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Supporting a Marine Corps Distributed Operations Platoon a quantitative analysis

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

SUPPORTING A MARINE CORPS DISTRIBUTED OPERATIONS PLATOON: A QUANTITATIVE ANALYSIS

by

Matthew D. Bain

September 2005

Thesis Advisor:	Thomas W. Lucas
Second Reader:	David Schrady

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This research analyzes the critical logistical requirements of a U.S. Marine Distributed Operations Platoon with the goal of developing a sustainable support plan. The development of Distributed Operations (DO) is one of the Marine Corps' major transformational efforts. The concept is designed to make infantry units more lethal by leveraging training and technology to allow more dispersed and intelligence driven operations. Since a DO platoon will operate far from secure lines of communication and support bases, logistically supporting it will be challenging. Through the use of simulation, statistical analysis, and logistical modeling, this thesis identifies critical factors and capabilities that are important to the sustainment of a DO platoon operating from a Marine Expeditionary Unit (MEU). The research concludes with a feasible support concept combined with the means to assess the effect that supporting a DO platoon has on other MEU missions. Results indicate that quick response time and dedicated support assets from the supporting agency, typically augmented by MEU helicopters, are critical to the success of a DO platoon. This limits the flexibility of the MEU aviation element to support other MEU missions. The biggest payoff in improving logistical effectiveness is given by reducing the response time.

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SUPPORTING A MARINE CORPS DISTRIBUTED OPERATIONS PLATOON: A QUANTITATIVE ANALYSIS

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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This research analyzes the critical logistical requirements of a U.S. Marine Distributed Operations Platoon with the goal of developing a sustainable support plan. The development of Distributed Operations (DO) is one of the Marine Corps' major transformational efforts. The concept is designed to make infantry units more lethal by leveraging training and technology to allow more dispersed and intelligence driven operations. Since a DO platoon will operate far from secure lines of communication and support bases, logistically supporting it will be challenging. Through the use of simulation, statistical analysis, and logistical modeling, this thesis identifies critical factors and capabilities that are important to the sustainment of a DO platoon operating from a Marine Expeditionary Unit (MEU). The research concludes with a feasible support concept combined with the means to assess the effect that supporting a DO platoon has on other MEU missions. Results indicate that quick response time and dedicated support assets from the supporting agency, typically augmented by MEU helicopters, are critical to the success of a DO platoon. This limits the flexibility of the MEU aviation element to support other MEU missions. The biggest payoff in improving logistical effectiveness is given by reducing the response time.

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THESIS DISCLAIMER

The reader is cautioned that the computer programs presented in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logical errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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LIST OF KEY WORDS, SYMBOLS, ACRONYMS AND ABBREVIATIONS

AOR	Area of Responsibility
CSV	Comma Separated Values
CSR	Controlled Supply Rate
DO	Distributed Operations
DoD	Department of Defense
DOS	Days of Supply
HQMC	Headquarters Marine Corps
ITG	Initial Terminal Guidance
ITV	Internally Transportable Vehicle
JTAC	Joint Terminal Air Controller
LOS	Line of Sight
LZ	Landing Zone
M&S	Modeling and Simulation
MAGTF	Marine Air Ground Task Force
MANA	Map Aware Non-uniform Automata
MCWL	Marine Corps Warfighting Lab
MCWP	Marine Corps Warfighting Publication
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MHPCC	Maui High Performance Computing Center
MOE	Measure of Effectiveness
NOLH	Nearly Orthogonal Latin Hypercube
NPS	Naval Postgraduate School
OMFTS	Operational Maneuver From The Sea
STOM	Ship To Objective Maneuver
XML	eXtensible Markup Language

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The three people who I worked most closely with throughout my research helped keep it focused and relevant. Without the efforts and support of my advisor, Dr. Tom Lucas, my second reader, Dr. David Schrady, and my consultant, Colonel Ed Lesnowicz, USMC (retired), I would not have produced such a quality product. They also made sure we had fun along the way.

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EXECUTIVE SUMMARY

This thesis addresses the logistical support issues of a United States Marine Corps distributed operations platoon which will be deployed with a Marine Expeditionary Unit (MEU) in late 2006. This summary gives a broad overview of distributed operations (DO), the research methodology, and focuses on conclusions and recommendations stemming from this research. This analysis is designed to support the development of concepts, tactics, and procedures which will make the DO platoon concept more robust and effective.

DO is a transformational USMC initiative, directed by the Commandant of the Marine Corps, General Hagee (Hagee, July 2005). It is an additive capability to support the Marine Corps' maneuver warfare philosophy by enabling operations which are further forward, more dispersed, and intelligence driven. The DO platoon leverages advanced sensors, communications, training, and fire support to accomplish a wide range of missions and put the enemy at a disadvantage. The DO platoon concept is based on the Marine rifle platoon table of organization (T/O 1013G, 1999) with the addition of vehicles, sensors, radios, crew served weapons, and some modifications to platoon command and control structure. The Marine Corps Warfighting Lab (MCWL) is developing a DO platoon for deployment with MEU in 2006. Logistically, the essential character of a DO platoon is that it lacks secure lines of communications. It must be able to operate over extended time periods. The additional risk presented by these facts necessitates a robust support concept that addresses the unique characteristics and requirements of a DO platoon.

This analysis answers three questions in order to help the Marine Corps solve the problem of logistically supporting DO. They are:

- What are the critical logistical factors relating to mission success for the DO platoon in the missions envisioned in MCWL's Wargame Scenarios?
- What are the critical logistical capabilities of the MEU that will enable it to provide continuous sustainment to a distributed force?

- What is the supportability of a DO platoon across the range of missions?

These questions are addressed using simulation, statistical analysis, and requirements determination. In the process of answering these questions, this thesis determines if a current MEU can support DO in 2006, and establishes a baseline of simulated operational experience to help make logisticians more proficient at supporting these types of operations. The motivation behind this analysis is to ensure that Marine warfighters have the support they need, when they need it.

The simulation model used in this analysis is based on a scenario from MCWL's DO Seminar Wargame held in November 2004. This scenario requires the DO platoon to prevent enemy infiltration across a six kilometer border region in rugged terrain for a one or two week mission. If the DO platoon's subordinate units are compromised or run out of supplies, they are rendered nearly ineffective until a support mission arrives. As a result, the measure of effectiveness (MOE) is the percent of enemy killed over the course of the mission. The simulation is implemented in the MANA agent-based combat modeling environment, which is part of the Marine Corps' Project Albert suite of models (MCWL Project Albert Website, March 2005).

The purpose of the simulation model is to experiment with various logistical systems through a technique called data farming. This technique leverages high performance computing to generate large numbers of data points. The input logistical parameters are varied systematically in an efficient way to broadly explore the consequences of various logistical policies and the interactions between various factors such as days of supply (DOS), resupply speed, rapid request setup time, and others. The simulation experiment produced over 200,000 data points using more than 700 CPU days computer time in a matter of a few weeks.

The analysis of the simulation output was used to identify the most critical characteristics of a logistical support system, thereby answering the first two research questions. Overall, responsiveness is the key logistical criteria for success for long term DO platoon operations. Answering the first research question, the most critical logistical factors are responsiveness, combat usage rate, and DOS. Answering the second research question, the critical capabilities are as follows:

- The DO platoon must have the capacity to carry at least three DOS.
- The CSS agency must have the ability to sustain scheduled resupply deliveries at least every two days.
- The CSS agency must be assigned dedicated, responsive, high speed delivery means.
- An anticipatory (or sense and respond) logistics system should launch missions twelve hours ahead of a predicted stock out or equipment failure.
- Resupply deliveries must be accomplished quickly, stealthily, or with heavy security (or a combination of all three).
- Logistical responsiveness, intelligence, aerial surveillance, and fire support are critical for unstable or extremely dangerous missions.
- The best performing logistics system (based on those modeled and analyzed) combines rapid request, fast delivery, aerial surveillance, a scheduled resupply rate, three or more DOS capacity, and a sense and respond logistics capability.

Following the analysis of the simulation data, this thesis determines the physical requirements of the DO platoon based on standard planning factors and the author's operational experience as a logistician in Operation Iraqi Freedom. Using existing MEU assets, a support plan is developed that is feasible and addresses the lessons learned from the data analysis. This results in a robust and responsive logistical support concept. This concept is summarized as follows:

- The DO platoon should carry three DOS and combat ammunition load.
- Two CH-46s should be assigned in direct support, transporting supplies internally.
- Two AH-1Ws should be assigned for escort and landing zone security.
- Two DOS resupply packages pre-staged and organized into fire team sized packages
- CSS agency should be located within 55 kilometers of the DO platoon.
- Pilots, aircraft, and supply and ammunition packages should be on standby to keep response time less than four hours.
- CSS agency should remain in continuous contact with DO platoon in order to track requirements and respond to demands.

Using this concept as a foundation, the third research question is answered. A DO platoon is currently logistically supportable across a wide range of missions, provided that the MEU is willing to commit the necessary resources, which are substantial, to support one platoon. Synthesizing all the lessons learned from this analysis, the following recommendations are made:

- Water is the biggest limiting factor in increasing DOS for the DO platoon. It is recommended that research be done into ways to reduce the water requirement by reclaiming waste water and capturing the water in engine exhaust.
- The DO platoon could be resupplied by air delivery provided it is in range of casualty evacuation aircraft. It is recommended that technologies for precision airdrop from the C-130 or MV-22 be explored for delivering tactical resupply packages to DO units in a clandestine manner.
- The risk of a DO platoon operation increases with the length of time it takes for supporting aircraft to reach it. This research estimates that a 15 minute or less time of flight is effective and gives an operational radius of approximately 50 kilometers using the CH-46. Poor flight conditions or bad weather may limit this radius. It is recommended that operational constraints for DO be developed that account for the travel time of aircraft carrying critical supplies or performing medical evacuation.
- Aerial surveillance of the DO platoon's area during resupply deliveries proved to be very valuable in the simulation model. It is recommended that a tactical unmanned aerial vehicle be considered for employment with the DO platoon.
- Autonomic logistics is useful in supporting the DO platoon in the simulation, but a responsive rapid request system is more critical overall in responding to high demand variability. It is recommended that intelligence and communications assets of the supporting agency be tailored to provide the maximum amount intelligence on usage rates and enemy activity in order to provide the supporting agency maximum flexibility in executing both push and pull logistics.

The result of this analysis is not merely an answer to whether or not a DO platoon is currently supportable. The body of this research provides a valuable reference tool to logisticians who will support DO in the future. The lessons learned, the data gathered, and the calculations performed provide a good foundation for planning effective support concepts for a DO platoon mission.

I. INTRODUCTION

*Successful implementation of the distributed operations concept requires enhancements in C^2, intelligence, fires, mobility, sustainment, and training/education.**

BGen Robert E. Schmidle, USMC

A. OVERVIEW

The Marine Corps is continuously developing new tactics, techniques, and procedures that complement emerging technologies in order to make the Marine Air-Ground Task Force (MAGTF) more lethal and efficient across the spectrum of missions. This development is part and parcel to the Department of Defense's general concept of transforming the military into a force that is more capable of performing the missions of the 21st century. Along with Ship-to-Objective Maneuver (STOM) and Sea-basing, the Marine Corps is looking very closely at a new infantry capability called "Distributed Operations." Distributed operations (DO) will represent a significant improvement in the training and equipment of Marine Corps infantry units, as well as a significant capability to influence the battlefield.

The Marine Corps is currently developing the equipment, doctrine, tactics, techniques, and procedures that will define how DO will work. One of the major players in this development is the Marine Corps Warfighting Lab (MCWL). MCWL is currently developing the concept for a DO platoon which will achieve initial operating capability with a Marine Expeditionary Unit (MEU) deploying in 2006. MCWL held a wargame in November 2004 to explore the missions, organization, and capabilities of a DO platoon. The preliminary results of this first wargame indicate that a DO platoon will likely need to operate independently for up to two weeks in order to have a significant impact on the area of operations (Goulding 2004, page 4). As a result, a major determining factor for success of this platoon will be the MAGTF's ability to provide sustainment.

* Quote taken from "Distributed Operations: From the Sea" by BGen Robert E. Schmidle, published in the *Marine Corps Gazette,* July 2004.

B. BACKGROUND AND MOTIVATION

DO is envisioned as an additive capability that will greatly improve the efficacy of traditional Marine infantry units. This is a concept in its infancy, and as such, the accompanying doctrine, tactics, and organization are currently being developed by the Marine Corps Warfighting Lab (MCWL), the Expeditionary Force Development Center (EFDC), and numerous other agencies within the Marine Corps. Several projects have been launched to help solve many of the problems associated with implementing and developing the DO concept. At MCWL, both the Sea Viking division and the Project Albert division have been working on projects which will help senior leaders synthesize advice from analysts and subject matter experts into a robust concept. The primary motivation for this thesis is a desire to take the work of Project Albert and the Sea Viking Division and use it as a foundation for an analysis of the logistical supportability of this emerging concept.

As a result of the first DO Wargame sponsored by MCWL in November 2004, a new definition of the concept was put forward by the participants as a:

> Technique that deploys tactical units across the depth and breadth of a battlespace in order to maximize opportunities to achieve favorable intelligence driven engagements. This is enabled by a robust and easily accessible backbone of C2 and prompt, responsive fires. (Wilson and Stephens 2004, page 1)

This represents an additive capability that will improve the ability of infantry to accomplish a wide range of missions across a much larger area of responsibility (AOR). While on the surface this definition may not seem to indicate much of a change from current doctrine, it indicates a major improvement in infantry capabilities that leverages technological advances and enhanced training to create a more lethal force.

