.[7]

Intelligence:
1) Collect Information
2) Disseminate Intelligence

Maneuver:
3) Conduct Tactical Movement
4) Engage Enemy with Direct Fire and Maneuver

Fire Support:
5) Employ Mortars
6) Employ Close Air Support
7) Employ Field Artillery

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[6] Coyne, et al., *Final Report: Company and Below Command and Control Information Exchange Study* (Washington D.C.: Naval Research Laboratory, 2006).

[7] Ibid.

8) Employ Naval Gunfire
9) Coordinate, Synchronize and Integrate Fire Support

Command and Control:

10) Plan for Combat Operations
11) Direct and Lead Unit during Preparation for the Battle
12) Direct and Lead Units in Execution of Battle

Logistics:

13) Handle Combat Support Issues (e.g., casualties, supply, POWs)

2. Information Exchanges Where Company is a Node

Table 1 gives a brief synopsis of the specific IERs generated by the NRL in which the Company Combat Operations Center (COC) is expected to be a node.[8] The exchanges can occur either up to the battalion, down to the platoon commander or to adjacent or supporting units. A detailed description of each information exchange and the HSI Laboratory suggested method and means of dissemination is provided in Chapter III, Paragraph A.2.b; Experiment Specifics.

The officer leadership of the 1st Battalion, 7th Marine Regiment, stationed aboard MCB Twenty-nine Palms, California, were interviewed in person and provided the list of IERs in Table 1. Those officers, including the Battalion Commanding Officer, Operations Officer, Assistant Operations Officer, Alpha Company Commander and the Intelligence Officer were asked to validate the list by indicating whether or not the traffic would actually be sent, how often the traffic would be sent, and if the HSI laboratory's suggested method and means of dissemination was valid.

[8] Coyne, et al., *Final Report: Company and Below Command and Control Information Exchange Study*, (Washington D.C.: Naval Research Laboratory, 2006).

INE#	IER #	SHORT TITLE	GOAL
1	1.2.1	Situation Report (SITREP)	Pass important information through the chain of command
2	1.2.2	Report Enemy Activity	Report enemy sighting and movement up the chain of command
3	1.5	Urgent Unformatted	Provide information on current situation which requires immediate action
4	1.6	Routine Unformatted	Provide information which may not require immediate action
5	2.2	Distribute Intel. to lower	Pass relevant intelligence down the chain of command
6	2.4	Request for Information (RFI)	Pass on intelligence need
7	2.5	Request for Intel.	The Platoon Commander or above requests specific intelligence from Battalion
8	3.1	Issue FRAGGO	Provide fragment of Operation Order with Commander's intent to lower levels
9	3.2	Position Report at Check Point	Provide confirmation of arrival at designated area or next checkpoint
10	6.2	Call for Fire (Artillery)	Request for fire support from the Artillery Fire Direction Center (FDC)
11	6.3	Message to Observer (Artillery)	Provide observer with basic information regarding artillery support
12	6.4	Shot / Splash Calls (Artillery)	Round is released on target based on call for fire
13	6.5	Adjust Fire (Artillery)	Redirect artillery fire so it is on target
14	6.6	Report Effects (Artillery)	Inform Fire Direction Center (FDC) of effect on the target
15	7.2	Request Air from FSCC	Request to Fire Support Coordination Center for air asset support
16	7.4	9-Line Brief (Close Air Support)	Air asset and observer coordinate attack to neutralize target
17	7.5	Check-in (Close Air Support)	The observer makes visual contact with the air asset and confirms the target
18	7.6	BDA (Close Air Support)	Report Battle Damage Assessment of attack on target
19	8.1	Call for Fire (NSFS)	Round is release on target based on call for fire.
20	8.2	MTO (NSFS)	Provide observer with basic information regarding NSFS support
21	8.3	Shot / Splash Calls (NSFS)	Round is released on target based on call for fire
22	8.4	Adjust Fire (NSFS)	Redirect NSFS fire so it is on target
23	8.5	Report Effects (NSFS)	Inform Fire Direction Center (FDC) of effect on the target
24	10.1	Issue WARNO	A Warning Order is issued to allow a unit to prepare for an upcoming order
25	11.1	Bn Issues OPORD	Company Commander receives the Operation Order from the Battalion
26	13.1.2	Supply Request from CSS Unit	Acquire supplies from the Battalion's Combat Service Support Unit
27	13.2.1	Casualty Report (CASREP)	Inform higher of wounded members
28	13.2.2	Casualty Evacuation (CASEVAC) Request	Have a serious casualty moved from the battlefield for immediate care
29	13.2.3	Bn Responds to CASEVAC	Provide information to the CASEVAC requester on how evacuation will occur
30	13.2.4	CASEVAC Asset Responds	Inform small unit leader of inbound CASEVAC unit and coordinate pick up

Table 1. Summary List of IERs in which Company is a Node

B. INTERVIEW SUMMARY

1. Recent Combat History of 1st Battalion, 7th Marines

First Battalion, 7th Marines first deployed to Iraq in March of 2003. The Battalion saw significant combat action in its movement towards Baghdad and in the streets of the Iraqi capital. In April, the Battalion turned over control of their sector to the US Army and took up positions in the city of An Najaf. The battalion redeployed to Twenty-nine Palms, CA in October 2003. In August 2004, the battalion deployed to Western Iraq in support of Operation Iraqi Freedom II. There the battalion conducted security operations in the cities and roadways along the Euphrates River and Syrian border to include Husaybah, Karabilah, Sadah, Ubaydi, Al Qa'im, Haditha, Hit and Haqlania. Involved in combat operations on a daily basis, the battalion conducted mounted and dismounted urban patrols, cordon knocks, Main Supply Route (MSR) security, sweep operations, and border security in the battalion's Area of Operation (AO). From February through September 2006, 1st Battalion, 7th Marines deployed to the Al Qa'im Region in Western Iraq. The battalion occupied fifteen platoon and company battle positions, which controlled over 5,000 square miles in the Western Euphrates River Valley. Each platoon, paired with an Iraqi Army platoon and members of the local constabulary, yielded tremendous impact on security throughout the Al Qa'im region and in so doing, created the model for Dispersed Operations throughout the Iraq Theater. [9]

In addition to the Battalion's extensive combat experience and familiarity with dispersed operations, all of the officers interviewed in Twenty-nine Palms also had combat experience either in Iraq during OPERATION IRAQI FREEDOM (OIF) or Afghanistan during OPERATION ENDURING FREEDOM (OEF). Of note, the Battalion's current operations officer, Capt Jeremiah Salame, a company commander during the 2006 deployment, operated from a Forward Operating Base in which his

[9] "1/7 History," *1st Battalion, 7th Marines*, http://www.i-mef.usmc.mil/div/7mar/1bn/history.asp (accessed August 20, 2008).

company was located at distances that served to isolate the company from higher headquarters and the ease at which that headquarters provided traditional support.[10]

2. Warfighter Feedback

First Battalion, 7th Marines is currently in an intensive training phase to include participation in numerous field exercises, firearms training, small unit tactics and many other activities in preparation for an upcoming deployment in support of current contingencies. This demanding schedule has precluded the unit from participating fully in the research associated with this thesis. Although the officers were not able to provide input via a formal survey they did provide some valuable insight during face to face interviews conducted at their headquarters in August. Unfortunately and shortsightedly, no time was allowed to interview other units that perhaps would have be able to accommodate the research involved.

The essence of the feedback received from the officers of 1st Battalion was that any list of required IERs tend to be customized by the small unit leader based on personality, assigned mission and operating area. In general, most IERs are part of SOP or based on doctrine, such as Casualty Evacuation requests, calls for fire, and requests for re-supply. There are other exchanges whose format and frequency depend on the preferences of the small unit leader or higher headquarters. Where one particular operating environment may support the display of a Common Operating Picture, to include both hostile and friendly tracks, on a big screen television there may be other instances where the company commander will have to rely on a laminated map and semi-permanent markers to maintain situational awareness of the friendly and hostile situation. There exists no line item list of IERs and their associated method of display to date.

During the interview, a point was made regarding why “video” or “chat” was required for the isolated decision maker. It was hypothesized that those particular methods of information exchange were less useful for the small unit leader executing tactical tasking then it was for higher headquarters or even high level decision makers

[10] Capt Salame (1/7 Battalion Operations Officer), interview by Maj Senn, 1/7 Headquarters, Twenty-nine Palms, CA, August 19, 2008.

located "back in CONUS" to monitor, in real time, the battlefield half a world away. There appeared to be a hesitancy to embrace any technology that would allow those higher echelons the temptation of micro-managing small unit actions from behind a plasma screen. Another point of emphasis during the interview was the second and third order effects on the Table of Organization (T/O) and Table of Equipment (T/E) fielding new communications technology at the company level and below, in other words, such technology would require more manpower, more training, and more support equipment.

Finally, although not formally recorded using standardized survey forms, the informal feedback received regarding the MCWL IERs generally validated that each of the thirty IERs summarized in Table 1 were legitimate reports, requests, and coordinating efforts. Based on the Battalion's experience in the FOB environment however, the laboratory suggested method of broadcasting the reports via a conventional Radio Frequency (RF), either the PRC-117 or PRC-105 radio set, was dropped in favor of software applications similar to those in the MCWL draft for the Company Level Operations Center.

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III. FIELD EXPERIMENTATION

A. EXPERIMENTATION METHODOLGY

The original intent for the Limited Objective Experiment was to test a validated list of IERs derived from the MCWL IER study over the network architecture proposed in the MCWL draft Company Level Operations Center concept documents. Using the proposed CLOC battle rhythm and its associated sixteen daily reports (see Chapter III, Paragraph A.2.b) to higher, adjacent, and subordinate units as the baseline for information exchanges, data would be collected to include throughput, transaction rate, and response time. Various information exchange scenarios would be run in addition to the baseline reports to increase network traffic until maximum throughput was achieved. However, due to a lack of access to the proposed CLOC applications or data regarding those applications the experiment involved evaluation of the network using a commercially available software application called IX Chariot® (by IXIA™), to simulate various types of data traffic between two nodes (see Appendix B for more information regarding the software). No two data type tests, or "scripts," were run concurrently and no encryption was applied, however, the experiment provides a set of reference data on how certain types of application layer data may effect communication via a SATCOM link.

Initial assumptions made to support the experiment included:

1. SATCOM (or MILSATCOM) coverage is available in the AOR.
2. Company node deployed beyond doctrinal distances and beyond LOS RF communication equipment capabilities; dictating the use of SATCOM as the sole means to pass IERs.
3. SATCOM configuration is a point to point connection over a commercially available, small aperture satellite communication terminal, with a network configuration downstream of the SATCOM terminal similar to that in the MCTOG concept document.

4. Company has established a Company Level Operations Center in a Forward Operations Base configuration, operating according to the MCTOG concept battle rhythm and is passing the MCWL defined list of IERs.

In addition to measuring data regarding IERs, another Master's degree candidate conducted concurrent experiments regarding Simple Network Management Protocol (SNMP) over the experimental network. The effects of the SNMP experiment on the LOE will be discussed in section 2 of this chapter.

All experiments were conducted at the Marine Corps Tactical Systems Support Activity, located on board MCB Camp Pendleton, California. MCTSSA generously donated previously leased satellite airtime, a cost that would have otherwise been prohibitive to the conduct of theses experiments.

1. Experiment Scenario

The scenario simulated in the LOE consisted of a Point-to-Point (P2P) connection between a battalion COC and a FOB CLOC over a geostationary (GEO) satellite utilizing two small aperture satellite terminals. A single workstation at the battalion COC would interact with a single workstation at the company COC, executing various types of information exchanges one would expect from workstations populated with the recommended decision making software applications. Power output at either SATCOM terminal would be limited in order to prevent bleed-over to adjacent channels on the leased satellite or adjacent satellites in geostationary orbits and hence there was no opportunity to increase bandwidth by increasing the gain of either terminal.

2. Experiment Specifics

The following paragraphs will detail the physical configuration, the representative IERs sent on the network, and the software suite used for the experiment. Definitions of the metrics used by the evaluation software to produce the data collected will also be provided.

a. Network (Physical) Configuration

Figure 1 shows the MCWL proposed network architecture for the CLOC concept of employment. The Wide Area Network (WAN) consists of a satellite or terrestrial communication terminal connected to the "cloud," which symbolizes external communication services, such as the internet or a database server. Line encryption between the communication terminal and the Layer 3 router provides security while the Layer 3 router serves as the cross over from the WAN to the Local Area Network (LAN). The Layer 2 or 3 switch distributes information packets to the appropriate node on the local backbone.

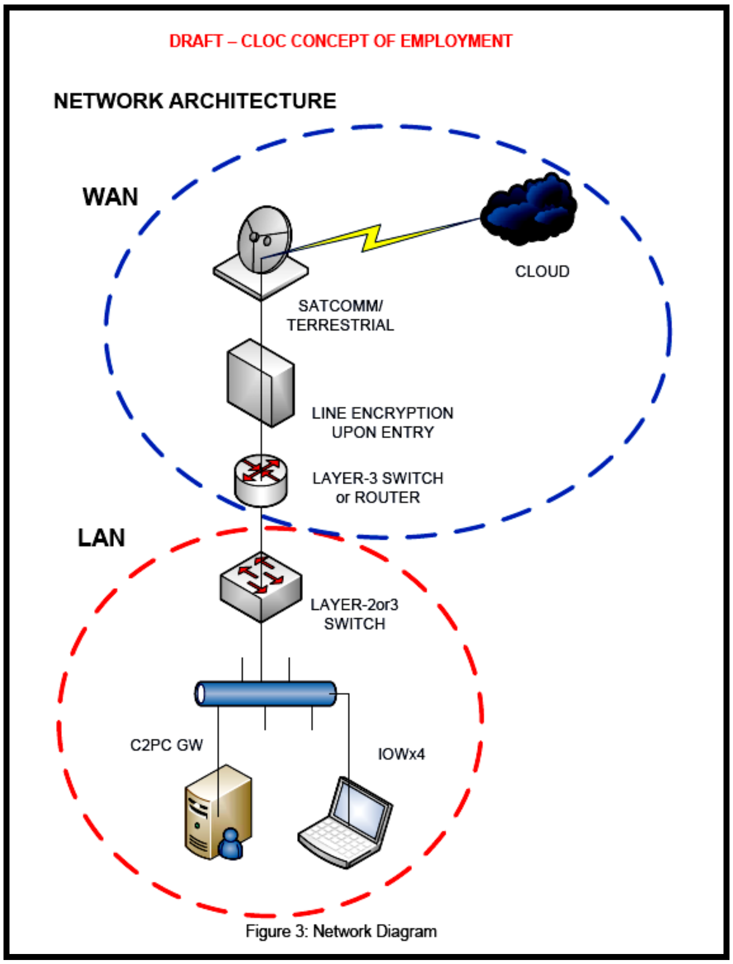

Figure 1. MCWL Concept Network Architecture[11]

[11] MCWL, *DRAFT-CLOC CONCEPT OF EMPLOYMENT*, (Quantico, VA: U.S. Marine Corps, 2007).

Figure 2 shows the actual network architecture used during the LOE. To establish a communications network, two Swe-Dish IPT-I Mil Suitcase terminals, version 2.4, were utilized as the communication terminal at both the battalion and company COC. Connected to the SATCOM terminal was a Cisco 2800 Router in line with a Cisco Catalyst 2950 Switch to route information data to the appropriate node on the LAN. Although the 2800 routers are capable of Advanced Encryption Standard (AES) type encryption, this LOE did not incorporate that capability.

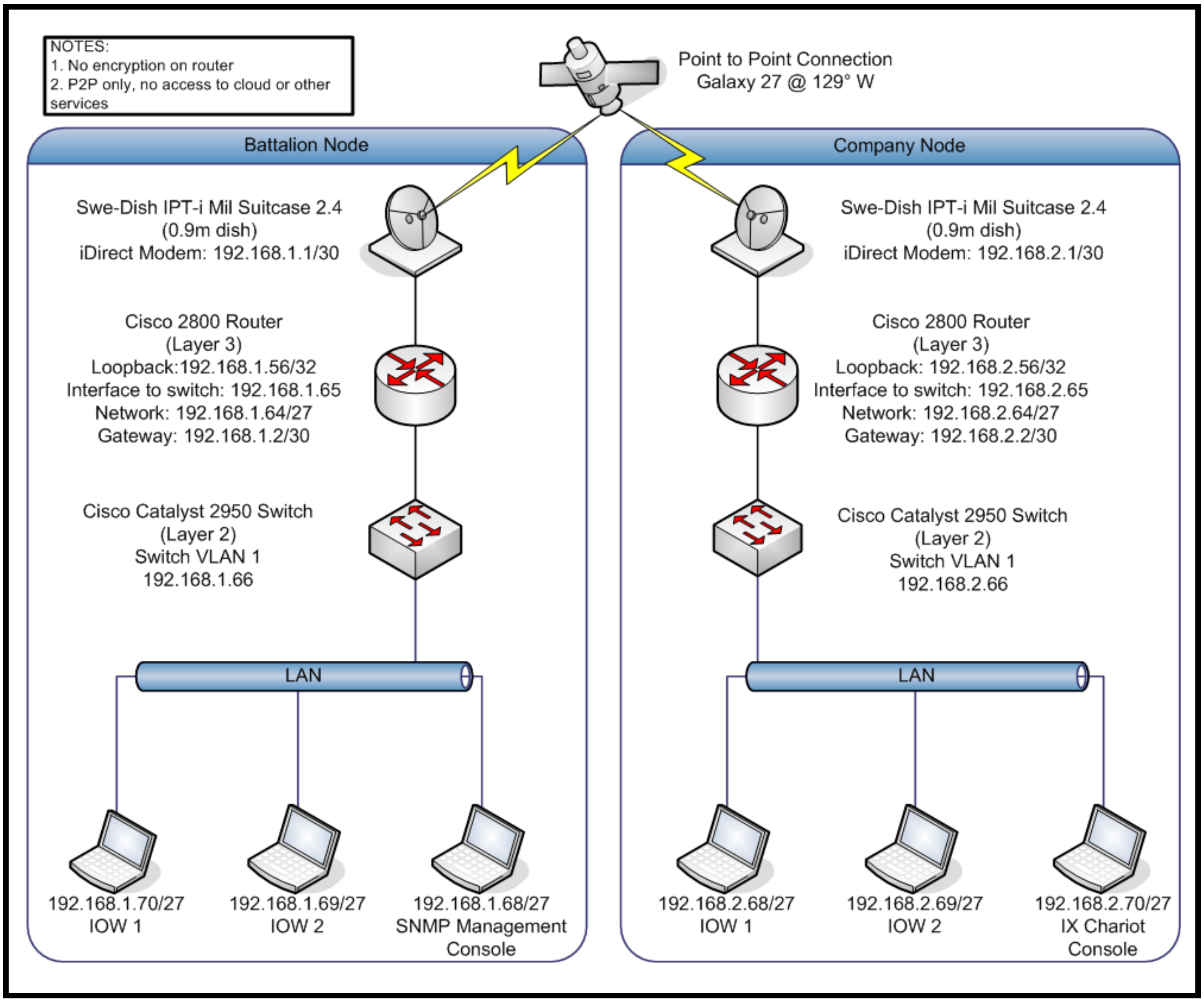

Figure 2. LOE Network Architecture

At the battalion node, one workstation served as the SNMP management console, while a workstation at the company node served as the IX Chariot® console, or controlling node. Various other workstations at both the battalion and company node acted as IX Chariot® "endpoints," which will be described in the Paragraph 1.c to follow.

The Swe-Dish IPTs, on loan from the Naval Postgraduate School's Center for Network Innovation and Experimentation (CENETIX), are Ku band (12-18 GHz) terminals with 0.9m diameter Gregorian offset dishes. The system advertises a capability of a 2Mbps duplex transmission of IP standard data, voice and video. Using MPEG2 video encoding the IPT Suitcase provides broadcast picture quality. With its 10/100 base-T port, the system works as an ordinary LAN for email, FTP, VoIP and data streams. An L-band port is optional.[12] For additional technical information on the Swe-Dish IPTs, see Appendix A.

b. Information Exchanges and Application Configuration

As previously discussed, the intent of the LOE was to test a particular set of IERs over a specific network configuration to determine the feasibility that such a network could support the information exchanges. The example battle rhythm, excerpted directly from MCWL's CLOC Concept of Employment (2007), will serve as a baseline requirement for the amount and frequency of information exchanges occurring at the company level.

EXAMPLE BATTLE RHYTHM

A 24-hour battle rhythm may include the following activities:

2345 Watch Officer change over
2345 Radio Watch change over
0000 CONOPS report due to Bn
0000 Ops/Intel NCO print digital watch log and place in binder
0530 Platoon POSREPs due to Co

[12] *Instructions for Use, IPT-I Mil Suitcase 2.4, Satellite Communications Terminal featuring iDirect,* CD-ROM, SWE-DISH Satellite Systems AB, 2007.