The current concept proposed by MCWL for a DO platoon creates three squads with three fire teams. Two fire teams of each squad are combat teams and one is a headquarters and fire support team. The squads report to the platoon commander who reports to the MAGTF Commander or whoever has overall responsibility for the Area of Operations (AO). The distributed platoon will have the capability to operate far forward in a widely dispersed manner while collecting intelligence, controlling fires, and shaping the battlespace. These units will have no ground lines of communication and likely will need to be resupplied by aviation. The distributed platoon will need the capability to operate over extended periods of time. In order to facilitate missions of fourteen days or longer, a DO platoon will need a robust support concept that will rely heavily on air delivery and assault support. Figure 1 shows the proposed organization of the DO platoon, which is based on a modification of the current Marine platoon organization. (Corbett, 2004)

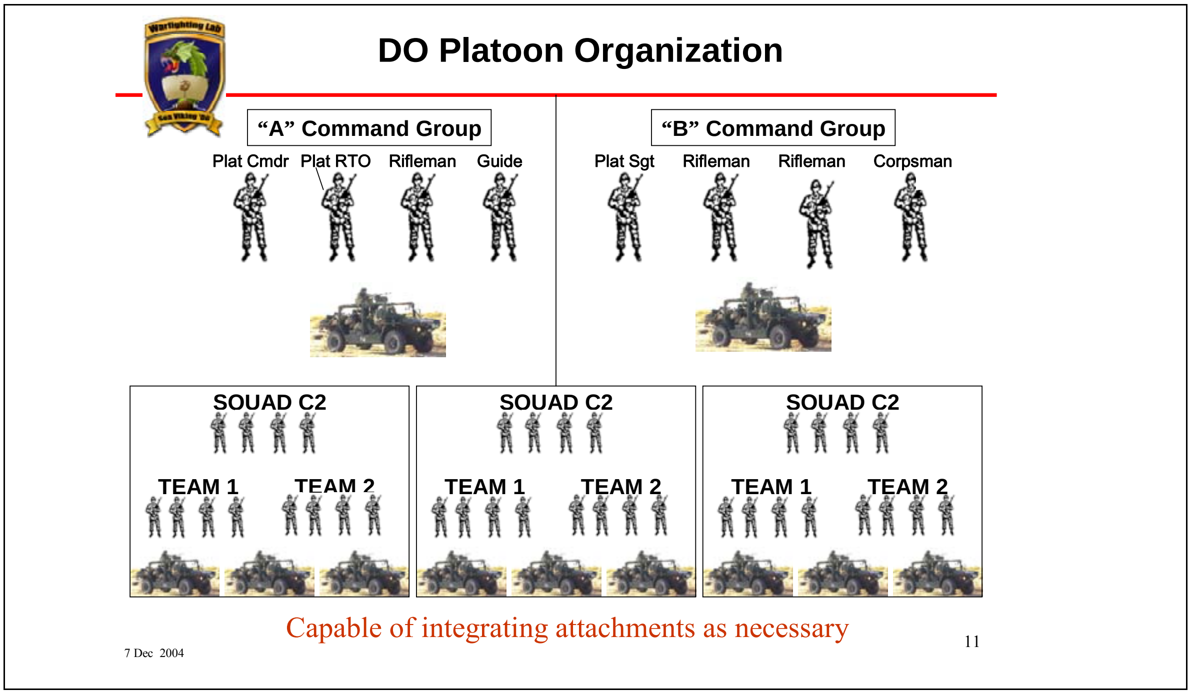

Figure 1. The current organization of a Marine Corps DO platoon. (from Corbett, 2004)

C. RESEARCH QUESTIONS

The goal of this thesis is to do a thorough quantitative analysis of the logistical issues pertaining to the combat service support of a DO platoon. While this analysis is by no means exhaustive, the following questions will be addressed:

- What are the critical logistical factors relating to mission success for the DO platoon in the missions envisioned in MCWL's Wargame Scenarios?
- What are the critical logistical capabilities of the MEU that will enable it to provide continuous sustainment to a distributed force?
- What is the supportability of a DO platoon across the range of missions?

This thesis uses simulation, data analysis, requirements determination, and other techniques to investigate these questions and develop a preliminary concept of support for a DO platoon.

D. BENEFITS OF THE STUDY

This study provides the Marine Corps with analysis support for the development of future tactics, techniques, and procedures for supporting units operating in a distributed environment. Additionally, it gives insights on the most important factors relating to force effectiveness that will enable leaders to make better acquisition and force structure decisions. The simulated operational experience that this analysis provides will help future logisticians to effectively support DO platoon operations. Ultimately, this thesis produces the means to develop an estimate of logistical supportability for a Marine DO platoon mission based on sound quantitative analysis that will support further concept development and experimentation.

E. METHODOLOGY

This thesis uses multiple quantitative analysis techniques in order to develop an estimate of logistical supportability for a DO platoon across a spectrum of operations envisioned by developers at MCWL. The foundation of the analysis is an agent-based computer simulation that is used to identify the critical logistical factors that affect mission success. Once these factors are identified, the results are used to develop a preliminary logistical estimate of supportability that accounts for these critical factors. This estimate is based on a combination of traditional logistical requirements determination, simulation analysis results, and principles of robust design. The ultimate motivation for this thesis is the need for a DO unit that is not only effective in its missions, but also supportable and flexible enough to be a ready tool for the MAGTF commander.

This thesis uses an agent-based distillation, which is a type of computer simulation which attempts to model the critical factors of interest in combat without explicitly modeling all of the physical details. The tool used is MANA (Map Aware

Non-Uniform Automata), which is in the Marine Corps Warfighting Lab's Project Albert suite of analysis tools (Marine Corps Warfighting Lab [MCWL] Project Albert Website, 2005). The methodology is to develop a realistic scenario based on MCWL's Sea Viking wargame with distributed operations. This scenario is then replicated in the simulation tool and then analyzed. The analysis process uses a technique called data farming, which is the major thrust of Project Albert. This involves using high performance computing to run the simulations thousands of times while simultaneously varying many input parameters. Using cutting edge experimental designs developed at the Naval Postgraduate School, the data resulting from these simulations is analyzed identifying critical factors, interactions, and thresholds (Cioppa, 2002). The results of the statistical analysis are then used to support the development of a logistical estimate of supportability for a DO platoon. The final product is a preliminary concept of support that is based on a solid foundation of analysis.

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II. MODEL DEVELOPMENT

A. INTRODUCTION

The foundation of any solid military analysis is a realistic scenario that will stress the system of interest. This chapter begins with a brief introduction to the concept of a DO platoon, which is followed by the scenario that forms the basis of this study. This scenario is introduced in a manner consistent with the experience of most military professionals. Following a description of the scenario is a brief description of the MANA simulation tool that is used to model and analyze the scenario. Finally, this chapter culminates with a detailed description of the behavior of the simulation model.

B. WHAT IS A DISTRIBUTED OPERATIONS PLATOON?

1. Overview

In chapter one, the concept of a DO platoon is introduced, but one may wonder how it is different from a traditional infantry platoon. Put simply, the DO platoon is a necessary first step forward in equipping, training, and supporting infantry units to be more flexible for missions in the future. According to General Hagee, the current Commandant of the Marine Corps, in a message addressed to all Marines, implementation of DO

> ...will require a focus on enhanced small units: more autonomous, more lethal, and better able to operate across the full spectrum of operations. This will require investing in the technologies and training that will provide individual communications, tactical mobility, and networked intelligence down to the squad level. Our logistics and fires capabilities must be adaptive and scalable in order to support these small units, whether dispersed across the battle space or aggregated for larger operations. (Hagee, 2005)

As a concept, it is not limited to the platoon level, but could potentially scale much higher, even to the company, battalion, or regimental level. DO is not simply a new doctrinal organization or a new suite of equipment. It is a synthesis of new equipment, training, doctrine, and tactics that will make the current Marine Corps infantry unit more flexible and lethal. In this section, the proposed organization and equipment for a DO platoon will be covered in more detail.

2. Organization

The DO platoon is based directly on the current table of organization for an infantry platoon. The current infantry platoon has one headquarters element of four personnel (five with corpsman) and three squads (13 per squad) with three fire teams (4 per team) in each squad. The platoon's end strength is one officer and 42 enlisted. The platoon is augmented with a Navy corpsman from the battalion's aid station platoon to make the total strength 44 personnel. The proposed table of organization for a DO platoon, shown in Figure 2, also has 44 personnel including the corpsman. (Marine Rifle Company Table of Organization, October 1999)

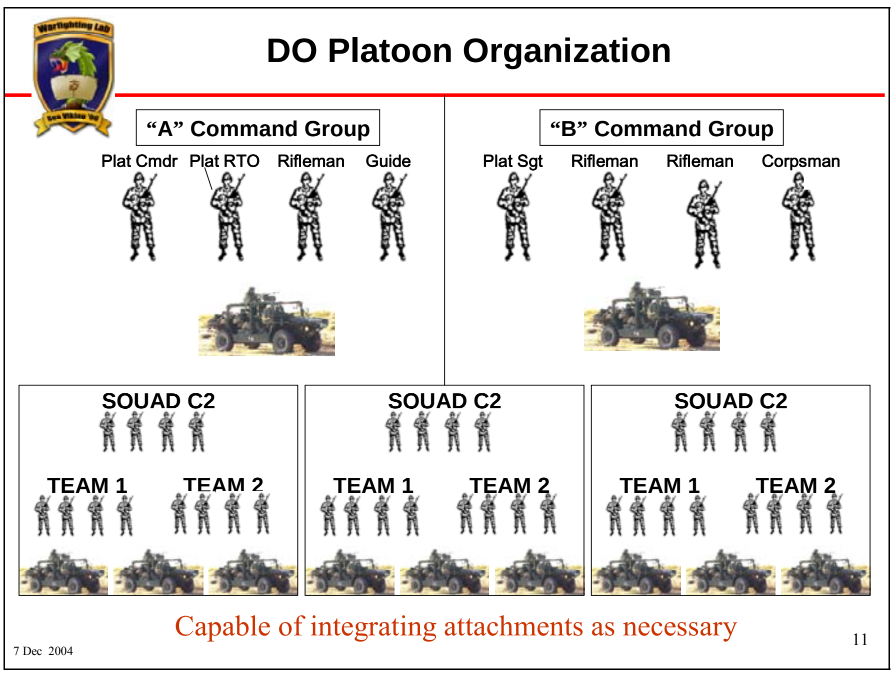


Figure 2. The current organization of a Marine Corps DO platoon reproduced from Chapter 1. (from Corbett, 2004)

The DO platoon is a reorganization of the current structure. Using the same number of Marines, the distributed platoon has two headquarters elements with redundant functions to facilitate command and control over a wider area. To facilitate advanced communication and fire support abilities, each squad has a command and control cell which operates the communication equipment and acts as a fire support team. To make up for the personnel in the command and control organizations, there are only two fire teams per squad, for a total of six fire teams per platoon, as opposed to the current organization of nine fire teams per platoon. The trade off is in advanced training, communication, sensors, fire support, and lethality, which should make the distributed platoon more lethal. (Corbett, 2004)

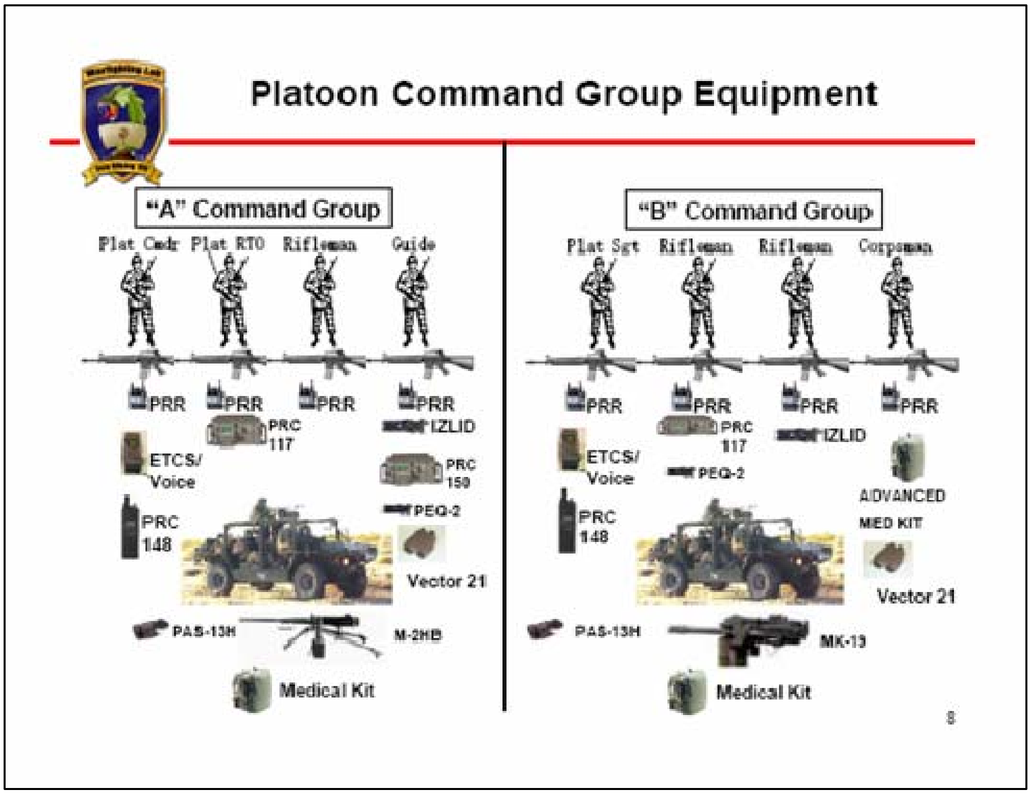


Figure 3. The equipment for the A and B command groups of the DO platoon. (from *Sea Viking 06 Distributed Operations Live Force Experimentation 25 Feb 05)*

3. Equipment

The equipment of a DO platoon is considerably more advanced than the current infantry platoon, especially in communications and sensors. The basic weapons for the platoon, like the M-16 rifle, M-203 grenade launcher, and the M249 Squad Automatic Weapon, remain the same as the current infantry platoon. However, the addition of vehicles allows the distributed platoon to carry several heavy automatic weapons, like the M2 .50 caliber machine gun and the Mk-19 automatic 40mm grenade launcher. The distributed platoon is by no means limited to operating from its vehicles, but the increased firepower of crew served weapons relies heavily on the use of the Internally Transportable Vehicle (ITV). The ITV is transportable aboard all Marine transport helicopters, including the MV-22 Osprey. It provides increased mobility, firepower, and sustainment for the platoon. The biggest advances, however, are in the communications, sensing, and targeting equipment.