0545 Ops / Intel NCO change over

0600 Platoon personnel updates due to Co

0630 Platoon LOGSTATS due to Co

0630 Co POSREPs due to Bn

0645 Company ECP status reports due to Bn

0730 Intel (collections) change over

0745 Watch Officer change over

0745 Radio Watch change over

0745 Intel (analysis) change over

0800 CONOPS report due to Bn

1130 Platoon POSREPs due to Co

1200 Intentions message due to Bn

1230 Co POSREPs due to Bn

1345 Ops / Intel NCO change over

1400 Co personnel updates due to Bn

1400 Company personnel updates due to Bn

1430 Company LOGSTATS due to Bn

1430 Bn POSREPs due to Regt

1445 Company ECP status reports due to Bn

1530 Intel (collections) change over

1545 Watch Officer change over

1545 Radio Watch change over

1545 Intel (analysis) change over

1930 Platoon POSREPs due to Co

2000 Intentions message due to Bn

2030 Co POSREPs due to Bn

2200 Bn Personnel Stats due to Regt

2345 Watch Officer change over

Once the baseline is tested, the amount and frequency of exchanges will be incrementally increased by simultaneously sending various information exchange scenarios along with the previously discussed baseline. Detailed listings of those information exchanges, excerpted from the U.S. Naval Research Laboratory Final Report: Company and Below Command and Control Information Exchange Study (2006), are included below.

DETAILED INFORMATION EXCHANGE REQUIRMENTS

1.2.1 Provide a Situation Report (SITREP)

Goal: Pass important information through the chain of command.

Description: Report information up the chain of command and horizontally when it is either critical, or an opportunity has presented itself to provide a larger report of less critical items.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	FT LDR	SQD LDR	Other FT LDRs	Squad Net
	SQD LDR	PLT CDR	Other SQD LDRs	Platoon Net
	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	BN CDR	Other Co Cos	Battalion Net
Information	Anything unusual such as trash that has not been picked up, potential IEDs. The formality of the exchange will depend on proximity, urgency, and experience. The exchange is more likely to be formal at higher levels of command as more information is filtered out.			
Purpose:	Provide battlefield information to higher level of command and others at the same level of command.			
Potential Problems:	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	PLT CDR: Voice Comms Co CO: Voice Comms		AN/PRC-150 w/ D-DACT AN/PRC-117F (SATCOM)	

1.2.2 Report Enemy Activity (SALUTE)

Goal: Report Enemy Sighting and Movement up the chain of command.

Description: Report information up the chain of command and horizontally regarding enemy sightings and movement. Information reported contains the enemy size, activities, location, unit identification, time, and equipment.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges	SQD LDR	PLT CDR	Other SQD LDRs	Platoon Net
	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	BN CDR	Other Co COs	Battalion Net
Information	The formality of the exchange will depend on proximity, urgency, and experience. The exchange is more likely to be formal at higher levels of command as more information is filtered out. A SALUTE Report contains Size of enemy force, Activities of the enemy, Location of enemy, Unit identification, Time, and Equipment carried by enemy.			
Purpose:	Provide intelligence on enemy movement to higher level of command and others at the same level of command.			
Potential Problen	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Plt CDR: Visual / Graphical Co CO: Visual / Graphical		AN/PRC-150 w/ D-DACT AN/PRC-117F (SATCOM)	

1.5 Urgent Unformatted Reports

Goal: Provide information on current situation which requires immediate action

Description: This is a generic communication for transmitting urgent information. It can be passed either up or down the chain.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchang	Bn	Co CO	Other PLT CDRs	Battalion Net
	CoCO	PLT CDR	Other PLT CDRs	Company Net
	PLT CDR	SQD LDR	Other SQD LDRs	Plt Net
	SQD LDR	FT LDR	Other FT LDRs	Sqd Net
Information	The is a generic communication type and is used when urgent information needs to be reported immediately up or down the chain of command. An example is a request for support.			
Purpose:	Provide actionable information to designated units.			
Potential Problem	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	PLT CDR: Voice Comms Co CO: Voice Comms		AN/PRC-150 w/ D-DACT AN/PRC-117F (SATCOM)	

1.6 Routine Unformatted Reports

Goal: Provide regular information on current situation which may not require immediate action

Description: This is a generic communication for transmitting regular information. It can be passed either up or down the chain.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchang	Bn CDR	Co CO	Other Cc COs	Battalion Net
	Co CO	PLT CDR	Other PLT CDRs	Company Net
	PLT CDR	SQD LDR	Other SQD LDRs	Plt Net
	SQD LDR	FT LDR	Other FT LDRs	Sqd Net
Information	The is a generic communication type and is used when regular information needs to be reported immediately up or down the chain of command. An example is a request for support.			
Purpose:	Provide information to designated units.			
Potential Problem	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	PLT CDR: Voice Comms Co CO: Voice Comms		AN/PRC-150 w/ D-DACT AN/PRC-117F (SATCOM)	

2.2 Distribute Intelligence to Lower Level of Command

Goal: Pass relevant intelligence down the chain of command

Description: Report relevant battlefield intelligence down the chain of command. This will allow the lower levels of command to maintain a battlefield Situation Awareness. Actionable intelligence will be sent down the chain immediately.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Co CO	PLT CDR	Other PLT CDRs	Company Net
	PLT CDR	SQD LDR	Other SQD LDRs	Platoon Net
	SQD LDR	FT LDR	Other FT LDRs	Squad Net
Information	There is no official format for intelligence passed down the chain of command.			
Purpose:	Provide a “heads up” to lower levels of command.			
Potential Problems:	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Visual/Graphical		AN/PRC-150 w/ D-DACT	

2.4 Request for Information (RFI)

Goal: Plt CDR / Co CDR informs the Co CDR / BN of an intelligence need.

Description: Subordinate LDR will request intelligence from higher.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	BN CDR	Other Co CO	Battalion Net
Information	Subordinate LDR informs higher of what information they need			
Purpose:	Indicate a need for intelligence to higher			
Potential Problems:	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Plt CDR: Voice Co CO: Voice		AN/PRC-150 w/ D-DACT AN/PRC-117F (SATCOM)	

2.5 Request Intelligence from Battalion S-2

Goal: The Company Commander requests specific intelligence from the Battalion S-2

Description: The Platoon Commander goes to the battalion S-2 to request an intelligence update. The Platoon Commander would usually only go direct to Battalion if they were the only platoon ashore.

Communication:

	Sender:	Receiver:	Monitor:	Network:
	Co CDR	Bn S-2	N/A	Battalion Net
Information	The Company CO requests specific information from the Bn S-2.			
Purpose:	Solicit information from the Bn-S2.			
Potential Problems:	None assuming a single Platoon ashore with the Company CO monitoring communications in the Battalion Command Operations Center (COC). Leaving the Company network would not present any problems since the Company Commander will still be able to monitor the Platoon's communications.			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Voice		AN/PRC-117F (SATCOM)	

3.1 Issue FRAG Order

Goal: Provide Mission Order with Commander's Intent to lower levels of command.

Description: The Frag order is a fragment of the Operation Order (OPORD). It informs lower units of their responsibilities within the OPORD. It should ideally leave the specific details to the lower level of command. For example the Company CO may inform a Platoon CDR to set up ambushes within a general area and where to expect enemy movement. The Platoon CDR then decides where to place the Squads to set up the ambush.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Bn CDR	Co CO	Other Co COs	Battalion Net
	Co CO	PLT CDR	Other PLT CDRs	Company Net
	PLT CDR	SQD LDR	Other SQD LDRs	Platoon Net
	SQD LDR	FT LDR	Other FT LDRs	Squad Net
Information	Provide information on the mission objective and the commander's intent, but allowing flexibility on how the mission will be carried out. Ideally this should contain all 5 elements of SMEAC. Situation (enemy and friendly forces), Mission, Execution (Commander's intent, concept of operation, etc), Administrative/Logistics, Command/Signal.			
Purpose:	Provide an objective to the Marine unit without necessarily forcing a specific solution.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Bn CDR: Visual / Graphical Co CO: Visual / Graphical		AN/PRC-117F (SATCOM) AN/PRC-150 w/ D-DACT	

3.2 Position Report at Designated Area/Check Point

Goal: The unit moves to either their designated area or their next checkpoint and then reports in.

Description: Unit provides position reports to keep the commanding officer informed on where the unit is and when they will be at their next designated area.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	FT LDR	SQD LDR	Other FT LDRs	Squad Net
	SQD LDR	PLT CDR	Other SQD LDRs	Platoon Net
	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	Bn CDR	Other Co COs	Bn Net
Information	Identify commanding unit, your unit, and the brevity code for the check point.			
Purpose:	Update your commanding unit of your present position.			
Potential Problems:	Range Limitations			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Visual / Graphical PLT CDR: Visual / Graphical		AN/PRC-117F (SATCOM) AN/PRC-150 w/ D-DACT	

6.2 Call for Fire (Artillery)

Goal: Platoon Commander requests fire from the artillery FDC

Description: Self explanatory.

Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	Co CO	Arty FDC		Battalion COF
Information	Standard Call For Fire (CFF) format			
Purpose:	Inform FDC about target so that artillery can be employed			
Potential Problems:	• Information is being relayed from initial source. Potential for interpretation errors in voice data transmission. • Currently need to talk to the FDC and the observer on two different radios. Cannot have one listen in while relaying information to the other. • The Platoon Commander would have to switch off the company net to go to the battalion FSCC net as both use the PRC-119/150. • Inform FDC of where fire is going to increase the splash time.			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Visual / Graphical		AN/PRC-150	

6.3 Message to Observer

Goal: Inform the observer who will be firing and what the volleys in effect are.

Description: This is the message from the FDC to the observer that details who will fire, any changes to the CFF, the number of volleys in effect and the target number.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Arty FDC	Co FST Arty Rep		Battalion COF
Information	1. Firing Unit 2. Changes/Additions to the CFF 3. Rounds in Effect (Number of Volleys) 4. Target Number			
Purpose:	Notify observer of any changes to the CFF and inform them of what the fire will be.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150	

6.4 Report Shot and Splash

Goal: Notify Company Commander of incoming rounds.
Description: Self explanatory
Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Arty FDC	Co FST Arty Rep		Battalion COF
Information	Shot is fired 1. Arty announce shot (i.e., "Shot over") 2. Company acknowledges (i.e., "Shot out") Ten seconds before impact: 3. Arty announces "Splash over" 4. Company acknowledges "Splash out"			
Purpose:	Notify Company of shot fired and its predicted impact.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150	

6.5 Adjust Fire (Artillery)

Goal: Redirect artillery fire so it is on target.
Description: Self explanatory
Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	Co FST Arty Rep	Arty FDC		Battalion COF
Information	Notify FDC to shift fire Left/Right and Add or Drop 1. Identification (FDC this is_____) 2. Warning Order (either adjust fire, fire for effect, immediate suppression, smoke, SEAD) ******FDC reads back information******* 3. Location of target (shift)			
Purpose:	Notify FDC to adjust mortar.			
Potential Problems:	• Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150	

6.6 Inform FDC of artillery's effect.

Goal: Inform FDC of artillery's effect on the target.