	Billet	Equipment	Description	Technology	Range
A Command					
	Plt Commander				
		M16A4	5.56 rifle w/ rifleman suite		800m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	7-10mi
	Plt Radio Operator				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	7-10mi
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms		500-1000m
	Guide				
		M-16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
		PRC 150	Platoon to HHQ comms OTH (logistics)	HF/HFDigital	30+ miles
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	ITV		Internally Transportable Vehicle	Can be transported inside MV-22	
		PAS-13H	Optic for .50 caliber MG		
		M-2HB	.50 Caliber Machine Gun		1830m
		Medical Kit	Standard First Aid Supplies		
B Command	Plt Sergeant				
		M16A4	5.56 rifle w/ rifleman suite		800m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	7-10mi
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	7-10mi
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Corpsman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		Adv. Medkit	Corpman emergency trauma kit		
	ITV		Internally Transportable Vehicle	Can be transported inside MV-22	
		PAS-13H	Optic for Mk-19		
		MK-19	Automatic 40mm Grenade Launcher		1500m
		Medical Kit	Standard First Aid Supplies		

M16A4 Rifleman suite consists of:
PRR, Bayonet, Bipod, Compass, White/IR Light, Suppressor, Bayonet, Collapsable Stock, Day RCO, Night RCO

Figure 4. Detailed explanation of the characteristics of command group equipment. (after Marine Corps Warfighting Lab Sea Viking Website, 2005)

With long range scopes that are effective both day and night combined with advanced communications and laser designators, the distributed platoon is capable of observing and coordinating all types of joint fires. The new suite of sensors for the distributed platoon allows it to maintain observation out to the maximum range of its weapons both day and night. Figures 3 through 6 show the equipment of the DO platoon in great detail. (Marine Corps Warfighting Lab Sea Viking Website, 2005)

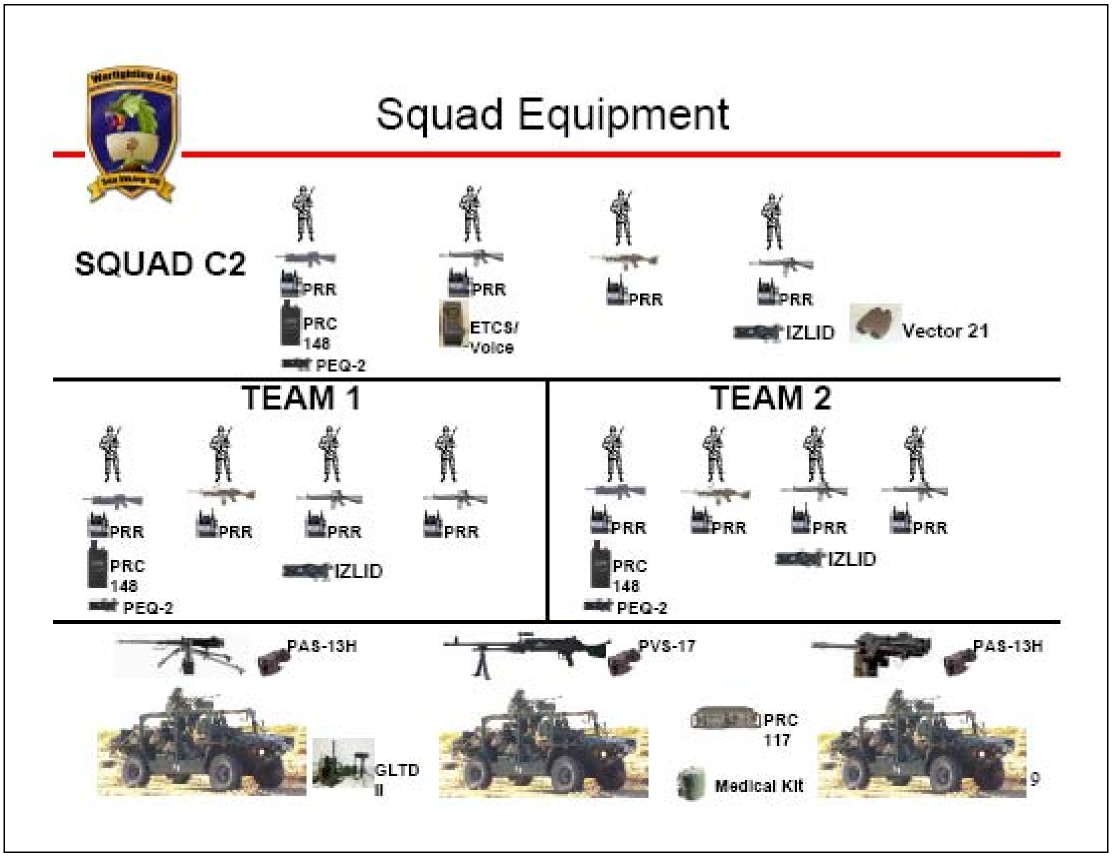


Figure 5. The equipment of the squad, of which there are three. Notice the large amount of communications equipment. (from Sea Viking 06 Distributed Operations Live Force Experimentation 25 Feb 05)

Squad Organization (3 per platoon)					
	Billet	**Equipment**	**Description**	**Technology**	**Range**
Squad C2					
	Squad Leader		SGT		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
	Automatic Rifleman				
		M249 SAW	5.56 Machine Gun w/ spare barrel		1000m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	ITV				
		M240G	7.62 Machine Gun		1800m
		PVS-17	Night Sight		
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	
		GLTD II	Ground Laser Target Designator	10x magnification	20km
		Medical Kit	Standard First Aid Supplies		
Team 1					
	Team Leader		CPL		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4			
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Automatic Rifleman		PVT-LCPL		
		M249 SAW	5.56 Machine Gun w/ spare barrel		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	ITV				
		M-2HB	.50 Caliber Machine Gun		1830m
		PAS-13H	Optic for M-2		
Team 2					
	Team Leader		CPL		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Automatic Rifleman		PVT-LCPL		
		M249 SAW	5.56 Machine Gun w/ spare barrel		1000m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	ITV				
		MK-19	Autmatic 40mm Grenade Launcher		1500m
		PAS-13H	Optic for Mk-19		

Figure 6. The squad equipment list with capabilities. Each squad has the communications and laser designators to be an effective fire support team. (after Marine Corps Warfighting Lab Sea Viking Website, 2005)

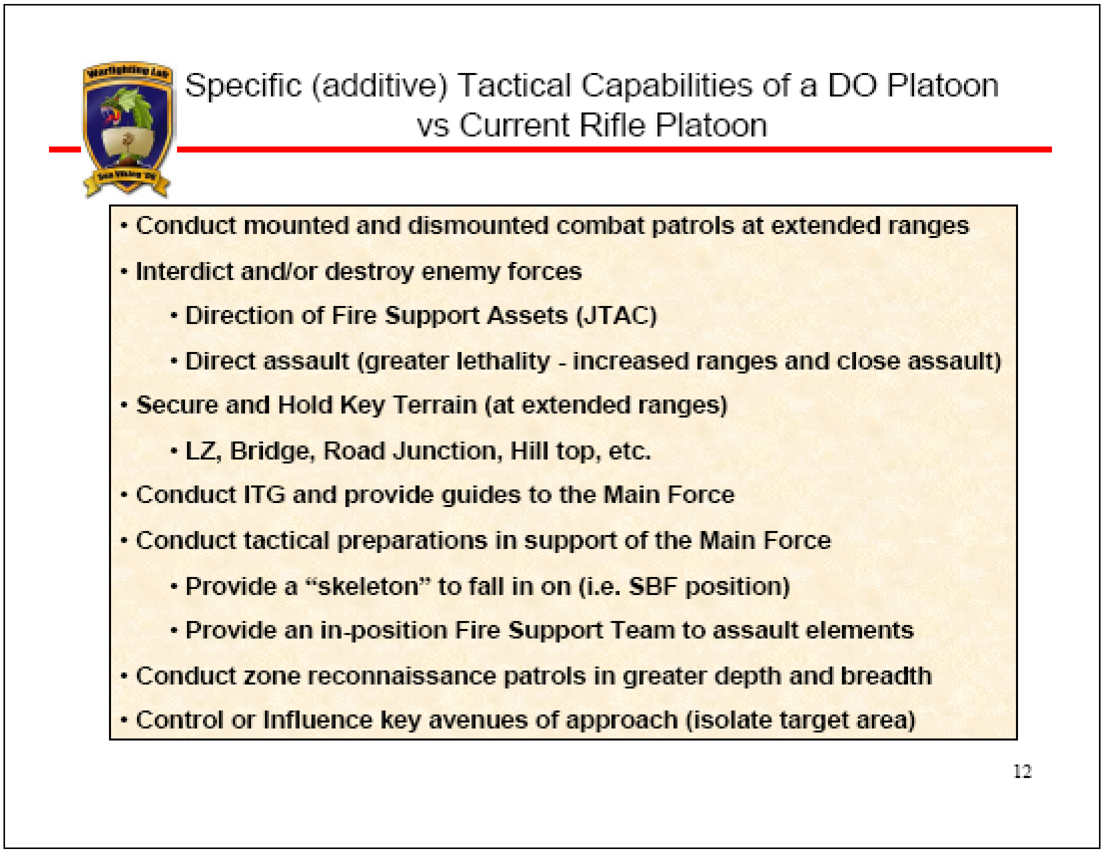


Figure 7. List of additive capabilities of a DO platoon. (from *Sea Viking 06 Distributed Operations Live Force Experimentation 25 Feb 05)*

4. Additional Capabilities

According to the table of organization, the mission of a Marine Infantry Platoon, also known as a Rifle Platoon, "is to locate, close with, and destroy the enemy by fire and maneuver, or to repel his assault by fire and close combat." (Marine Rifle Company Table of Organization, October 1999) This is also the mission of the Rifle Company of which the platoon is a part. The current concept of employment of an infantry company is as a maneuver element of the infantry battalion, but it does have limited capability to operate independently with appropriate attachments. Under existing doctrine, the platoon does not normally operate independently. The DO concept provides additive capabilities to the rifle platoon that will enable it to operate independently across a wide spectrum of missions. Figure 7 shows a brief summary of the additional capabilities of the DO platoon. For the scenario that will be presented in the next section, the major capabilities being utilized are to secure key terrain, control key avenues of approach, and interdict enemy forces.

C. SCENARIO DESCRIPTION

Figure 8. The basic geography of the scenario based on California geography. (from MCWL Sea Viking 2006 Distributed Operations Wargame 1 CD-ROM, November 2004) [Best viewed in color]

1. Overview

To conduct a simulation study, it is necessary to draw from realistic operational scenarios that will allow the analyst to measure factors of interest in a way that is sensible to decision makers. For this thesis, the basic outline for the scenario was obtained from MCWL's Sea Viking 2006 DO Wargame #1 held in Quantico, VA in November 2004. In the second scenario from the war game, the mission of the DO platoon was to conduct surveillance and interdiction along a border similar to the situation along the border of Pakistan and Afghanistan. The purpose of this section of the thesis is to relate that scenario to potential consumers of this research in order to provide a strong foundation for the subsequent analysis. What follows is a brief synopsis of the scenario which forms the basis of the simulation models. Figure 8 shows the basic geography of the region in question. (MCWL Sea Viking 2006 Distributed Operations Wargame 1 CD-ROM, November 2004).

2. General Situation

The United States and its allies have recently liberated the country of Panacea from an Islamist regime that sponsored acts of terrorism on the U.S. and other Western Nations. The situation is beginning to stabilize as the new government takes over, but opium production, pockets of former regime loyalists and terrorist warlords continue to be a major problem. Currently there is a significant problem of terrorist movement along the northeastern border between Panacea and Utopia, which is shown in Figure 9. Coalition forces in Panacea consist mainly of military advisors and aviation support to the Panacean fledgling military.

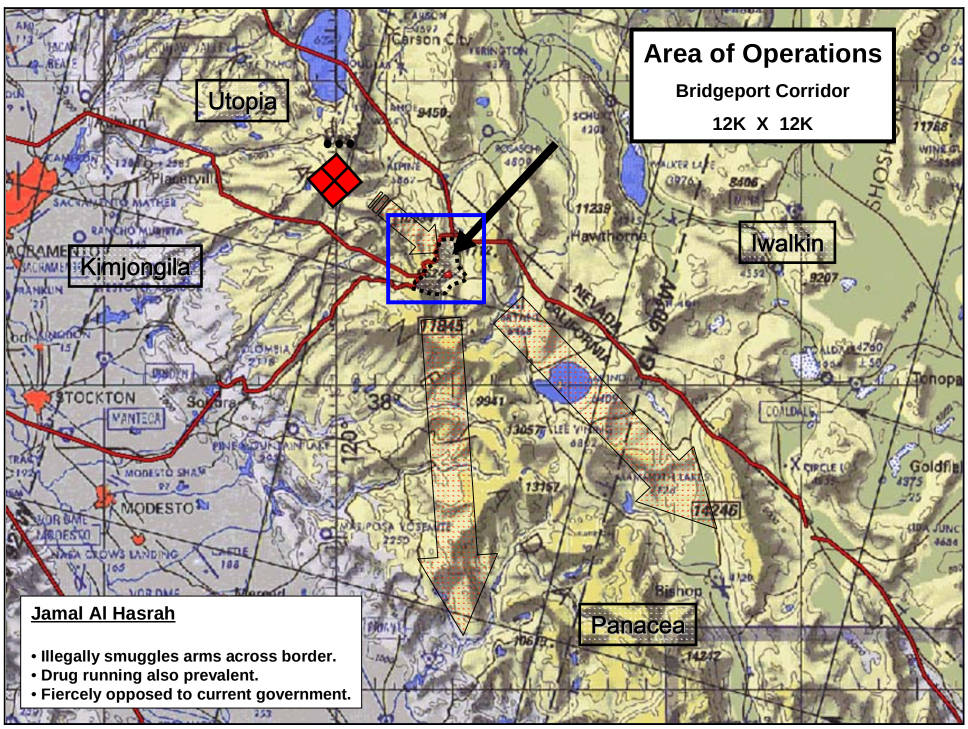


Figure 9. Infiltration into Panacea from Utopia through the Bridgeport corridor is a significant problem. (from MCWL Sea Viking 2006 Distributed Operations Wargame 1 CD-ROM, November 2004) [Best viewed in color]

3. Special Situation

a. Enemy

Human intelligence reporting indicates that a splinter group known as Jamal Al Hasrah (JAH), led by a previous warlord and insurgent, intends to capitalize on the ever growing drug trade and the challenges now posed for transnational terrorist movement in and out of Panacea by Panacea's strong alliances and borders with Kimjongila, Cuswakia, and Iwalkin. This splinter group mainly operates in the Bridgeport corridor using this area as a staging area, link up point, and access point for the passage of transnational terrorists, drug money for funding terrorism, and arms. Intelligence assesses that the JAH uses the Utopia/Panacea border region as a safe haven and the Bridgeport corridor as their main mobility corridor for movement in and out of Panacea. The enemy's most likely course of action, shown in Figure 10, is to infiltrate through the Bridgeport corridor using its knowledge of the terrain to avoid detection and engagement with coalition forces.