Description: Self explanatory

Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	Co CO	Arty FDC		Battalion COF
Information	Notify Artillery that the target has been destroyed, suppressed, or where additional fire should be delivered.			
Purpose:	Provide Artillery with a BDA			
Potential Problems:	• Range limitations force this step in the communication process.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150	

7.2 Request air asset from Fire Support Coordination Center (FSCC).

Goal: Company commander seeks approval from FSCC to use an air asset to neutralize an identified target.

Description: Company commander evaluates the request for air and uses their experience to determine whether an air asset should be used. If an asset should be utilized, they "forward" the information from the Platoon CDR to the FSCC.

Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	Co FST Air Rep	FSCC or SACC		TAR/HR
Information	TAR*:* Unit identifier, priority, mission, payload, instructions, target type, location, assets being requested, desired ordnance/results, etc.			
Purpose:	Provide FSCC with information necessary to evaluate call for air with available assets and target priority. If necessary allocate the appropriate asset.			
Potential Problems:	• Information is being relayed from initial source. Potential for interpretation errors in voice data transmission. • Currently need to talk to the FSCC and the Observer/ Squad node on two different radios. Cannot have one listen in while relaying information to the other. • If Aircraft is not available FSCC or currently under the FSCC's control they may need to keep the company commander on "hold" thus potentially keeping them off the company net.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Visual/Graphical		AN/PRC-117F (SATCOM)	

7.4 Air Asset and Observer coordinate attack (9 Line)

Goal: Neutralize target.

Description: The Observer has been told the CFF has been approved, and is provided information on contacting the Air Asset. The Observer communicates with asset to coordinate the attack and provides a standard nine line.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Co FST Air Rep	Air Asset	FSCC	Air Asset's Frequency
Information	Standard "9-Line" Format			
Purpose:	Provide target information to the air asset; neutralize the target.			
Potential Problems:	• De-confliction with other forces in area is traditionally done at the platoon or Co level.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Visual/Graphical (w/ audio)		AN/PRC-150 with D-DACT	

7.5 Air Asset Enters Target Area and Confirms Target

Goal: The observer makes visual contact with the air asset and confirms the target.

Description: The air asset enters into the designated air space and requests confirmation from the observer. The observer visual identifies the air asset is lined up and confirms the attack.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Co FST Air Rep	Air Asset	FSCC	Air Asset's Frequency
Information	• Aircraft will announce that they are inbound and distance from target • Observer will inform aircraft to continue • Observer will inform aircraft of where the target is from the mark. • Aircraft goes into "the pop" and observer confirms aircrafts location. • Aircraft goes "wings level" and proceeds to target • Observer confirms aircraft is inbound to target and announces "Cleared Hot"			
Purpose:	Confirm target location and direct aircraft to the target.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150 with D-DACT	

7.6 Observer reports Battle Damage Assessment (BDA) of target back to Air Asset.

Goal: Report effectiveness of attack.

Description: The Observer communicates with Air Asset to report damage to target.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Co FST Air Rep	Air Asset	FSCC	Air Asset's Frequency
Information	Target neutralized, damage assessment, new coordinates, etc.			
Purpose:	Provide damage information to the Air Asset			
Potential Problems:	• Aircraft may leave the area (range issue)			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-150 with D-DACT	

8.1 Call for Fire (Naval Gunfire)

Goal: The company commander requests fire from Naval Guns

Description: Self explanatory

Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	Co CO	Naval FDC		?
Information	Standard Call For Fire Format			
Purpose:	Inform FDC about target so that artillery can be employed			
Potential Problems:	• Information is being relayed from initial source. Potential for interpretation errors in voice data transmission. • Inform FDC of where fire is going to increase the splash time.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-117F (SATCOM)	

8.2 Message to Observer

Goal: Inform the observer who will be firing and what the volleys in effect are.

Description: This is the message from the FDC to the observer that details who will be firing, any changes to the CFF, the number of volleys in effect, and the target number.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Naval FDC	Co CO		
Information	1. Firing Unit 2. Changes/Additions to the CFF 3. Rounds in Effect (Number of Volleys) 4. Target Number			
Purpose:	Notify observer of any changes to the CFF and inform them of what the fire will be.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice		AN/PRC-117F (SATCOM)	

8.3 Splash and Shot (Naval Gunfire)

Goal: Round is released on target based upon CFF

Description: Naval gun battery fires round and FDC announces shot and splash. The Announcement is passed down the chain to the observer.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Naval FDC	Co CO		
	Co CO	PLT CDR	Other PLT CDRs	Company Net
Information	Shot is fired 1. FDC announces shot (i.e., "Shot over") 2. Co CO acknowledges (i.e., "Shot out") 3. Co CO announces shot (i.e., "Shot over") 4. PLT CDR acknowledges (i.e., "Shot out") Fifteen seconds before impact: 5. FDC announces "Splash over" 6. Co CO acknowledges "Splash out" Ten Seconds before impact: 7. Co CO announces "Splash over" 8. PLT CDR acknowledges "Splash out"			
Purpose:	Notify Platoon of shot fired and its predicted impact.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice PLT CDR: Voice		AN/PRC-117F (SATCOM) AN/PRC-150	

8.4 Adjust Fire (Naval Gunfire)

Goal: Redirect Naval gunfire so it is on target.
Description: Self explanatory
Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	Naval FDC		
Information	Notify FDC to shift fire Left/Right and Add or Drop 1. Identification (FDC this is_____) 2. Warning Order (either adjust fire, fire for effect, immediate suppression, smoke, SEAD) ******FDC reads back information******* 3. Location of target (shift)			
Purpose:	Notify FDC to adjust fire.			
Potential Problems:	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice PLT CDR: Voice		AN/PRC-117F (SATCOM) AN/PRC-150	

8.5 Report on Rounds Effect (Naval Gunfire)

Goal: Provide information up the chain of command regarding effectiveness of naval gunfire.
Description: Self explanatory
Communication:

	Sender	Receiver	Monitor:	Network:
Potential Exchanges:	PLT CDR	Co CO	Other PLT CDRs	Company Net
	Co CO	Naval FDC		
Information	Notify up the chain of command that the target has been destroyed, suppressed, or where additional fire should be delivered.			
Purpose:	Inform the commanders on effectiveness of delivered rounds.			
Potential Problems:	• Range limitations force this step in the communication process. • This slows down the speed of the CFF.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Voice PLT CDR: Voice		AN/PRC-117F (SATCOM) AN/PRC-150	

10.1 Issue a Warning Order

Goal: A Warning Order is issued to allow a unit to prepare for an upcoming order.

Description: A warning order is issued to provide a unit to time to prepare for an upcoming order. It should contain as much information as is available at the time and follow the 5 paragraph SMEAC format as closely as possible.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	CO Co	PLT CDR	Other PLT CDRs	Company Net
Information	There is no official format for warning orders. It may include elements of a SMEAC or may simply instruct a unit to prepare to move out.			
Purpose:	Provide a "heads up" to lower levels of command that an order will be coming down the chain.			
Potential Problems:	Range limitations.			
HSI Recommended	Recommended Format		Recommended System	
	Co FST: Visual / Graphical		AN/PRC-150 w/ D-DACT	

11.1 Battalion Issues OPORD

Goal: Company Commander Receives the Operation Order from the Battalion

Description: The Operations Order (OPORD) it usually follows the 5 paragraph SMEAC format. It sets forth the **Situation**, the **Mission**, the plan and method of **Execution**, **Administration** and Logistics, and **Command** and Signal information.

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Battalion CDR	Co CO	Other Co COs	Battalion Net
Information	Provide information on the mission objective and the commander's intent, but allowing flexibility on how the mission will be carried out. Ideally this should contain all 5 elements of SMEAC. Situation (enemy and friendly forces), Mission, Execution (Commander's intent, concept of operation, etc), Administrative/Logistics, Command/Signal. The OPORD is a more formal document and may be distributed in a digital format.			
Purpose:	Provide an overall objective to the Marine unit without necessarily forcing a specific solution.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Visual / Graphical		AN/PRC-117F (SATCOM)	

13.1.2 Request Supplies from Combat Supporting Supply (CSS)

Goal: Acquire supplies from the Battalion's Combat Supporting Supply

Description: Self explanatory

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Co CO	CSS		Battalion Net
Information	Unit Identification, location, types of supplies needed, urgency of request.			
Purpose:	Acquire supplies from the Battalion's Combat Supporting Supply			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Visual / Graphical		AN/PRC-117F (SATCOM)	

13.2.1 Casualty Report (CASREP)

Goal: Inform commanding unit on wounded.

Description: Self explanatory

Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	PLT CDR	CO Co	Other PLT CDRs	Company Net
	Co CO	BN CDR	Other Co Cos	Battalion Net
Information	Number of casualties, types of injuries, urgency of request.			
Purpose:	Inform command unit on injuries. Determine the appropriate course of action for handling wounded.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	Co CO: Voice		AN/PRC-117F (SATCOM)	

13.2.2 Request Casualty Evacuation (CASEVAC) from Battalion

Goal: Have a serious casualty moved from the battlefield for immediate care.
Description: Self explanatory
Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	SQD LDR	Battalion	PLT CDR, Co CO	
	PLT CDR	Battalion	Co CO	
	Co CO	Battalion		
Information	Number of casualties, types of injuries, urgency of request.			
Purpose:	Inform command unit on injuries. Request immediate extraction of critically wounded marines.			
Potential Problems:	Range limitations.			
Questions	What radio would be used?			
HSI Recommended	Recommended Format		Recommended System	
	?		?	

13.2.3 Battalion Responds to CASEVAC Request and Provides Contact Information

Goals: Provide information to CASEVAC requester on how CASEVAC will occur.
Description: Self explanatory
Communication:

	Sender:	Receiver:	Monitor:	Network:
Potential Exchanges:	Battalion	SQD LDR	PLT CDR, Co CO	??
	Battalion	PLT CDR	Co CO	
	Battalion	Co CO		
Information	Type of CASEVAC asset that is inbound, how to contact asset, when asset will arrive.			
Purpose:	Provide information to CASEVAC requestor on how CASEVAC will occur.			
Potential Problems:	No identified problems			
HSI Recommended	Recommended Format		Recommended System	
	?		?	