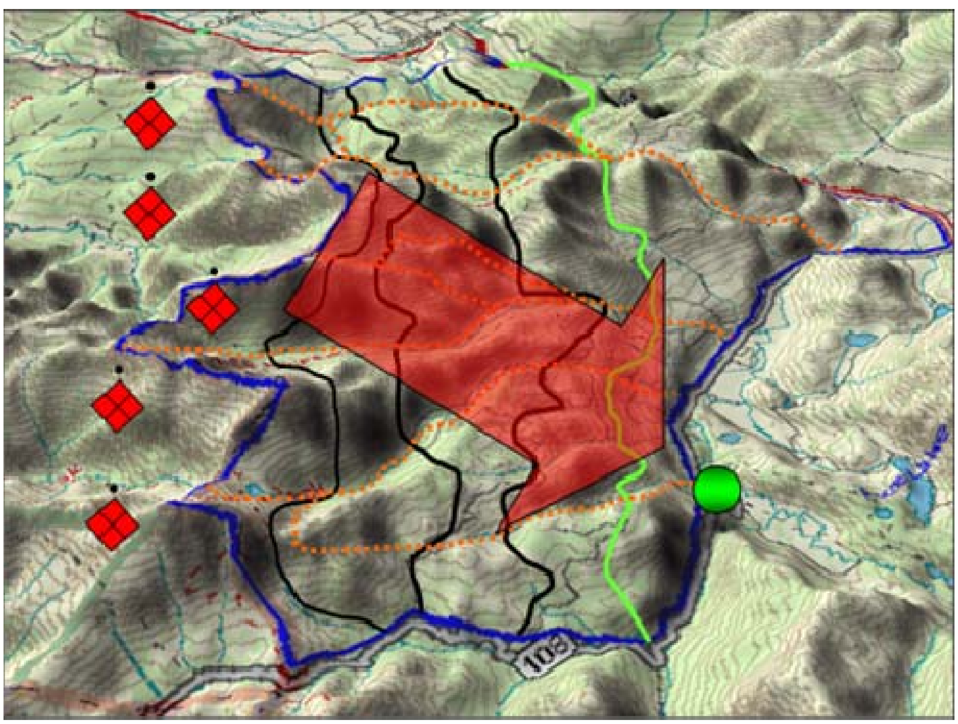


Figure 10. This picture shows the enemy's most likely course of action (from MCWL Sea Viking 2006 Distributed Operations Wargame 1 CD-ROM, November 2004). [Best viewed in color]

b. Friendly

The coalition commander and the Panacean government have decided to take the offensive. One of the forces at their disposal is an Expeditionary Strike Group with an embarked Marine Expeditionary Unit. The MEU commander has tasked the DO platoon with the mission of interdicting terrorist traffic coming into Panacea from Utopia in the Bridgeport corridor. The MEU C-130 detachment is ashore based at Twenty-Nine Palms in Panacea.

4. Mission

The mission of the DO platoon is to locate and interdict insurgent forces operating in the border region between Panacea and Utopia in order to block the flow of drugs, arms, and terrorists into Panacea.

5. Execution

The DO platoon will establish three squad patrol bases at maximum dispersion in order to cover the entire Bridgeport corridor with observation and fires. Squads will conduct patrols in the vicinity of patrol bases to ensure adequate coverage of the diverse terrain. The platoon will make maximum use of long range indirect fires to harass and kill the enemy. It will remain in place for an extended period (one to two weeks) in order to gain familiarity with the environment and operating characteristics of the enemy. The basic scheme of maneuver is shown in Figure 11.

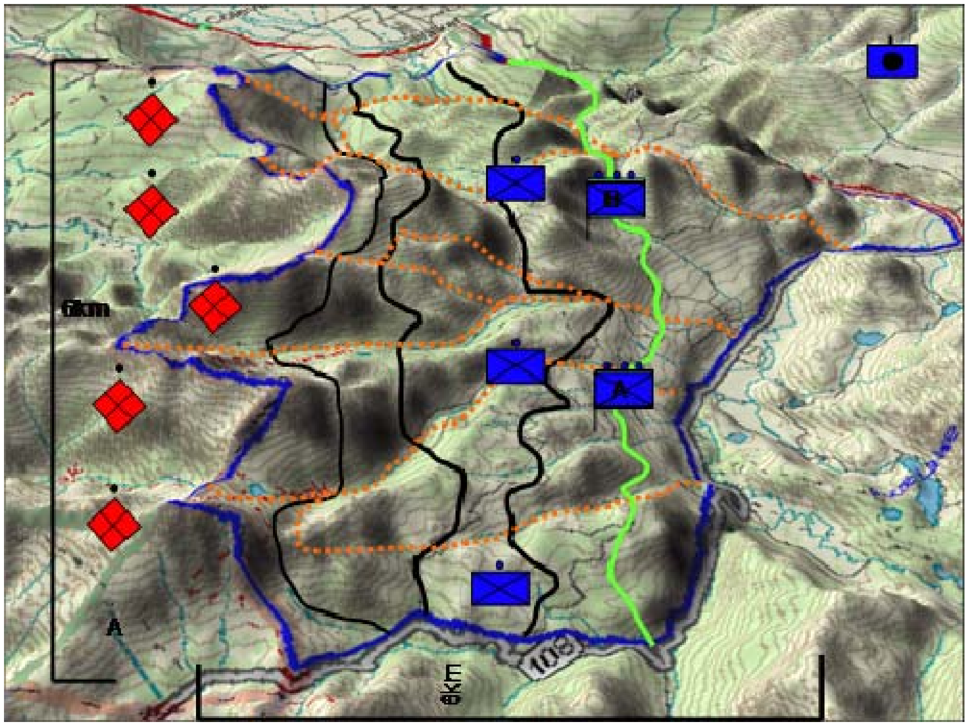


Figure 11. This figure shows the deployment of the DO platoon and supporting artillery as modeled in the computer simulation. (after MCWL Sea Viking 2006 Distributed Operations Wargame 1 CD-ROM, November 2004) [Best viewed in color]

6. Administration and Logistics

The DO platoon will be resupplied by aviation assault support via landing zones in the vicinity of their patrol bases. This support will come from the MEU Aviation Combat Element in the form of helicopters or air delivery by C-130. Medical evacuations will be conducted by helicopter. The CSS supporting agency is located approximately 50 kilometers from the DO platoon. There will be no ground lines of communication.

7. Command and Signal

The DO platoon will maintain a common operational picture and submit fire support and logistics requests using organic VHF, UHF, and HF radios and satellite communications. The Expeditionary Tactical Communication System (see Figure 4) has worldwide range, so communications range is not a limiting factor the DO platoon in this analysis. Each squad reports positions and contacts to the headquarters elements. For the purpose of this scenario, who the platoon reports to is not important, but it is assumed that the platoon is able to pass actionable intelligence and support requests through to the highest levels of the MEU staff with minimum delays.

D. THE MANA COMBAT SIMULATION TOOL

Now that the scenario has been described, this section briefly describes the MANA combat modeling environment, a tool for creating agent-based distillations, and why it was chosen. In the next section, the implementation of the scenario in MANA will be covered. Readers interested in a detailed technical description of the software should consult the user's manual, which can be downloaded from the Project Albert Website at http://www.projectalbert.org/.

1. Why MANA?

Map Aware Non-uniform Automata, or MANA, is the modeling environment selected for the development of the combat simulation used in this research. David Galligan and Michael Lauren began development of MANA for the New Zealand Army and Defense Force in 2000 after being exposed to early Project Albert agent-based models in 1999. In a nutshell, the goal of MANA is to, "explore the greatest range of possible outcomes with the least set-up time."(MANA Help File) Developer contact information is provided on the about screen from the help menu, shown in Figure 12. Since its development, MANA has been one of the data farming tools in the Project Albert suite of tools. It has been used in several Naval Postgraduate School (NPS) theses in recent years to analyze real world problems including humanitarian relief operations, unmanned aerial vehicles, convoy protection, and command and control (Dr. Tom Lucas Web Page, NPS, 2005). It is often referred to as an agent-based distillation, since it provides capability to model many of the most critical combat interactions by creating independent entities with unique characteristics, but not with the physical precision of an engineering model. MANA allows an analyst to model complex combat situations with terrain and communications in a relatively short amount of time. As distillations, models built in the MANA environment tend to run very quickly, allowing the analyst to execute the model thousands or millions of times as part of a sophisticated designed experiment.

The ability to run these large scale experiments is what enables the analyst to extract a large amount of information from the model.

Figure 12. MANA About screen provides contact information. (from MANA v3.0.39 Help File)

The main reasons the MANA modeling environment was chosen over other available options were flexibility, ease of use, and the ability to run large experiments. The MANA model allows the easy incorporation of terrain and elevation, communications, and numerous pre-programmed state changes. In MANA, one can quickly build a rough skeleton of the model from a realistic scenario, and then refine agent parameters and state changes to create a reasonably accurate model of the combat interactions desired. The flexibility of the model allows easy changes to be made to conduct experiments and what if analysis. In this research, a MANA model was constructed iteratively from the data provided in the MCWL scenario outlined previously in this chapter. Once the base case was constructed, it was easy to create numerous variations to fully explore the questions posed by this research.

2. Characteristics of the MANA Combat Modeling Environment

MANA is a time-step, agent-based modeling environment. In a MANA model, the agents are:

- Map Aware—Agents have situational awareness of the other agents and terrain that is updated by sensors and communications.
- Non-uniform—Individual agents may have different behavior parameters, capabilities, sensors, weapons, and communications.
- Automata—Agents react independently on the battlefield according to their own individual characteristics and awareness.

This distillation allows for graphical depiction of the terrain and agents to the desired level of detail. It is essentially a two-dimensional environment, with elevation being factored in when calculating line of sight and firing solutions. MANA is a straight forward application that is intuitive and easy to use with a well developed Graphical User Interface (GUI). The data farming techniques built in and provided by MCWL provide the ability to explore an extensive range of input parameter settings in minimal time. More details are readily available in the MANA User's Manual and at the Project Albert Website listed at the beginning of this section.

E. CHARACTERISTICS OF THE SIMULATION MODEL

This section describes in layman's terms the basic characteristics of the MANA simulation model developed for this thesis. It starts with a description of the goal of the simulation, followed by an overview of the model at a conceptual level. Following the conceptual description are detailed descriptions of the scale and terrain model, the enemy force, the Marine platoon, and the logistical support schemes which are the focus of the analysis. Throughout this research, the enemy insurgent force is often referred to as the red force, while the friendly Marine platoon is referred to as the blue force. A detailed breakdown of the technical specifications of model parameters is contained in Appendix B.

1. Goal

The simulation models the scenario described in this chapter as a long term mission (7-14 days) with the goal of measuring the effectiveness of different logistical support systems on the effectiveness of the DO platoon in its mission to stop the insurgents. The measure of effectiveness is the number of insurgents that are successfully interdicted. Factors of interest include but are not limited to: blue force days of supply, routine resupply rate, resupply signature, usage rates in various combat states, rapid request setup time, and resupply policy. The data farming techniques used by Project Albert allow the exploration of these and many other factors to determine effective support paradigms and significant factors.

2. Conceptual Model

In Figure 13, the overall concept of the simulation model is represented as an inventory queuing model. In a basic queuing model, there are customers who arrive for service, servers who provide the service, an inventory available to the servers, and a warehouse where additional inventory is stored. In this model, the customers are the enemy insurgents. The service they require is interdiction by Marines (to put it bluntly, they need to be killed). The Marine platoon provides the service using its combat capabilities to destroy the insurgents. If the Marine platoon's inventory of logistical supplies and combat power becomes depleted, it becomes more likely that the enemy will not be interdicted. The platoon's inventory of supplies can be refilled by several different methods, in much the same way that a store must reorder inventory from a central warehouse. Depending on the strength of the enemy and the effectiveness of the logistical support plan, more or less enemy will be successfully served. An effective service is a killed enemy insurgent; therefore, the measure of effectiveness (MOE) is the number of enemy killed divided by the total end strength of the enemy force. In other words, the effectiveness of the scheme of logistical support is measured by how well the platoon is able to prevent the enemy soldiers from crossing the border. While conceptually this model is fairly straightforward, the interactions between the customers, servers, and resupply agents is based on combat interactions, including command and control, intelligence, fire support, tactical movements, and air delivery.

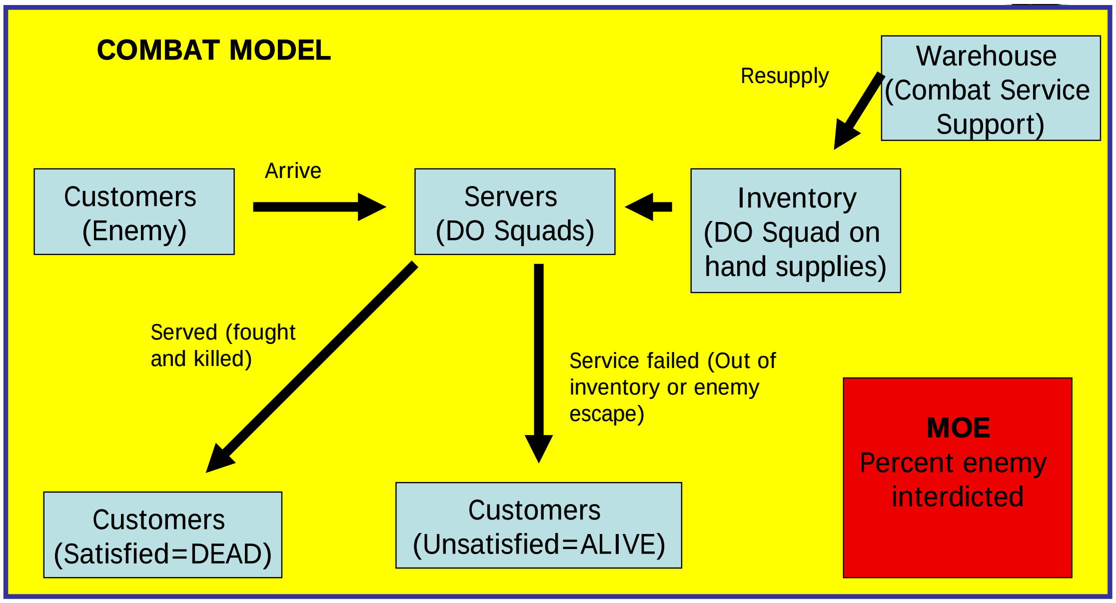


Figure 13. This figure shows the logical flow of the combat simulation used in this study.

3. Terrain and Scale

Since MANA is a time step model, there must be a mapping from real time to simulation time, and real space to the simulation space. In the implementation of this scenario, one model time step is equal to thirty seconds of real time. For a seven day scenario this equates to 20,160 model time steps. In order to minimize the potential inaccuracies of using a time step model, the scale of the terrain was chosen to be thirty meters per map cell. The map consists of a 200 by 200 grid of cells which translates into the six kilometer by six kilometer area alluded to in the scenario description. This scale level limits the likelihood of time step anomalies which can be caused when agents can move more than one cell in a time step. Under these scaling factors, a seven day scenario takes between two and ten minutes per execution and a fourteen day scenario averages about forty minutes of run time. The major reason for the variability of the run times is that time step model run time increases as a function of the number of entities squared.

The terrain in the model is composed of two separate and distinct elements. The foundation is the elevation file shown in Figure 14. In the elevation map, pure white represents the highest elevation, while pure black represents the lowest. MANA uses the elevation data to calculate whether or not a line of sight exists between two agents. The elevation used in the scenario is only relative, with mountain tops defined as the highest elevation and roads and valley being the lowest. The inclusion of terrain allows the red force to use terrain to mask its movement and prevents the blue force from simply sitting back and waiting on the enemy to get within range.

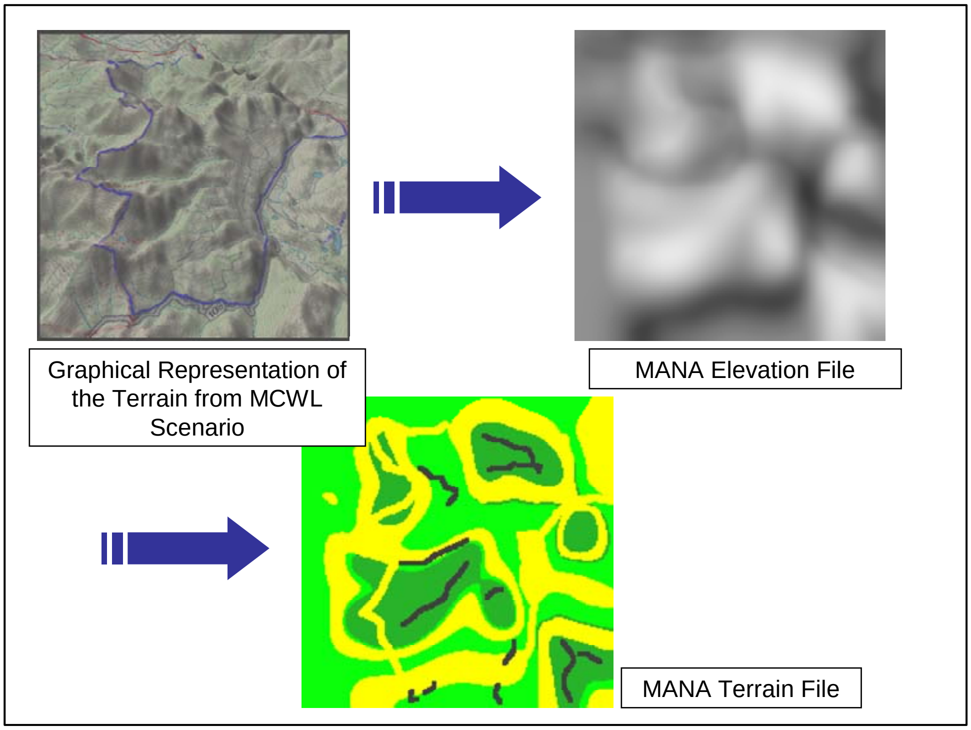
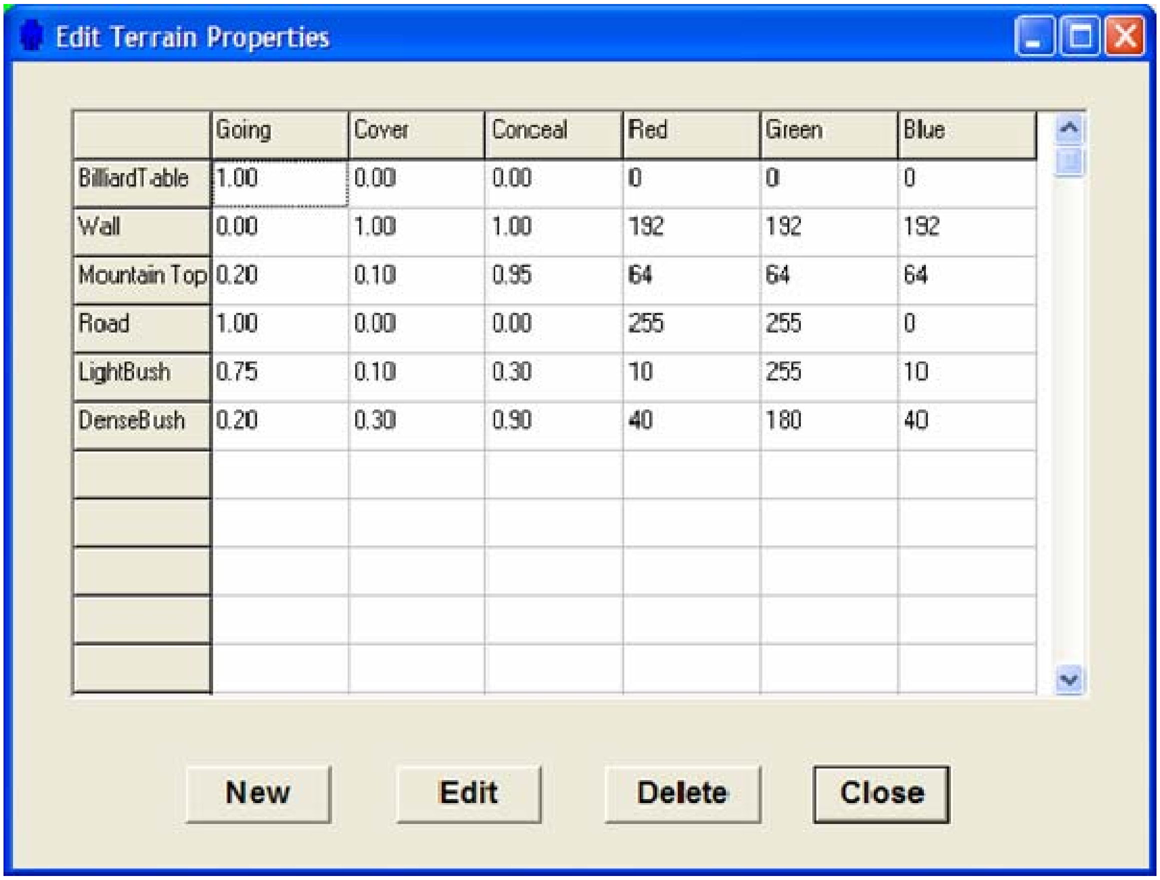


Figure 14. The Elevation and Terrain files used by MANA were derived from the terrain in the MCWL Scenario. [Best viewed in color]

The second element of the terrain is the terrain file, also shown in Figure 14. The various colors represent roads, vegetation, and hills. Figure 15 shows the way the various terrain colors affect movement speed (going), probability of hit (cover), and probability of detection (conceal). The effects are per time step. For the light bush terrain, which comprises the low foot hills and roadsides in the terrain map, movement speed is only 75% of the maximum speed for the agent, the probability of a bullet being blocked by terrain is 10%, and the probability of not being seen per time step is 30%. It must be remembered that these effects only matter if a line of sight exists between the agents. If two agents are on either side of a tall hill, the probability that they will see each other is zero, regardless of the terrain.



	Going	Cover	Conceal	Red	Green	Blue
BilliardTable	1.00	0.00	0.00	0	0	0
Wall	0.00	1.00	1.00	192	192	192
Mountain Top	0.20	0.10	0.95	64	64	64
Road	1.00	0.00	0.00	255	255	0
LightBush	0.75	0.10	0.30	10	255	10
DenseBush	0.20	0.30	0.90	40	180	40

Figure 15. The characteristics of the colors in the terrain file for the MANA model used in this research. (from MANA 3.0.39)

4. Red Force (Enemy Insurgents)

Insurgents arrive in the western area of the corridor at random locations periodically throughout the mission. As long as they think they are safe from blue forces they attempt to move quickly to their destination along known paths. If they are engaged with indirect fire, they will hide (hunker down) for a period of time, provided they survive the volley. When engaged with direct fire, they return fire and attempt to move away from friendly forces seeking cover and concealment. If there are enough insurgents moving together they may try to suppress blue forces with fire while moving to their objective. If red forces detect that a resupply operation is taking place, they will use the distraction of friendly forces to their advantage by advancing on their objective. Enemy forces move as individuals or small groups. The main goal of enemy is to reach their objective on the other side of the border without being eliminated by the blue force.

5. Blue Force (Marine DO Platoon)

The blue force is arrayed as shown in Figure 11 as a dismounted (due to terrain) infantry platoon and each squad conducts patrols in the vicinity of its patrol base in order to maximize observation of the area. Patrols are necessary due to the obscuration effects of the terrain. Blue force sensors, weapons, and communications are sufficient to provide mutual support with fires and intelligence, but their dispersion is too great for internal redistribution of supplies. Indirect fire is modeled as the MEU's artillery battery, but could be considered any type of joint or coalition fires whether land or air based. If MEU artillery was the only available fire support, a DO platoon would have very limited range, but the current concept is predicated on accessing joint and aviation fire support, so the limiting factor of artillery range is not considered in this analysis. Blue squads begin their mission with a specified number of days of supply and use them at different rates depending on their state. When blue squads are conducting surveillance or patrolling operations they use supplies at a rate of one day of supply per day. When engaged in combat operations they use supplies more quickly. When a blue fire team runs out of supplies they become combat ineffective and retreat to the patrol base to await resupply. Casualties are modeled as a fire team running out of supplies as well, since one casualty would take at least one fire team out of operation to evacuate that Marine. When out of supplies or while distributing supplies, it is much easier for red forces to maneuver past blue positions.

6. Logistical Support

Logistical support is modeled as a fuel tank for each blue fire team and headquarters element. When the tank is empty, the team is not effective at coordinating fire support or engaging terrorists. Each squad has a resupply point at which it receives deliveries and conducts evacuations. Supply operations are scheduled, but can be triggered by rapid requests or by sense and respond (autonomic) logistics. Since medical evacuation or resupply represent a significant effort by support agencies, it is assumed that any rapid request mission or medical evacuation will bring the platoon a full set of supplies depending on how much they can carry. For instance, if the platoon goes in with one day of supply, it is assumed that it is all it can carry.

7. Data Sources, Abstractions, Assumptions, and Validation

In a combat model, the source of the data is a matter of some concern. For this model, several abstractions have been made that reduce these requirements somewhat. Radio communication and common operational picture equipment is assumed to function perfectly throughout the AOR. DO platoon sensor and radio capabilities are available on MCWL's website and in the reports that have been cited.

Weapons ranges and firing rates are available at <http://www.globalsecurity.org> and <www.fas.org> and are assumed to have a probability of hit of near one at close range. The probability of hit reduces linearly to 0.5 at max effective range. This modeling technique was obtained from a tool developed by Captain Mike Babilot, USMC at NPS, who consolidated the ranges and effectiveness of all DO weapons. Since this model uses a single agent to model a fire team, it has the hit probability of an M-16, out to max effective range, and then hit probability degrades to 0.1 at the max effective range of the M-249. Enemy weapons have the same range as friendly weapons, but blue casualties are modeled as a depletion of supplies instead of as a loss of available hit points since the model does not allow for the resurrection of dead or wounded agents. Red force agents die when their available hit points run out. . As a result, the sensitivity of direct fire weapon effectiveness will be explored indirectly in the simulation experiment by varying the red agents' hit points.

Artillery characteristics and ground tactics were validated with Colonel Ed Lesnowicz, a retired Marine artillery officer with Wisdom Jacket Consulting, who consulted on this research. The scheme of maneuver and scheme of support for the scenario were derived from the MCWL scenario, but were not directly specified. They were derived by a mission analysis process and the application of professional skill that the author has gained as a logistician and Marine officer coupled with recommendations in the MCWL wargame report. Simulation parameters that can not be established solidly from data or to which the outcome is sensitive are explored by the experimental design described in Chapter III. After the model development was complete, it was reviewed by a panel of Marines and scientists familiar with this type of research. A skeptical reader must keep in mind that this simulation model will not be used to predict success or failure for a particular mission. This model is used to more fully understand the problems associated with sustaining a DO platoon in order to develop a logistical support concept that will be based on the actual requirements of the Marines while also accounting for the increased risk associated with DO. Appendix B contains a detailed breakdown of all the simulation parameter settings. Figure 16 shows a screen shot of the working simulation model.