SOFTWARE APPLICATIONS

The MCWL concept of employment for the Company Level Operations Center details several software applications to be made available for CLOC personnel to pass IERs via electronic means (e.g., e-mail attachments, live chat, etc.) vice traditional voice reports sent via portable radios. The paragraphs to follow provide detail regarding applications included at each CLOC work station.

COMMAND AND CONTROL PERSONAL COMPUTER (C2PC)

Intelligence Operations Workstations (IOWs) are the equipment suite, which provide automated support to the CLOC via the C2 application called C2PC. An IOW is simply a laptop inside the CLOC, which is pre-loaded with C2PC and many other software applications. C2PC provides map overlays, friendly unit locations with status and plans of intended movement, and hostile unit locations. C2PC is linked together within the CLOC via a Local Area Network (LAN) allowing rapid information exchange between staff sections, and they are also linked with adjacent, subordinate, and higher headquarters via a Wide Area Network (WAN). Using the Intelligence Operations Server (IOS), C2PC also links with the Intelligence Analysis System (IAS) for the reception of intelligence information and may be linked with the Enhanced Position Location and Reporting System (EPLRS) network (if used). C2PC provides an automated message generation and validation capability for the exchange of MTF messages and a capability to generate and validate Variable Message Format (VMF) messages. C2PC has multiple injectors that allow modular systems with an interface with other capabilities such as AFATDS through the Effects Management Tool (EMT).

C2PC Capabilities:

- Facilitates C2 functions
- Displays the CTP
- Simultaneously displays multiple, independent map windows
- Capable of displaying multiple areas of interest
- Supports over 200 different mapping datum

• Allows users to display mapping features including political boundaries, rivers, and major roadways

FORCE XXI BATTLE COMMAND BRIGADE AND BELOW – BLUE FORCE TRACKER (FBCB2-BFT)

Force XXI Battle Command Brigade and Below (FBCB2) – Blue Force Tracker (BFT) is a battle command information system designed for units performing missions at the tactical level. FBCB2-BFT displays the relevant SA picture of the battlefield. SA shows the user his location, the location of other friendly forces, observed enemy locations, and all known battlefield obstacles. FBCB2-BFT will be employed by the regimental CLOC, battalion CLOC, each company CLOC, and convoys and/or patrols traversing throughout the area of operations (AO). A significant advantage of FBCB2-BFT is that the information is passed via L-Band satellite. This means that it is not limited to Line-of-Sight (LOS) characteristics of the EPLRS network.

FBCB2-BFT Capabilities

• Automated Positional Reporting

• Displays Maneuver Graphics

• Free text and formatted messaging capability

• Over the Horizon (OTH) communications

• Message Transmitter providing ID, GPS location, Course, and Speed

BIOMETRIC AUTOMATED TOOLSET (BAT)

BAT provides a means of identifying people via fingerprint, iris scan, and photo identification (ID), which enables the creation of individual records. The system includes a laptop with the BAT software, a fingerprint scanner, an iris scanner, a digital camera, and an ID card printer. ID badges can be provided to residents of a city or other identified geographic area. By controlling the routes in and out of cities via Entry Control Points (ECPs), and only providing positively identified residents with badges, it creates an obstacle to others posing as residents. Using iris scans or fingerprints, Marines at ECPs can verify identity via connectivity to the shared records database. The Marine can access information such as the person's birth date, occupation, place of residence, and any documentation addressing affiliation with anyone involved in terrorist activities.

BAT Capabilities:

• Efficiently enroll, verify, and identify individuals encountered in the conduct of operations

• Rapidly compare identity information to watch lists.

• Rapidly record various types of information associated with an individual

• Rapidly recall, update, and manage 'trusted' information associated with individuals

• Rapidly assess credibility of a witness

• Operates remotely/non-intrusively against non-cooperative subjects

MARINELINK

MarineLink is designed to allow analysts to mine internal and external data sources, visually display the data on a map, store the data locally, and generate products and reports to help disseminate the information and intelligence. This program is provided as part of the Intelligence Analysis System (IAS) software package that is on all IOW computers.

Importance of MarineLink to the CLOC

Using MarineLink, users can visualize data within the map viewer, filter or sort results, generate graphs, copy data from an external data source to Intel Tracker, and copy data into Report Builder. It allows users to quickly search, sort, build graphs and reports, and provides information in a usable format. MarineLink reduces the amount of time required to do these tasks.

Sources that MarineLink Can Query

MarineLink supports data mining, pattern analysis, and trends and tactics analysis. It provides the ability to query the following data sources:

- All Source Analysis System-Light (ASAS-L) – Army S-2
- Analyst Notebook (Link Analysis Charts)
- BAT and HIIDE systems (Biometric Databases)
- C2PC overlays and tracks (C2PC 6.1.1 required)
- Digital Aeronautical Flight Information File (DAFIF)
- Google Desktop (Documents/email stored on your computer)
- Gazetteer (Geographic place-names if the world)
- Imagery Product Library (IPL) (National, Theater and MEF-level Geo-rectified imagery)
- Intel Tracker (as available from unit and external sources)
- Local Map Server (Raster, CIB, DTED maps)
- Modernized Integrated Database (MIDB) (DIA database of worldwide General Military Intelligence)

c. Experiment Metrics

The IX Chariot® software used in this experiment makes three basic types of measurements that are useful when determining network performance. The measurements include throughput, transaction rate, and response time. For this experiment the software was installed on one of the nodes at the CLOC; this laptop served as the "console," which sends scripts to "endpoints" and also collects polling data sent from the endpoints. In this particular LOE only two endpoints were established, although the user's manual states the software can manage thousands of endpoints which will simulate very large networks. See Appendix B for a more detailed explanation of the software. The following paragraphs define, according to the IX Chariot® user's manual, how the software calculates each of the metrics.

Throughput is defined as the "amount of data that a medium can transmit during a given period of time." [13] IX Chariot® calculates throughput for a pair of endpoints in a non-streaming script using the following equation:

(Bytes_Sent+Bytes_Received_By_Endpoint_1) / Throughput_Units) / Measured_Time[14]

The transaction rate is the number of script transactions that are executed per second. What defines a transaction depends on the particular script. In general a single transaction is one loop through a particular scripts actions, for example, in a file send script a transaction would include the file request, the acknowledgement of request, the file being sent and the acknowledgement of receipt. Transaction rate is calculated by IX Chariot® using the following formula:

Transaction_Count / Measured_Time[15]

The final set of data collected during the experiment was response time. The response time is the inverse of the transaction rate. The calculations are shown in seconds per transaction. This value is calculated as follows:

Measured_Time / Transaction_Count[16]

d. Experiment Scripts

During this LOE, fourteen IX Chariot® default scripts were run as well as two tests that involved the actual collaborative software applications, mIRC Chat and Microsoft's NetMeeting. The following is a list of the IX Chariot® scripts. Unless otherwise noted each script was run between one pair of endpoints, utilizing the Internet Protocol (IP) core protocol, Transmission Control Protocol (TCP). All script descriptions are excerpted from the IX Chariot® Scripts and Streams Library Reference, release 6.50, Revision A, 2007.

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[13] Tamara Dean, *Network+ Guide to Networks* (Massachusetts: Course Technology,2006), 144.

[14] *IX Chariot User Guide*, CD-ROM Release 6.50, IXIA, 2007.

[15] Ibid.

[16] Ibid.

1. Throughput.scr: In Throughput.scr, Endpoint 1 sends a 100,000 byte file to Endpoint 2. Endpoint 2 sends an acknowledgment upon receipt of the file.
2. Throughput.scr: Same as above utilizing User Datagram Protocol (UDP).
3. Responsetime.scr: This script tests network response time. Endpoint 1 sends a 100-byte file; Endpoint 2 receives it and sends an acknowledgment.
4. Responsetime.scr: Same as above utilizing UDP.
5. Filesndl.scr: File Send, Long Connection. Endpoint 1 requests and receives a file; Endpoint 2 sends the requested file and receives an acknowledgement. One connection is made for the entire transaction.
6. Filercvl.scr: File Receive, Long Connection. The pair script to File Send. Two endpoints interact to send and receive a 100,000 byte file. The request and acknowledgement default to 100 bytes.
7. DBaseL.scr: Database Update, Long Connection. The database update scripts are the most complex of the benchmarks. These scripts emulate a program that requests a record from Endpoint 2, receives it, updates it, and sends it back. Last, Endpoint 1 receives a confirmation that the update was completed. All file sizes default to 100 bytes.
8. SMTP_Payload.scr: The SMTP_Payload.scr script emulates the sending of one or more email messages over a TCP network. The default size of an email message is 1,000 bytes, with an additional 20-byte header. In addition to a login/logout sequence, payload data is included for an email containing an IxChariot newsletter notice.
9. activeFTPget_Payload.scr: This script emulate sending a file from Endpoint 1, using active-mode FTP. Only the data channel is emulated, and an active (versus passive) connection is used. The script emulates the transfer of an IxChariot newsletter file. The activeFTPget_Payload script is designed to emulate the actual file transfer portion of an FTP transaction.

10. HTTPText_Payload.scr: These scripts emulate the transfer of graphics and text files from an HTTP server for the Web page: http://www.ixiacom.com/about_us/. The actual request and data are enclosed in embedded payloads.
11. ICQ_Text_Chat.scr: The text chat scripts emulate an IRC client sending the word *Hello* to a receiving IRC client on his buddy list. The receiving IRC client responds with the words *Hello back*. A number of IRC Text chat scripts (for example, Microsoft) include a more explicit client authentication and join process between the two clients prior to the message exchange. All scripts include a separate loop to allow the user to determine the exact count of messages that are being exchanged. The default number of messages is set to ten (10) per transaction. In addition, prior and post any message send requests, SLEEP commands have been added to the script to simulate the users either typing or reading the message. The default setting for each SLEEP is zero seconds.
12. Netmtgv.scr: These script emulate sending video streams, using Microsoft NetMeeting v2.1 over a 100 Mbps Ethernet LAN. Along with the audio or video traffic, a small amount of control traffic is exchanged between the participating computers using a different port number pair. The control traffic is not emulated in these scripts. The send_data_rate is set to 64 kbps. The type value for the RTP_PAYLOAD_TYPE is set to H261 for H.261.
13. HTTP_Streaming.iag: This application group uses two pairs to emulate an HTTP session with streaming video data. The HTTP session involves these tasks:
    1. Browse to a Web page containing a video link.
    2. Select the video link.
    3. View the video in the player that is automatically opened when the link is selected.

    The first pair provides the Control connection, via the HTTP_streaming_control.scr script. The control connection is a TCP connection that emulates browsing to a Web page and clicking on a video link. The second pair provides the Data connection, via the HTTP_streaming_data.scr script. This connection emulates the video streaming from the Web server to the user's desktop.