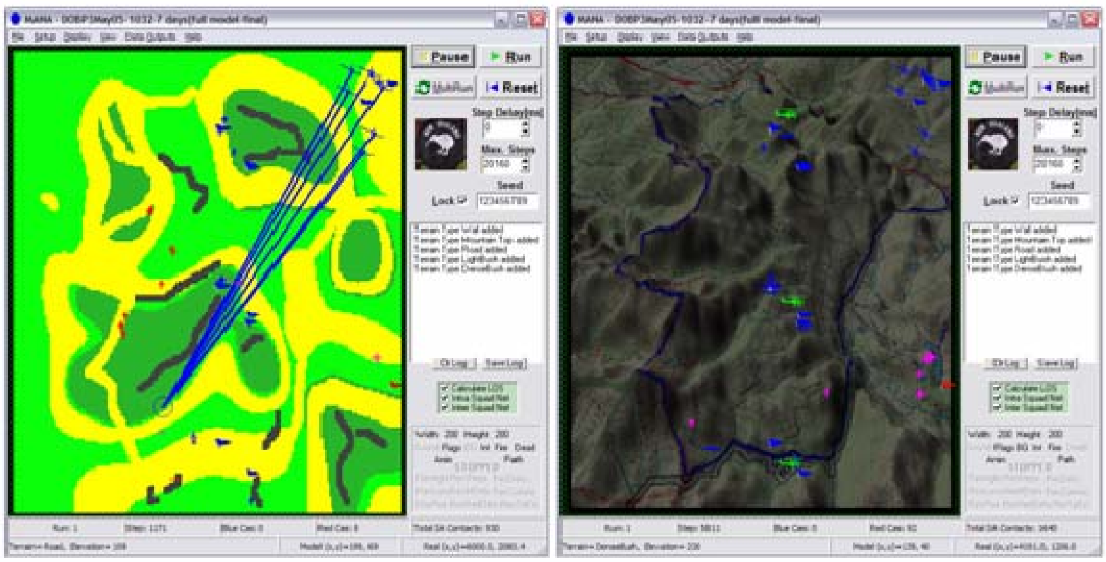


Figure 16. This shows two different views of the simulation running. On the left is artillery firing with the terrain map displayed. On the right is a resupply with the scenario background. [Best viewed in color]

The best illustration of the quality, credibility, and utility of the model developed for this research, other than the data analysis in Chapter IV, is the level of team work that went into its production. The simulation model development process occurred between January and April 2005. During this time frame, the model development process was evaluated weekly by other military officers, combat and simulation modeling experts, and international military officers. The model development process even included a trip to the Maui High Performance Computing Center (MHPCC) to work directly with experts in agent-based simulation modeling. Each parameter of the final model was scrutinized in detail by a panel which included Dr. Tom Lucas, PhD, a combat modeling expert at the Naval Postgraduate School, Ed Lesnowicz, a Marine artillery colonel with experience in Vietnam at Khe Sanh and as Chief of Staff for Marine Forces Europe, Todd Sanders, an infantry captain and operations research analyst with experience in widely dispersed small unit tactics on rough terrain, and Kevin McMindes, a Marine major helicopter pilot and operations research analyst with assault support experience. The model was debugged by varying parameters simultaneously throughout their ranges in order to ensure the model behavior was correct across the ranges of interest. Additionally, before any research quality data was generated from the model, the entire model development process was briefed to the director of MCWL's Project Albert, Dr. Gary Horne, PhD.

8. Summary

To put it all together, this thesis uses the MANA simulation tool to model a realistic combat scenario that might be faced by a Marine DO platoon. This particular scenario was chosen because it is logistically challenging and based on a scenario used during MCWL's DO wargame. The resulting model captures the essential critical combat interactions necessary to gain insight into the effectiveness of various concepts of logistical support.

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III. EXPERIMENTAL DESIGN

A. INTRODUCTION

This thesis makes use of a MCWL Project Albert technique called Data Farming, which was developed in large part by the director of the project, Dr. Gary Horne, in 1998. Put as succinctly as possible, Data Farming involves taking a relatively simple simulation model, like the one used in this thesis, and running it many times while simultaneously changing many of the input parameters. The resulting data set allows an analyst to explore the landscape of possible outcomes in order to more fully understand a problem. The goal is not prediction. According to Dr. Horne, "You can't really predict anything, but if you look at enough possibilities, you can begin to understand."(Lawlor, 2005) It would be nice if one could look at all possibilities, but, "You can never cover the landscape because you're up against virtual infinity."(ibid) Since it is not possible to look at everything, even with access to the Maui High Performance Computing Center (MHPCC), it was necessary to design experiments that explore the possible outputs of the simulation in a smart way, recognizing that an analyst cannot look at everything he would like.

This chapter starts by outlining the parameters chosen as variables for the simulation experiment in this thesis. Since model refinement and exploration required several experiments, the next topic covered is the debugging experiment which was used to debug the model and narrow the focus of the study. Finally, this chapter describes the final experimental designs used to generate the data used to more fully understand the challenges associated with supporting a DO platoon.

B. VARIABLES OF INTEREST

This section describes the simulation parameters, or factors, that were chosen for the experiment. Controllable factors are those factors that a decision maker can control in the real world, and are often called decision factors. The uncontrollable factors are those that cannot be controlled in the real world by a decision maker, such as enemy capabilities. Since they cannot be controlled in the real world yet contribute to the overall variability, they are often called noise factors. Since there are many abstractions in the simulation, it would be possible to consider certain factors as both decision and noise factors. For example, the speed of the logistics delivery agency can represent vehicle speed, which is controllable, or it can represent the affect of weather on a fixed doctrinal speed, which is uncontrollable. Since these distinctions can tend to become murky, especially *a priori*, this research considers decision factors as those that are more or less controllable by the Marines, and the noise factors are those that are more or less controllable by the enemy. Since some variables of interest are categorical as defined by various logistical support systems, this section concludes with a description of several scenarios that were created as slight variations of the basic scenario described in Chapter II. Figure 17 summarizes the variable simulation parameters, and their maximum ranges used in the experimental designs.

Factor	**Value Range**	**Explanation**
DO Platoon Days of Supply	1..5	The amount of supplies, in days, carried into initial deployment
Scheduled Resupply Days	1..5	The number of days between scheduled resupply missions
Consumption rate when in enemy contact (fuel/step)	1..100	Consumption rate of blue squads when in contact with the enemy
Consumption rate when shot at (fuel / step)	1..100	Consumption rate of blue squads when in direct contact (i.e. in a fire fight with the enemy)
Rapid request setup time (min)	1..360	Time, in minutes, from time of request to time of resupply unit departure from combat service support area
Time to conduct resupply (min)	1..60	Time, in minutes, to execute the transfer of supplies and casualties when the resupply unit arrives at DO platoon
Resupply speed (m/s)	50..1000	Movement speed, in meters per second, of the Resupply force
Resupply stealth (rate per time step)	0..100	Concealment rate of resupply force per time step
Resupply sensor range	34..167	Sensor detection and classification range, in meters, of resupply force
Inorganic sensor persistence friendly (min)	1..120	Time, in minutes, a blue force sensor will maintain a previously reported track of an enemy agent
Sense and respond lead time (hrs)	0..12	The amount of lead time built into the sense and respond (autonomic logistics) system in hours
Enemy Sensor Range (m)	90..2040	Sensor range, in meters, of the enemy's sensors
Enemy Squad Size	1..20	Number of agents in an enemy squad
Contact Persistence Enemy (min)	1..120	Time, in minutes, enemy forces will continually track a blue agent
Enemy hits to kill	1..10	Number of weapon hits required to kill an enemy agent

Figure 17. The variable factors in the experimental design. Decision factors are in yellow, and noise factors are in white. Value ranges are for the Debugging design. [Best viewed in color]

1. Controllable Factors

The following factors were chosen to explore the effectiveness of the DO platoon under various logistical systems:

a. DO Platoon Days of Supply

This is defined as the number of days of supply the DO platoon carries into the AOR.

b. Scheduled Resupply Days

This is the number of days between scheduled resupply missions.

c. Consumption Rate When in Enemy Contact (fuel/thirty seconds)

This is the defined as the usage rate of supplies by the DO platoon while maneuvering against or engaging the enemy.

d. Consumption Rate When Shot At (fuel/thirty seconds)

This is defined as the usage rate of supplies by the DO platoon while being fired upon by the enemy. This is a creative use of limited features in the simulation tool to capture unanticipated logistics events such as casualties and equipment failure.

e. Rapid Request Setup Time (minutes)

This is the time lag between receipt of an emergency request (at least one fire team of the DO platoon is out of action) until the resupply mission is launched. It represents the difficulty in responding to urgent requests by assets that may not be dedicated or properly configured.

f. Time to Conduct Resupply (minutes)

This is the amount of time the individual elements of the platoon are out of action while receiving supplies from the supporting agency. While a fire team is downloading supplies, it is not very effective at conducting its interdiction mission.

g. Resupply Speed (meters/second)

This is the movement speed of the agents that conduct the resupply missions. It can represent either the speed with which the resupply assets are capable of moving to the delivery point or the distance they must travel. It could also be interpreted as the delay caused by operating in poor weather conditions.

h. Resupply Stealth (percentage)

This is the concealment rate, per time step, of the resupply agents. The enemy agents try to take advantage of the resupply mission by moving more quickly while the DO platoon is out of action downloading supplies. If the resupply agents are undetected, this enemy tactic is negated.

i. Resupply Sensor Range (meters)

This is the range of sensors on board the resupply agents which are modeled as aircraft. The sensors can be used to pass intelligence on enemy activities while conducting a resupply mission. The DO platoon can use intelligence from the resupply agents to coordinate indirect fires on the enemy.

j. Inorganic Sensor Persistence Friendly (minutes)

This is the amount of time tracks are maintained on the blue force situational awareness map. This is used to provide some sensitivity analysis on the value and effect of information. If tracks are maintained long after the enemy is out of the area, the DO platoon could potentially waste resources or fire support assets in a vain attempt to seek out and destroy the enemy.

k. Sense and Respond Lead Time (hours)

This is the amount of lead time that the autonomic logistics system uses to conduct push logistics. The sense and respond system tracks the DO platoon usage rate when in and out of enemy contact exactly, but it cannot track or anticipate the usage rates generated by enemy fire. Essentially, it cannot predict casualties. Based on its tracking of supply levels, it can trigger a resupply mission before it expects the DO platoon to run out of supplies.

2. Uncontrollable Factors

These are the noise factors, used to ensure that any conclusions drawn are based on a broad exploration of enemy threat levels. They are listed below:

a. Enemy Sensor Range (meters)

This is the detection and classification range, in meters, of the enemy's sensors. Since the enemy is trying to infiltrate and avoid blue forces, having a longer sensor range is an advantage. Conversely, with a shorter sensor range, the enemy is placed at a disadvantage.

b. Enemy Squad Size

This is the number of enemy agents in each squad of enemy. There are forty enemy squads in the seven day scenario. Varying this parameter directly changes the level of combat intensity.

c. Enemy Contact Persistence (minutes)

Defined as the time, in minutes, enemy forces will keep a blue contact on their situational awareness map. This parameter is used for sensitivity analysis.

d. Enemy Hits to Kill

This is the number of times an enemy agent has to be hit by direct or indirect fire to be killed. It is a way to vary the intensity of combat. A low value could also represent very effective blue weapons while a high value could represent less effective weapons.

3. Scenarios

The basic scenario is described in great detail in Chapter II, but, for the purposes of the simulation experiment, four additional scenarios were created as simple modifications. These scenarios are useful for identifying the key characteristics of an effective logistics system. The scenarios are as follows:

a. Full Model

This model is as described in Chapter II. In this model, there are scheduled resupply missions, rapid requests, and autonomic logistics. Additionally, the resupply agents can deliver battlefield intelligence gained from their sensors.

b. No Resupply Intelligence Model

This is identical to the Full model, except that the resupply agents, which are modeled like helicopters, cannot provide intelligence information on enemy movements to the DO platoon. This is to measure the utility of resupply assets doubling as intelligence platforms. This scenario is referred to as the “NoHelo” model during the data analysis.

c. No Rapid Request Model

This is identical to the Full Model except that the DO platoon is unable to request support via rapid request. Under this circumstance, a fire team could remain out of commission due to a maintenance or medical issue until the next scheduled supply or until the sense and respond system triggers a resupply mission. One would not deliberately send Marines into combat without the ability to conduct rapid requests, but this model helps to measure the utility of rapid requests by comparison. This scenario is referred to as the "NoRR" model during the analysis.

d. No Sense and Respond Model

This is identical to the Full Model except that the autonomic logistics capability is removed. This scenario is referred to as the "NoSR" model during the analysis.

e. Scheduled Resupply Only Model

This is identical to the Full Model but both rapid requests and sense and respond logistics are removed. Only scheduled resupply missions are allowed. Once again this helps measure the utility of rapid requests and autonomic logistics.

Each of these scenarios can be run as either a seven or fourteen day mission. In the next sections, the way in which these scenarios and parameters are put together to form an experiment is described in detail. This scenario is referred to as the "SchedOnly" model during the analysis.

C. THE EXPERIMENT

Developing a simulation experiment is an iterative process in which experimentation and data analysis is done in order to debug the model, verify behaviors, and narrow the focus of the final experiment. The experiment done is this thesis was done in three stages. The first stage was a debugging experiment. The second stage was a fairly large exploration across all the parameters. The final stage was a much more focused exploration and very large in scale. This section begins by describing a critical tool in the experimental design, the Nearly Orthogonal Latin Hypercube (NOLH). It then describes the experiments designed for each of the three stages of experimental development. Detailed tables of the actual experimental designs are contained in Appendix C.

1. The Nearly Orthogonal Latin Hypercube

The NOLH space filling experimental design technique used in this research was developed by LtCol Thomas Cioppa, U.S. Army, at NPS in 2002. This technique allows for the exploration of a large number of input parameters in an efficient number of runs while maintaining nearly orthogonal design columns. (Cioppa, 2002) For example, using just high and low levels for each of the variables listed in Figure 17 would result in 2^{15}, or 32,768 combinations of input parameters. The NOLH allows the exploration of the same space with sixty-five combinations of input parameters, and does not limit one to using only high and low values. Nearly orthogonal design columns are essentially uncorrelated, which gives the resulting data nice statistical properties. Since this technique is merely the tool that helps make this research possible, and not a subject of the research itself, the algorithms are not covered here. The reader is cautioned that one never gets something for nothing and that a NOLH design, while efficient, is not complete. For this reason, this research uses a combination of experimental design techniques combining factorial designs with the NOLH designs. This technique provides more data in critical regions and ensures fair comparisons between various input levels.

2. Debugging Design

The debugging design was simple to create using the NOLH generating spreadsheet tool, created by Dr. Susan Sanchez, a Professor of Operations Research at NPS, and used in the Advanced Simulation course. (Sanchez, 2005) The experimental design consisted of taking all of the factors listed in Figure 17 and the ranges listed, except for sense and respond lead time, and inputting them into the tool. Since this experiment had fourteen variables, the NOLH tool generated sixty-five excursions. An excursion is a unique combination of input parameters. The experiment was designed to run each of the sixty-five excursions twenty times each. Each repetition of an excursion is called a replication. This experiment called for a total of 1,300 replications and was only run for the Full Model as a seven day mission. The resulting data was not usable for the research, but it was useful in tracking down several bugs in the model. After corrections and further tests were made, the model was ready for producing analysis quality data.

Figure 18 shows a scatter plot matrix of the debugging design. The factor names are on the diagonal. Each of the plots shows all the input combinations of the factors in its column and row. Notice the excellent space filling properties. The maximum correlation coefficient between any two factors is 0.079. This helps to ensure that factor effects will not be confounded with other factors.

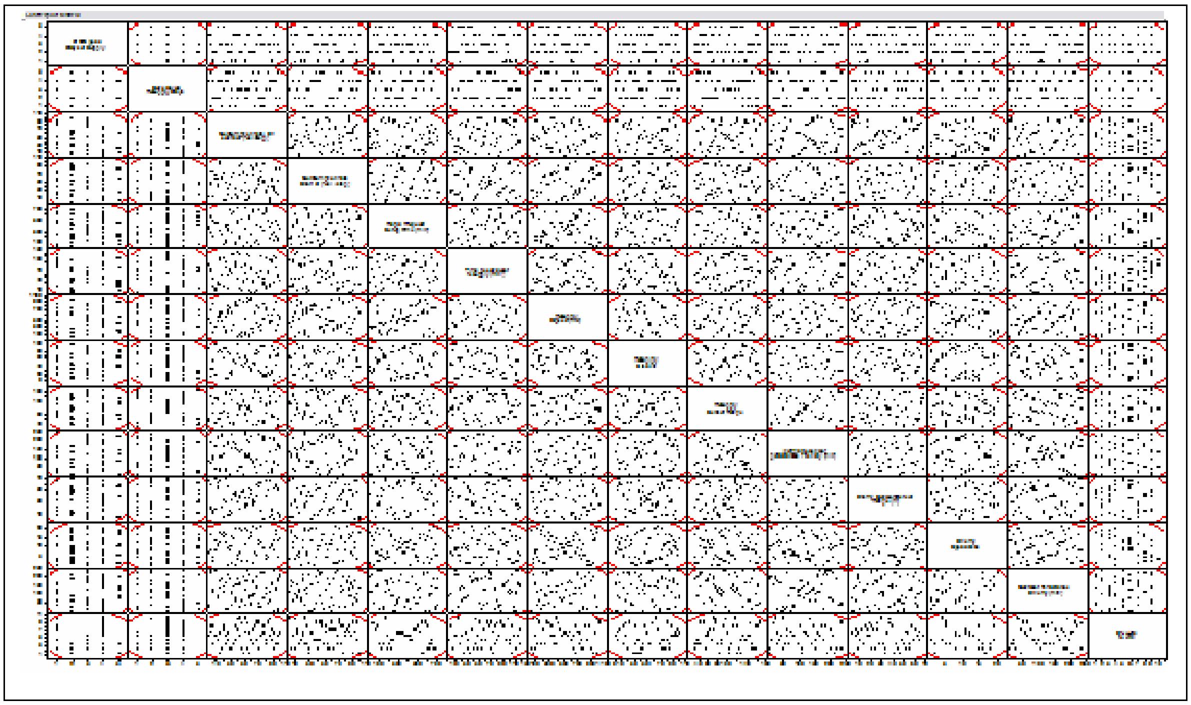


Figure 18. A scatter plot matrix of the debugging design.

3. Exploration Design

The exploratory design was devised to provide a broad brush analysis of all the parameters across all the scenarios. It consists of thirty-three excursions of the decision factors (except sense and respond lead time) and seventeen excursions of the noise factors. The Cartesian product of the decision and noise factors results in 561 excursions. This ensures that each decision point is compared against all seventeen excursions of noise. This 561 excursion experiment was run with twenty replications per excursion for each of the five scenarios using a seven day mission. This resulted in 56,100 data points. A quick exploration of this data revealed that more information was needed about days of supply and that a parameter needed to be added to test sense and respond lead time. This data also gave a fairly good understanding of the effects of the noise factors. One of the decision factors, resupply sensor range, was so insignificant that it was dropped from the next design and replaced with sense and respond lead time.

4. Large Scale Experiment

This experiment ran from 7 June 2005 to 7 July 2005 at MHPCC, anecdotally setting a record for the longest simulation run submitted for an NPS thesis using Project Albert tools. While there is no way to really check this, it is an illustration of the desire to widely explore the decision space. The excursion values are in Appendix C. Briefly summarized here, this design was developed to widely explore areas where logistical decisions have to be made. All feasible scheduled resupply policies, fifteen total, were crossed with three levels of sense and respond lead time. The resulting 45 excursion design was then crossed with 17 excursions of the seven remaining decision factors in an NOLH. This resulted in 765 design points in the decision space. This design was then crossed with three levels of noise which can best be characterized as low intensity, medium intensity, and high intensity combat. The result, 2,295 excursions times five scenarios. The full model was run with twenty replications per excursion. The remaining models were run with ten replications in order to save time. This resulted in 137,700 data points.

D. RUNNING THE EXPERIMENT

One of the core strengths of Project Albert is its ability to leverage supercomputing assets to run simulations many times. MHPCC is where all the simulation experiments for this research were done. MHPCC takes the simulation files along with an eXtensible Markup Language (XML) study file which specifies how the input parameters are to be varied. Development of the study file is not trivial, but Project Albert provides both an application and a web interface for study file creation. Study packages can be submitted online from anywhere in the world via the Internet or electronic mail. Once the study is submitted, the personnel at MHPCC run it on the cluster and generate the output files. While the simulation is running, the analyst can check its progress in real time via a web interface. The value of MHPCC is that it enables the analyst to run large scale, long term experiments, in an almost fire and forget fashion. The experiments run for this research utilized more than 700 CPU days at MHPCC. In other words, a normal desktop computer would have to run for nearly two years non-stop to generate all the data used in this research. MHPCC was able to do it in about a month and a half. Had NOLH techniques not been used in this research, the simulations could have taken over 2,000 CPU years to explore the same decision space. In the next chapter, the 193,800 data points generated from the experiments are analyzed to draw conclusions about the best way to sustain the DO platoon and to begin to answer the questions posed by this research. More information about the study submission process at MHPCC can be obtained at <http://www.projectalbert.org>. (Project Albert Website, July 2005)

IV. DATA ANALYSIS

The experimental designs described in the previous chapter combined with the computing power of the data farming environment at the Maui High Performance Computing Center (MHPCC) allows a great deal of information to be extracted from the simulation model. In this chapter, the data collection and post processing is briefly described, followed by a more detailed analysis of the data. In order to gain the most information possible in a short time, this analysis focuses on answering the research questions presented in Chapter I. Following this, additional analytical insights are presented. Throughout this analysis, it is useful to keep in mind a quote by the late mathematician and NPS professor of computer science, Richard Hamming. He once said, “The purpose of computing is insight, not numbers.” In this chapter, the focus will be gaining insights into supporting a distributed operations (DO) platoon.

A. DATA COLLECTION AND POST PROCESSING

Using the Project Albert data farming environment hosted at MHPCC makes data collection and post processing a simple process. When an experiment is complete, the MHPCC cluster generates a comma-separated values (CSV) text file containing all the input variables from the experimental design along with the desired measures of effectiveness (MOEs). The raw CSV file contains the input and output data in the terms of the simulation parameters. Post processing consists mainly of converting simulation units into sensible measurements like days of supply (DOS), hours, minutes, et cetera. The MOE, proportion of enemy killed, is calculated by simply adding up the total number of enemy killed and dividing by the total number of enemy. The MOE is bounded between zero and one and bigger is better. It is often presented as a percentage for readability. The MOE is approximately normally distributed by construction since it is calculated from the sum of a large number of random variables. This is because each enemy squad that attempts to cross the border has a random number of fatalities. The sample size for each run is at least forty enemy squads. The general conditions set forth by the Central Limit Theorem for approximate normality seem to be met. (Conover, 1999) In order to measure the variability of these proportion estimates and to get a good estimate of the mean performance, the experiment is replicated at least ten times at each excursion. A series of goodness of fit tests for the normal distribution (Shapiro-Wilk W-test) on randomly selected excursions do not provide any evidence against the claim of normality. An example is shown below. As a result, this data is robust for analysis using a wide variety of statistical techniques, including regression. JMP Statistical Discovery Software version 5.1.2 was used as the primary tool for data post processing and analysis.

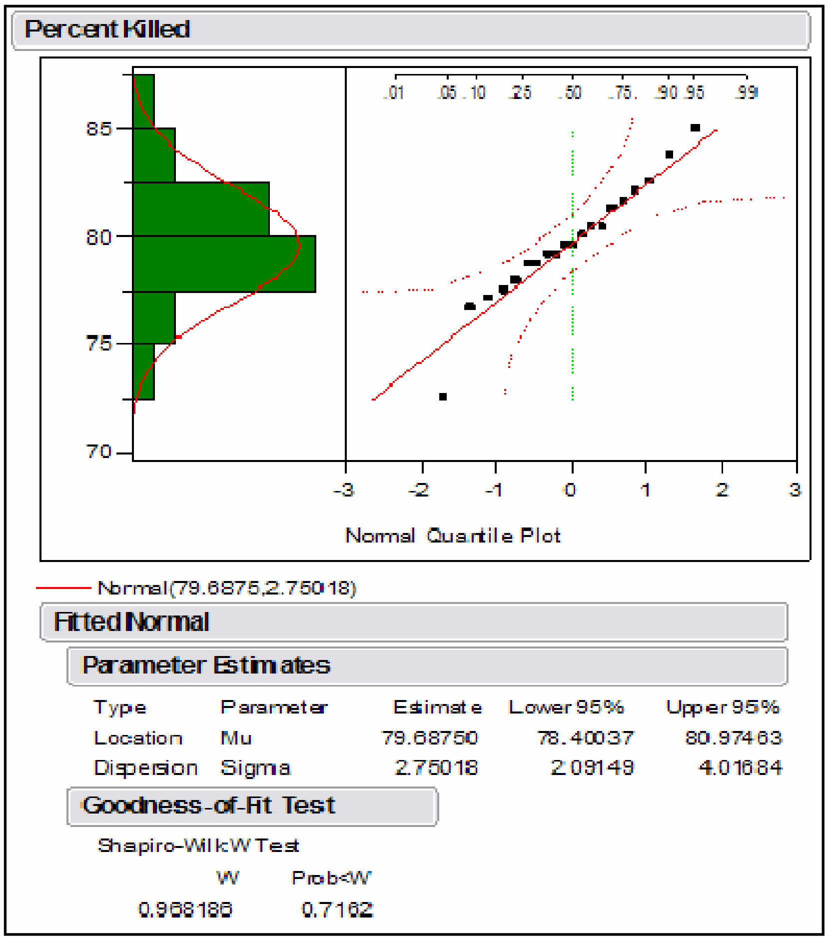


Figure 19. One of a series of random goodness of fit tests on the MOE for an excursion. The large p-value (Prob<W) indicates that there is no statistical evidence against normality.

B. INSIGHTS INTO RESEARCH QUESTIONS

Recall from Chapter I that this research set out to answer three specific questions about supporting a DO platoon. The first two can be directly addressed through data analysis, while the third will have to wait until the next chapter. These questions are reproduced below:

- What are the critical logistical factors relating to mission success for the DO platoon in the missions envisioned in MCWL's Wargame Scenarios?
- What are the critical logistical capabilities of the MEU that will enable it to provide continuous sustainment to a distributed force?
- What is the supportability of a DO platoon across the range of missions?

1. Critical factors

This section identifies the critical logistical factors by doing a top down analysis of the simulation data. It starts with a data summary and works its way down into the details of the critical factors.

a. Data Summary

To begin identifying critical factors, it is best to first look at a summarization of the entire data set and then drill down into specific factors. The distribution of all the seven day scenario data (both the Exploration and Large Scale experiments) is shown in Figure 20. A 95% confidence interval for the mean proportion killed is (0.582, 0.590).

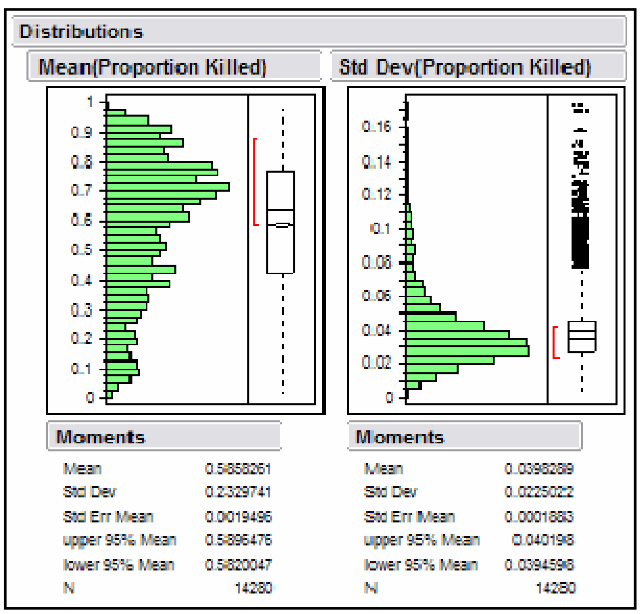
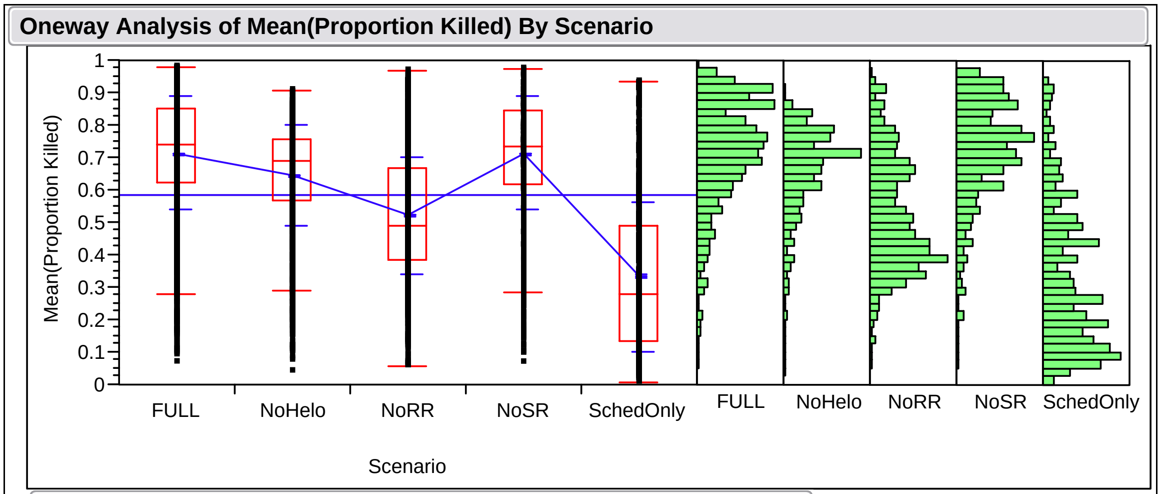


Figure 20. The distribution of the MOE and the standard deviation of the MOE for all the 7 day scenario data.

b. Scenarios

When the data is divided into the five qualitative scenarios, the first insights are revealed. In Figure 21, one can clearly see that the Full scenario has the most favorable distribution of the MOE. The Scheduled Resupply Only (SchedOnly) scenario has the worst. Removing observers from the helicopters (NoHelo) causes a significant reduction in effectiveness. Adding sense and respond to the SchedOnly model creates the No Rapid Request Model (NoRR), which is clearly better than SchedOnly. Translating the statistical insights into logistical ones clearly shows that the best logistical support system includes a rapid request system, a sense and respond system, and airborne intelligence assets. This means that a good balance between push and pull logistics combined with intelligence and fire support will contribute to the most effective DO platoon. Logistically, it is clear that given the uncertainties of combat demands, a strong rapid request system is the most important element of the support system.