14. active_FTP.iag: This application group uses two pairs to emulate the two connections needed to accomplish an active FTP operation. In active mode FTP, the client connects from a random unprivileged port (the port number is higher than 1,024) to the FTP server's command port (port 21). Then, the client starts listening to port N+1 and sends the FTP command PORT N+1 to the FTP server. The server then connects back to the client's specified data port from its local data port (port 20). The first pair provides the Control connection, via the active_FTP_control.scr script. The second pair provides the Data connection, via the active_FTP_data.scr script.

e. Impact of Concurrent Experiment

As mentioned earlier, another Master's degree candidate was running, concurrent with this LOE, an experiment on the feasibility of network management using SNMP in an effort to determine if a SATCOM type network could be managed from higher headquarters in an effort to ease the manpower and training impact adoption of SATCOM technology at a company level would incur. The SNMP console was running the commercial software SolarWinds Engineering Edition as the network management application, and was responsible for collecting data on network performance and was the originator of network management-related tasks. In addition to running SolarWinds, the management host was also running the traffic analyzer Wireshark, which was used to capture packets traversing from the management agent to the rest of the network. In addition to the transfer of the IX Chariot® Scripts across the network, the management agent set a polling interval for SNMP data at 120 to 240 seconds. The SNMP data sent over the network included User Data Protocol (UDP) datagrams which contained the polling data and the Internet Control Message Protocol (ICMP) messages encapsulated within an Internet Protocol (IP) datagram. SNMP is typically a 64 bit datagram, while ICMP, a Network layer protocol that indicates data delivery success or failure, can range between 576 bytes to 65 kilobytes.[17] Although the overhead associated with remote network management will decrease the overall bandwidth available to pass IERs and should always be considered when testing a new material solution for networked communication, the SNMP traffic across the network was consistent for each of the scripts run during this LOE, and therefore overhead will become transparent in a comparison of the different types of IER scripts.

B. EXPERIMENT UTILITY

The LOE for this thesis was scheduled to take place from 0800 on Monday, August 4, 2008 through 1600 on Thursday, August 7, 2008. Day one (Monday) was to include a half day of set-up with baseline testing to begin in the afternoon. The remaining days were to be used to test an incremental increase in the number of scenario scripts passed across the network. Encryption would be applied, and the same tests run again. However, due to issues with the software operating system on one of the Swe-Dish IPTs, it took three days, with extensive phone support from a Swe-Dish technical representative to establish the satellite connection. This setback left only Thursday for actual testing. With one day to gather data on test scripts that at times took upwards of four hours to run to completion only the most basic testing was completed. For purposes other than base lining one particular small aperture satellite configuration all but two of the tests provide no utility in determining whether or not SATCOM is a viable solution to meet the IERs at CLOC. Those two tests, where mIRC Chat and NetMeeting were used, each provided data demonstrating that a specific disadvantaged terminal can support multiple types of traffic broadcast over the network at the same time using actual applications installed on the operating workstations. Another shortcoming induced by the equipment malfunction and subsequent decreased timeline include the lack of any measurements on the effects encryption would have had on the performance of the network in supporting the exchange requirements.

Given the previously mentioned lack of a standard list of IERs for units smaller than a battalion, it was determined that even if the experiment had been executed

[17] Tamara Dean, *Network+ Guide to Networks* (Massachusetts: Course Technology, 2006).

according to plan that particular set of data would only have been representative at most of one particular battalion's opinion of what exchanges should be measured. Such data, measured for utility across infantry companies throughout the Marine Corps, is as useful as no data. While the LOE failed to provide the data necessary to meet the primary thesis objective the process of researching a validated list of IERs provided a much better understanding regarding how similar experiments should be conducted in the future. The data gathered during one day of testing is provided in the next chapter, including an in depth analysis of the last test scenario, while the remaining portions of the thesis will emphasize those actions required to make similar testing valuable to the designers of future communication networks utilizing SATCOM.

Although the IPT malfunction decreased the utility of this LOE as a tool for future Marine Corps communications architects detailing possible solutions for an Enhanced Company, the reader should note that the Swe-Dish terminals employed in this experiment have successfully been used as a means to pass comparable information exchanges in other experiments run by the Naval Postgraduate School's CENETIX Laboratory. The authors have personally used the equipment in a number of the lab's Tactical Network Topology (TNT) series of experiments, whose objective is the study of "multiplatform tactical networks, Global Information Grid connectivity, collaborative technologies, situational awareness systems, multi-agent architectures, and management of sensor-unmanned vehicle-decision maker self-organizing environments."[18] The TNT experiments have previously focused on the use of the 802.16 wireless standard and traditional RF radio technology during scenarios that include the passing of biometric data between deployed forces and a local operations center as well as the maritime interdiction of possible Weapons of Mass Destruction (WMD) material. The scenarios first incorporated SATCOM as a backup link to the primary wireless link. During several experiments the wireless link did indeed fail and the Swe-Dish terminal provided a backup capability that proved transparent to the users; allowing each node to seamlessly continue the same information exchanges and use the same situational awareness

[18] "Center for Network Innovation and Experimentation," *Center for Network Innovation and Experimentation*, http://cenetix.nps.edu/cenetix/ (accessed September 15, 2008).

building software applications as before the failure with no noted degradation in service. Recently, the TNT experiments have begun to include point to point configurations using the Swe-Dish terminals to successfully connect nodes in several states as well as nodes as far away as Europe.

IV. RESULTS

A. ANALYSIS OF DATA

To understand the data collected during the LOE, the relationship between data rate, antenna size, and transmitter power must first be defined. When communication architects set out to design a SATCOM network they size the link using the link equation or link budget. This equation, shown below, relates all the parameters of a SATCOM "link" needed to compute the signal-to-noise ratio of the connection.[19]

$$\frac{E_b}{N_o} = \frac{P L_l G_t L_s L_a G_r}{k T_s R}$$

E_b/N_o is the ratio of received energy-per-bit to the noise density; for a system to be able to pick the intended signal out of the noise associated with the connection the ratio must be higher than 1. Typically an E_b/N_o ratio between 5 and 10 is adequate for digital communications with low probability of error.[20] P represents the power of the transmitter. L_l, L_s, L_a are various losses, or reductions in power, from transmitter-to-antenna line loss, space loss and transmission path loss respectively. G_t and G_r are gain of the transmitter and receiver respectively (both depend on the diameter of the dish as well as frequency broadcast). k is Boltzmann's constant, T_s is the system noise temperature and R is the data rate. If all but P, R and G_t were held constant then an increase in data rate, would require a similar increase in the power of the transmitter, the gain of the transmitter, or both. Current fielded small aperture SATCOM technology, due to requirements for portability and compactness, are necessarily limited in both power and transmit antenna gain. Therefore, data rates for users of such technology are similarly restricted. In this LOE, both the uplink and downlink were leased at 1 Mbps data rates, however, the data collected in this experiment shows that the base line raw data rate was 570 Kbps, emphasizing the disadvantaged nature of the tested equipment.

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[19] Wiley Larson and James Wertz (eds.), *Space Mission Analysis and Design,* (New York, NY: Springer-Verlag New York LLC, 1992), 520.

[20] Ibid.

A point to consider when examining the data is the fact that IX Chariot® measures only the throughput associated with the Internet Protocol (IP) packet payload and disregarding the 198 bit IP headers associated with the traffic. Therefore the data represents throughput that is actually less than what was actually passed over the network.

Also, keep in mind that while the IX Chariot® test scripts were being executed, a small amount of network management traffic was simultaneously injected into the network which subsequently reduced the bandwidth available for data generated by the test scripts. However, since the SNMP traffic was running at a set interval for all tests its effect was constant for all the scripts it could be considered insignificant for comparisons of two or more types of test scripts.

Table 2 shows the average throughput, transaction rate and response time from the IX Chariot® test console for all tests except the final two which utilized actual software applications previously loaded onto workstations at both the battalion and company nodes. A separate application, Wireshark, was used to capture the data for the mIRC and NetMeeting based exchanges.

The first two tests were run to determine the baseline capability of the tested network configuration. The response time results concur with expected response times for a transmission link with a geostationary communications satellite. For the purpose of this LOE, a non-streaming script is one that requires two way communication while streaming scripts require one-way flow at a specific data rate.[21]

[21] *IX Chariot® Scripts Development and Editing Guide,* CD-ROM Release 6.50, Version 1.9, IXIA, 2008.

SCRIPT	THROUGHPUT AVG. (Mbps)	TRANSACTION RATE AVG. (# / sec.)	RESPONSE TIME AVG. (sec.)
Throughput[1]	0.570	0.715	1.398
Response time[1]	0.003	1.971	0.507
File Send Long[1]	0.586	0.735	1.361
File Rec. Long[1]	0.587	0.736	1.359
Data Base[1]	0.002	0.986	1.014
SMTP Payload[1]	0.012	0.237	4.225
FTP Get (Active) [1]	0.033	0.826	1.211
HTTP Text Payload[1]	0.108	1.427	0.701
ICQ Text Chat[1]	0.016	0.143	7.001
NetMeeting (Video)[2]	0.064	Not measured	Not measured
HTTP Streaming[2]	0.876	1.974	22.889
Active FTP[1]	0.093	1.037	2.365
mIRC (Actual)[2,3]	0.400	Not measured	0.510
NetMeeting (Actual)[2,3]	0.400	Not measured	0.510
1 – Non-streaming script 2 – Streaming script 3 – Data pulled from Solar Winds software program vice IX Chariot®			

Table 2. Summary of LOE Data

The final test set, using NetMeeting, was the most comprehensive, and was originally developed to stress the satellite link. This particular test consisted of multiple NetMeeting protocols being transferred simultaneously, specifically a video and text chat session, a file transfer, and an application share, where the receiving node of the exchange has access to the sender's desktop applications. Microsoft's TechNet website, explains that NetMeeting utilizes both the TCP standard for data transport and call control, and the UDP standard for secondary connections for sending and receiving audio and video.[22] As with the previous test sets, the presence of the ICMP and SNMP management data is purposely injected by the network management agent. Comparing this last sample with the previous, there is a marked increase in the receive/transmit kilobits per second (Kbps) on each of the two nodes. Figure 3 shows throughput at levels almost the advertised data rate of the leased satellite channels.

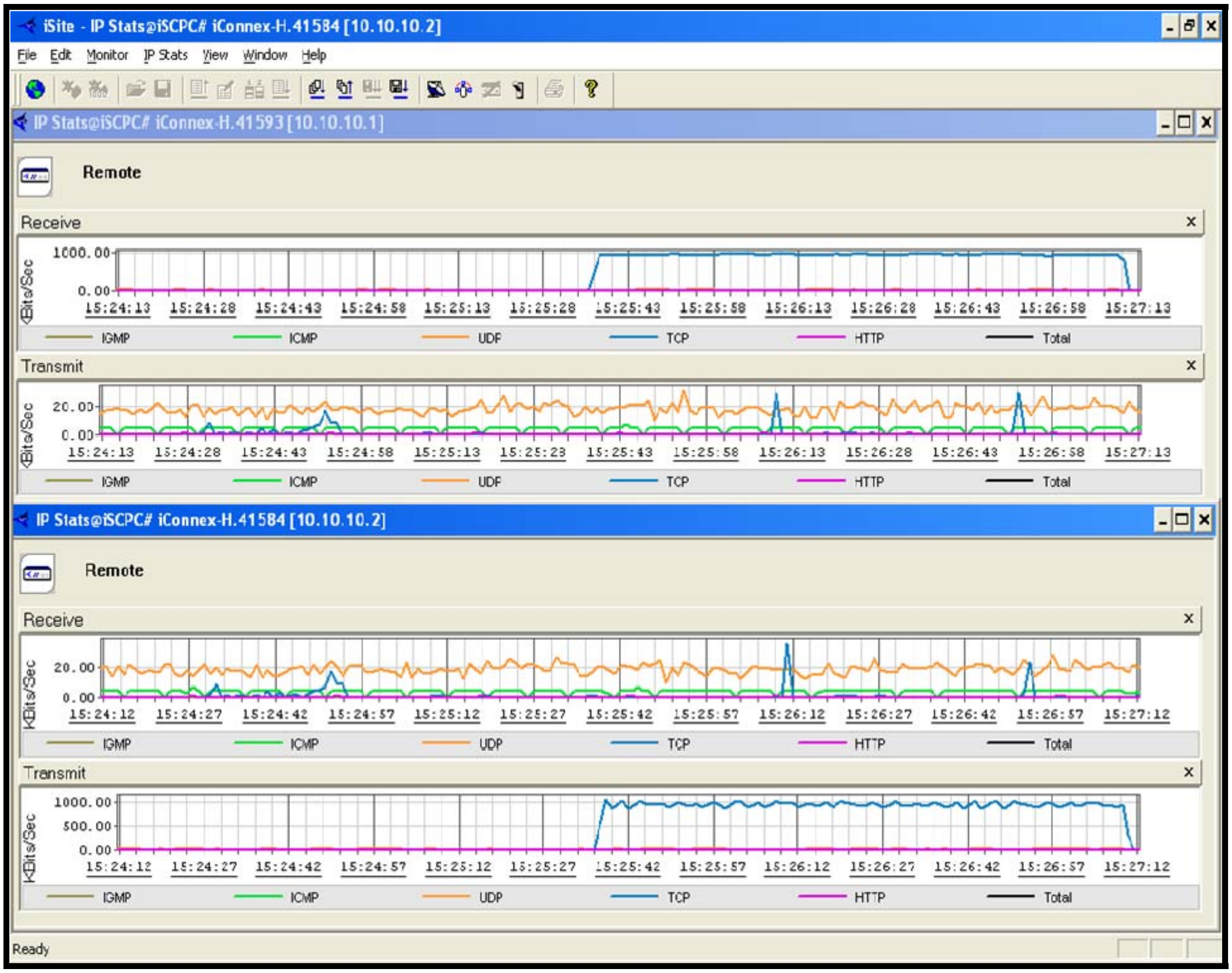

Figure 3. Portion of screen shot from NetMeeting test

[22] "NetMeeting 3.0 Resource Kit," *Microsoft Tech Net*, http://technet.microsoft.com/en-us/library/cc767134.aspx (accessed September 8, 2008).

B. COMPARISON OF TESTED SCRIPTS TO SOFTWARE IN MCTOG CLOC CONCEPT APPLICATIONS

Table 3 maps the IX Chariot® scripts to the applicable MCTOG software requirements. Development of this table was difficult due to lack of information on the majority of the MCTOG software. Repeated attempts to gain detailed information (packet sizes, protocols used, and frequency of exchanges) were hampered because most of the software is proprietary and vendors were not forthcoming with the information. Based on discussion with MCWL representatives and Marines, the MCTOG software was mapped back to the IX Chariot® scripts as follows.

IX Chariot® Script	MCTOG Software
Filesndl.scr	MarineLink C2PC BAT FBCB2-BFT
Filercvl.scr	MarineLink C2PC BAT FBCB2-BFT
DBaseL.scr	MarineLink C2PC BAT
SMTP_Payload.scr	C2PC Email
activeFTPget_Payload.scr	BAT
HTTPText_Payload.scr	C2PC
ICQ_Text_Chat.scr	mIRC
Netmtgv.scr	mIRC
HTTP_Streaming.iag	VTC
active_FTP.iag	C2PC BAT

Table 3. Comparison of IX Chariot® Script to MCTOG Software Applications

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V. CONCLUSION AND RECOMMENDATIONS

A. WHAT WAS LEARNED

The main objective of this thesis was to conduct an LOE on a particular SATCOM terminal technology against a standardized list of small unit IERs. However, through research, it was determined that no such list existed and that results of experimentation regarding IERs are of no value until the Marine Corps develops a consistent list that applies to company and below sized units. Important insight to the second and third order impacts of fielding SATCOM technology at the less than battalion size unit will help expand the evaluation metrics of future LOEs beyond a purely data centric measurement set. During research for this thesis, the authors conversed with many stakeholders regarding the exact nature of which information exchange requirements were required for isolated decision-making. To our surprise, although there are many different research bodies genuinely interested in defining IERs for company and below sized units, there exists no definitive sources for this information and there is a noticeable lack of coordination between the various efforts to determine a standardized list.

Despite the previously noted shortcomings of the limited objective experiment, the authors learned a tremendous amount regarding the minutiae involved in finding and evaluating solutions to the problem of providing the technical support needed by a small unit leader to make decisions in an isolated environment. Based on the knowledge gained over the past months the authors provide the following recommendations regarding the objectives of this thesis as well as some strategic recommendations on the subject of procuring technical solutions in support of information exchange requirements required for the asymmetric battlefield of today and the future.

B. SATCOM TERMINAL RECOMMENDATION

1. Proof of Concept

Although only supported with one set of data points, the results of the final NetMeeting test script serve as a proof of concept that two disadvantaged terminals were capable of managing an sufficient collection of simultaneously transmitted application protocols, in addition to network management related data. The following additions to the LOE will serve to improve the utility of the experiment:

- To provide a more concrete data, a similar test should be scheduled with ample time to run test scripts in their entirety as well testing of scenarios containing multiple application protocols.
- The test should include or simulate the exact specifications and protocols of the determined set of applications that will support the isolated decision maker.
- Due to the nature of military communications, security is paramount. Therefore, the test should be run again with encryption applied. The data derived from this experiment can be compared to the unencrypted data set to provide knowledge on the impact of encryption on required bandwidth.
- Because disadvantaged users are physically limited to data rates, enhancements, such as IP accelerators should be tested as a method of improving the capacity of such networks.
- All of these tests should only be conducted after a line item list of IERs and their associated applications or modes of transmittal are validated by the user, namely the small unit leader.

2. Higher Order Impacts

In addition to the purely data centric metrics above, consideration should be made regarding the impacts of fielding new equipment will have on manpower, training, logistics and cost. Laboratory assumptions should be confirmed by seeking input from the warfighter user. Even if a certain technology is capable of providing all the necessary bandwidth required for the appropriate information exchanges, that equipment is no more than ballast if it can’t be transported using organic assets, can’t be run without lightweight power sources or cannot be operated with a minimum amount of training.

This experiment is a perfect example that something as simple as equipment set-up can often be a show stopper without proper technical support or training.

C. BANDWIDTH MANAGEMENT

The electro-magnetic spectrum is a finite physical resource; it can only be divided and sub-divided to a certain point. Rather than continuing attempts to divide a decreasing asset among ever-increasing users, efforts should be made to develop methods of decreasing demand while supplying the same amount of utility.

1. Re-examine "Network Centric Warfare" Specifics

Operational View-Level One (OV-1) diagrams depicting the "Network Centric" warfare concept are very appropriate for illustrating the level of connectivity that will be required to successfully wage war on an asymmetric battlefield and gain the information advantage over any adversary. However, the lightning bolts that connect the magnitude of nodes in the diagram fail to quantify exactly what tools are necessary for the small unit leader and tactical level warfighter to complete their mission successfully. Future network architects must use a bottom up approach to design allowing them to focus on information the tactical unit and isolated decision maker require to execute its mission; not necessarily what would increase the situational awareness of higher headquarters or operational and strategic level decision makers. After those requirements have been defined researchers can work in reverse to convert lower level requirements into data that is useful to higher level units. Rather than live video feed from a helmet-mounted camera to indicate enemy contact, could an application be developed that uses voice recognition to convert a verbal report to map grids? Will a low-resolution snapshot suffice for positive I.D. instead of Unmanned Aerial Vehicle (UAV) feed? Can a small unit commander act as a "step site" for his Marines to gain access to higher level communication services thus reducing the number of nodes that require bandwidth from a dozen to one?

2. Improved Use of Bandwidth

In 2004, the U.S. Army commissioned Rand Corporation to study the bandwidth requirements of its forces. In the report, the authors stated that "New Technologies will greatly increase capacity, but unchecked user demands will probably keep pace and exceed available capacities. No single technique will solve the problem. There are no silver bullets."[23]

The report is an excellent source of methods to optimize the existing bandwidth. The report was conducted for the U.S. Army; however, the concept could easily be adapted by the Marine Corps. Optimally, a similar report should be conducted that analyzes the Marine Corps use of the EM spectrum to transmit information. At a minimum, this report should be used as a reference for those defining Standard Operating Procedures (SOPs) as well as Tactics, Techniques and Procedures (TTPs) for future small unit operations centers.

D. DEFINING BANDWIDTH REQUIREMENTS

One of the most challenging parts of the thesis was attempting to define the IER set required by a company commander to make a timely, well-informed decision in an isolated environment. Expectations of finding a subject matter expert in the many Marine Corps agencies dedicated to improving Warfighting capability or receiving a definitive answer through face-to-face interviews were met with disappointment. What was discovered were various uncoordinated efforts by a number of different agencies trying to gather the same information.

To address this situation, Marine Corps Combat Development should appoint a single entity to maintain oversight on efforts to define a list of IERs for units below battalion size. Two candidates exist for this position: MCCDC's Command and Control Integration Division (C2ID) based on their efforts in defining the Capability Sets (CAPESETs) 1-4 for the Combat Operations Center and the newly formed Marine Corps

[23] Leland Joe and Isaac Porche III, *Future Army Bandwidth and Capabilities* (Santa Monica, CA: Rand Corporation, 2004).

Tactics and Operations Group, because they have been tasked to provide standardized training and instructor qualifications for the Ground Combat Elements (GCEs).

The designated oversight entity should then hold host conferences or Integrated Process Team (IPT) meetings that include all GCE stakeholders (battalion and company commanders, platoon leaders, communications officers) with an interest in company and below IERs. Due to current Operational Tempo (OPTEMPO) the development of the IER list may be best completed by students at the resident Command and Staff (C&S) course or the Expeditionary Warfare School (EWS). The IPT or resident students, with guidance from the USMC "scientific body" to define technical limits of what is possible and also means to optimize bandwidth as discussed above, should develop three capability sets based on what net-centric means (or should mean) at the tactical level and combat experience in current asymmetric battlefield.

Those three capability sets should fall within the MCTOG concept of "heavy," "medium" and "light" CLOCs, to address the information exchange requirements for a FOB setting, a mechanized or mobile force, and a foot mobile or heli-borne force. The list should be standardized enough to be applicable to any GCE element from the company and below but also allow growth room for personalized operating procedures and also allow for the introduction of new technology as it becomes available.

The infantry company is just one element of the MAGTF that requires further research into the IERs for small unit leaders. In order to optimize the combined arms effects that MAGTF organization allows, small unit leaders across the combat elements will need support in making decisions in an isolated environment, therefore similar IER lists should be developed for those elements.

1. Capability Based Acquisition across the MAGTF

Once the line item list of IERs that support small unit decision makers has been developed Marine Corps Systems Command (MCSC) should seek out applications or technical solutions to be used to pass those exchanges across whatever network is established in the AOR. Again, the developers of these applications should keep in mind efforts to redefine network centric and optimize bandwidth.

When the optimized list of IERs and associated applications for transmittal are determined, testing can be done to determine the bandwidth requirements of that particular mix. The list should be tested for bandwidth requirements during actual training scenarios (i.e., Mojave Viper or other pre-deployment training opportunities). This would provide validation of the line item list, help determine how much or how little training is required to successfully operate the new equipment, and how much or how little manpower requirements would be impacted.

E. THE FINAL WORD

Within days of finalizing the draft of this thesis, the authors received a draft version of the most recent COC Study of CAPESET V for MAGTF Command and Control.[24] This report, validated by MCCDC C2ID, develops similar recommendations and notes similar shortfalls in defined IERs for smaller than battalion size units. It is very comprehensive in its analysis of the issues this thesis addresses and should be referenced for those who intend to continue the research started in this thesis.

[24] MCCDC, C2ID, *Combat Operations Center (COC) Study Capability Set (CAPSET) V for Marine Corps Air-Ground Task Force (MAGTF) Command and Control (C2)*, ver. 1.9. (Quantico, VA: U.S. Marine Corps, 2008).

APPENDIX A. SWE-DISH IPT TECHNICAL SPECIFICATIONS

The following tables are copied directly from the Swe-Dish Instructions for Use: IPT-i Mil Suitcase 2.4 Satellite Communications Terminal featuring iDirect, rev. 3.3, March 2007.

RF Characteristics	Ku band
General RF	
Antenna concept	Gregorian type dual optics antenna at Ku band. Elliptical 4-piece main reflector with size 0.90 x 0.66 m, and folding feed arm. Carbon reinforced plastic (CRP) construction.
Antenna model designation	SWE-DISH 90-66K EDS
Sidelobe performance	29 – 25 Log θ dBi in azimuth
Receive Performance	
Frequency	10.95 – 12.75 GHz
Gain at midband	38.3 dBi
G/T at 58 K (0.8 dB) LNB, 20º el, 20º C, clear sky	19.3 dB/K
Transmit Performance	
Frequency	13.75 – 14.50 GHz (Extended Ku)
Gain at midband	38.4 dBi
Polarization Performance	
Polarization	Linear
Cross-polar discrimination within 1 dB cone	>30 dB
EIRP Capability	
EIRP	53 dBW @ P -1 dB

Table 4. IPT RF Characteristics

General Characteristics	Ku band
General	
PC platform	The Suitcase has an embedded Linux PC platform with network connection.
Monitoring and Control	The Suitcase is controlled via graphical web interface and an embedded http server.
Data inputs and processing	
Network connections	TCP/IP LAN interconnectivity 10/100 base T on a MIL-C-26482 series 1 connector.
IP Routing	
Transmission modes	Bi-directional (duplex) and uni-directional (simplex) operation supported
Video streaming	Supports transmission of live video stream over IP
Modulation iDirect	
Transmit mode	Network TDMA
Modulation type	QPSK
Date rate, maximum	4200 kbps
Code types	TPC
Antenna travel	
Antenna alignment	Built in GPS, electronic compass and inclinometer.
Positioning	Motorized
Azimuth range	± 30°, 0.1° step size
Elevation range	5° – 90°, 0.1° step size
Polarization range, linear	186°, 0.1° step size
Platform levelling	
Pitch and roll	Built-in compensation for pitch and roll due to using platform independent reference to true vertical/horizontal.
Environmental Performance	
Ambient temperature	Operational -20° C to +40° C, internal heater/cooler Mil version -20° C to +50° C Storage -40º to +70º C
Solar radiation	Operational in up to 1100 W/m^2
Wind speed	Operational up to 20 m/s, anchored unit (Eutelsat type approval)
Humidity	Operational: 95% non-condensing

General Characteristics	Ku band
Rainfall	Maximum 100 mm/h excluding link budget effects
Sealing, including PSU	IP65
Altitude	Operational up to 3 000 m, survival up to 12 000 m altitude
Mechanical	
Weight	Approximately 39 kg depending on options
Dimensions	70 x 47 x 31 cm stowed for transportation
Electrical	
Mains supply	External dedicated power supply unit (PSU) accepting AC or DC input: AC supply: 100 – 240 V AC, 50 – 400 Hz, 900 W DC supply: 21 – 32 V DC, 39 – 26 A
Total power consumption (Suitcase)	700 W

Table 5. IPT General Characteristics

PSU Parameters	Value
Operating temperature	-30° to + 50°C
Rain	100 mm/h
Humidity	95% condensing
Sealing	IP65
Altitude operational	5,000 meters
Altitude non operational	13,600 meters
Low air pressure	150 mbar
Pressure change	100 mbar/min
Dimensions	38x14x18 cm
Weight	4.5 kg

Table 6. Power Supply Unit Parameter

BUC Parameter	Value
Input Frequency	950 – 1700 MHz
Output Frequency	13.75 – 14.50 GHz
Local Oscillator Frequency	12.80 GHz
Local Oscillator	3 dBm ± 7
Reference Frequency	10 MHz
Power Requirements	+10.5 to +18.0 VDC

Table 7. Block Up Converter Parameters

Modem Parameter	Value
Type	Network TDMA modem (L band)
Operating frequency	950 – 1700 MHz
Maximum transfer rate	4200 kbps
Power requirements	20.5 – 27.5 VDC

Table 8. Internal i-Direct Modem Parameters

SSPA Parameter	Value
Operating Frequency	13.75 – 14.50 GHz
Saturated Power Output (nominal)	35 W
Power Requirements	+10.5 to +13 VDC

Table 9. Solid State Power Amplifier Parameters

LNB Parameter	Value
Input Frequency	10.95 – 11.70 GHz 11.70 – 12.20 GHz 11.25 – 12.75 GHz
Output Frequency	950 – 1700 MHz
Conversion Gain (25º)	55 – 60 dB typical
Noise Figure (25º)	0.8 dB typical
Power Requirements	+15 to +24 VDC

Table 10. Low Noise Block Down converter Parameters

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APPENDIX B. IX CHARIOT® TECHNICAL SPECIFICATIONS

The following description and figure of the IX Chariot® software and its processes is taken directly from the IXIA manual Getting Started with IX Chariot®, release 6.50, 2006.

A. ABOUT IX CHARIOT®

"IxChariot provides thorough performance assessment and device testing by emulating hundreds of protocols and applications across thousands of network endpoints. Available with both node-locked and floating license support, IxChariot provides the ability to confidently predict the expected performance characteristics of any application running on wired and wireless networks. Using application scripts that emulate application data flows, IxChariot can help you:

- Test the performance and capacity of network hardware and software.
- Compare competing network products before purchase.
- Identify the source of performance problems.
- Predict the effects of running new applications.
- Measure and baseline typical network operations.
- Verify the performance you are expecting from network service providers."

B. BASIC SETUP

The application consists of a Console Program and distributed Performance Endpoints. The Console stores all test files and scripts as well as collects all performance statistics sent from the Performance Endpoints via polling. Polling rate can be set by the user. Endpoints use the Application Scripts to create the same data flows an application would send between computers, without having to install the actual application. Each Application Script can also be altered by the user to reflect a specific application, if no such definition exists in the Console's library of scripts. Figure 4 shows the basic setup of IX Chariot® .

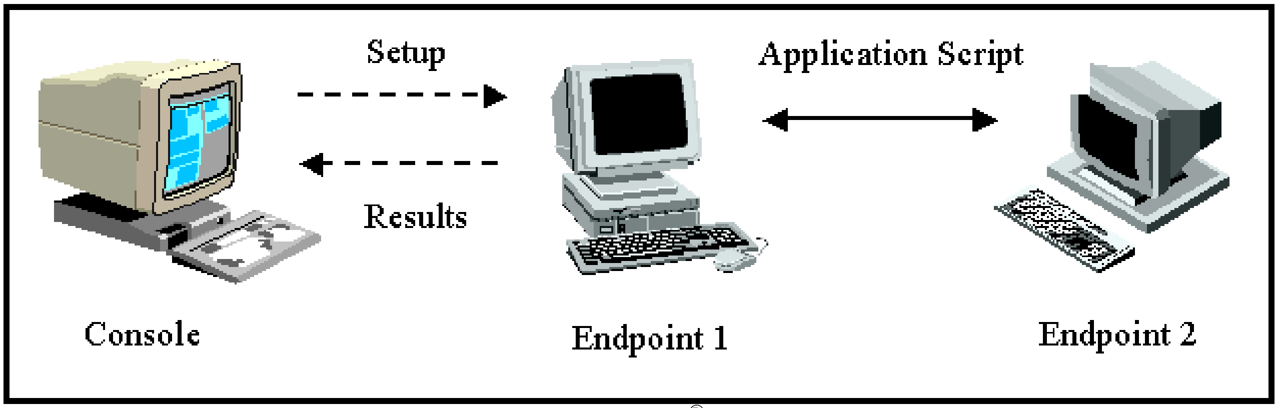

Figure 4. IX Chariot® Basic Setup

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