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
FULL	2856	0.712764	0.171633	0.00321	0.70647	0.71906
NoHelo	2856	0.645988	0.154935	0.00290	0.64030	0.65167
NoRR	2856	0.523165	0.181794	0.00340	0.51649	0.52983
NoSR	2856	0.711885	0.171707	0.00321	0.70559	0.71819
SchedOnly	2856	0.335328	0.230500	0.00431	0.32687	0.34379

Figure 21. The distribution of seven day mission data for each of the five scenarios. The Full model scenario has the best overall performance.

c. Quantitative factors

In this section, all of the quantitative factors are looked at, followed by a detailed look at the logistical factors in order to support the development of the estimate in the next chapter. In Figure 22, the percent of the variability of the data explained by each of the quantitative factors alone is shown. These values were calculated by fitting a single factor regression model against the MOE. Knowing which factors have the most explanatory power helps guide further analysis. The four most significant logistical factors are resupply speed, the DO platoon supply usage rate while in contact, the maximum DOS on hand, and the rapid request setup time. These factors are consistent between the two experiments. Enemy factors clearly dominate the first experiment and so the only enemy parameter varied in the second experiment is the enemy squad size. From the importance of the noise factors and of the use rate while in contact, it is clear that the intensity of the combat is a critical indicator of how successful the DO platoon will be.

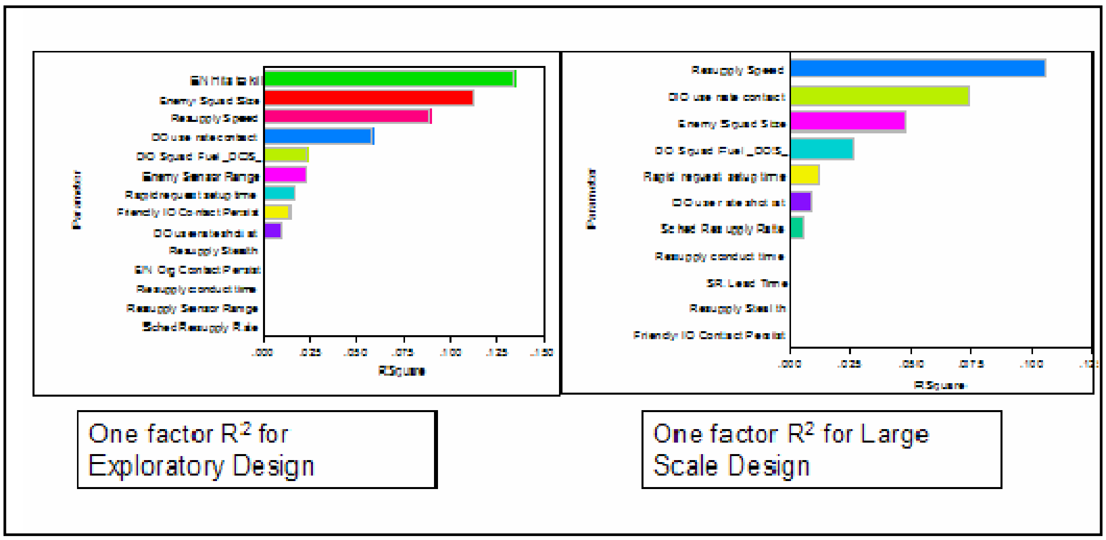


Figure 22. Shows the variability explained by each quantitative factor alone (no interactions accounted for). Clearly, resupply speed has the most explanatory power of all logistical factors.

One thing to keep in mind at this point is that these factors are across all scenarios. For example, rapid request setup time is not going to explain much in situations without rapid request. Figure 22 provides some rough guidance on significant factors if one is unaware of what combination of rapid request, intelligence, and sense and respond will be used for a particular mission. Since it t the full scenario provides the best performance, it is analyzed independently.

Figure 23 shows the same single factor coefficients of determination (R^2) for the Full scenario. The same four logistical factors are the most explanatory, but for the Full model, rapid request setup time explains more of the variance independently than does resupply speed. The two most explanatory variables are tied to responsiveness, which, according to Marine Corps Warfighting Publication (MCWP) 4-1, is the “keystone” of effective logistical support. (MCWP 4-1, 1999)

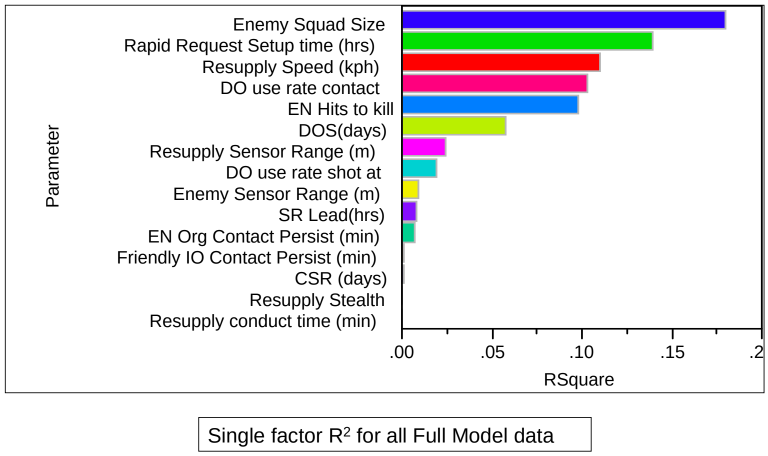


Figure 23. The single factor coefficients of determination for the Full scenario model.

d. Full Scenario Regression Model

In order to identify the effects of the important factors already discovered, a multiple regression model is fit to the data for the Full scenario. Before fitting the regression model, the data was averaged across the replications to generate a mean value of the MOE for each excursion. This resulted in 2570 data points (reduced from 51,400) with no loss of information for computing the regression coefficients. The JMP statistical software allows the user to execute a stepwise regression, which is a heuristic for finding a good linear mathematical model that fits the data. Any regression model must balance simplicity with explanatory power, so this analysis will only consider polynomial and interaction terms to the second degree. The data collected has a high level of variability for proportions of enemy killed that are near 50% and low variability for proportions near 10% and 90%. Since this condition seemed to manifest itself as a heavy tailed residual distribution no matter which type of regression or transformation was used, this research uses basic least squares linear regression, since its results are the easiest to explain. With heavy tailed residuals, the confidence intervals generated from the regression model (which are not a subject of this research) will not have the exact theoretical confidence levels, but the parameter estimates are still unbiased since the response variable is normally distributed.

When fitting a regression model, especially from data with numerous predictor variables and interactions, it is important to balance the explanatory power of the model with simplicity. Figure 24 shows how adding more terms in a step-wise regression with all the 2nd order power and interaction terms has diminishing improvement in explanatory power as more terms are added. As a result, this analysis limits the number of terms in the regression model to those absolutely necessary to understand what is happening in the simulation. After an iterative process of examining various models and their strengths and weaknesses, the model shown in Figure 25 was chosen. Ten percent of the data set was withheld at random from the model calculations in order to form a test data set. The regression model predicted the observed values in the test data set very well, providing evidence that the model was not over fit.

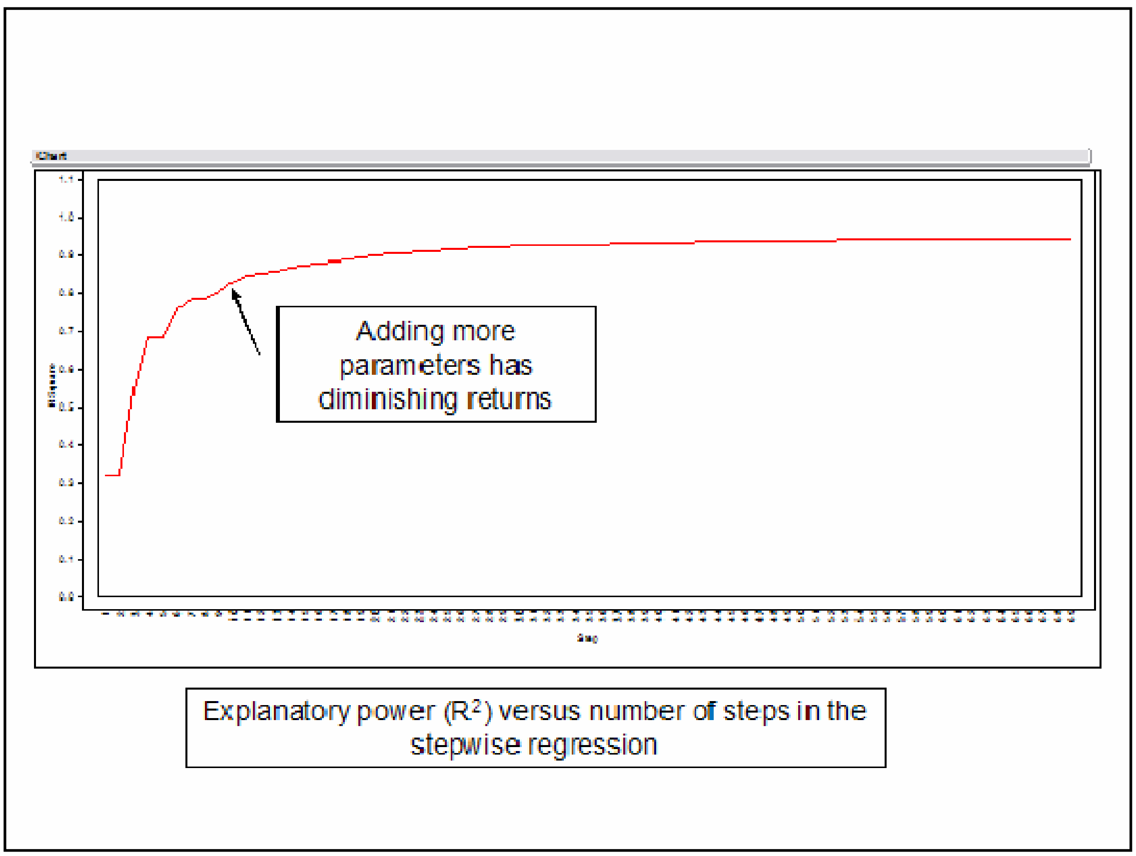
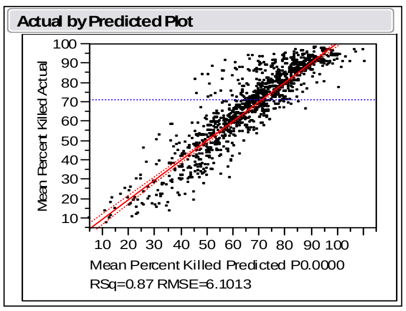


Figure 24. Shows the diminishing returns of making the regression model more complex.

Without interpretation, a linear regression model is just a bunch of numbers. In summary, the model fit for this research, shown in Figure 25, explains 87% of the variability in the 2570 observations with an equation that contains 24 terms. Each parameter in the model is statistically significant at the 5% level. The model also explains 87% of the variability in the test data set, which indicates that this model predicts the results of the simulation well within the data ranges in the experiment. The usefulness of this model is its ability to show the relationship between the important factors and the MOE. The next series of charts will use the regression model to display these relationships graphically.

Chosen Linear Regression Model



Whole Model

RSquare	0.87
RSquare Adj	0.87
Root Mean Square Error	6.10
Mean of Response	71.24
Observations	2570.00
Mallow's Cp	24.00
F Statistic	766.00
Prob(>F)	0.00
Model Degrees of Freedom	23.00
Error Degrees of Freedom	2546.00

	Term	Estimate	Std Error	t Ratio	Prob>|t|
1	Intercept	110.7376	1.2565	88.1337	0.0000
2	SR Lead(hrs)	0.0574	0.0267	2.1476	0.0318
3	Resupply conduct time (min)	0.0159	0.0067	2.3668	0.0180
4	Resupply Stealth	0.0079	0.0040	2.0019	0.0454
5	Resupply Speed (kph)	0.0551	0.0012	47.6094	0.0000
6	Resupply Sensor Range (m)	0.0007	0.0002	3.5589	0.0004
7	Rapid Request Setup time (hrs)	-3.5482	0.0658	-53.9463	0.0000
8	Friendly IO Contact Persist (min)	-0.0322	0.0067	-4.8484	0.0000
9	Enemy Squad Size	-1.7595	0.0295	-59.6471	0.0000
10	Enemy Sensor Range (m)	-0.0050	0.0004	-13.4704	0.0000
11	EN Hits to kill	-7.8307	0.2012	-38.9161	0.0000
12	DOS(days)	2.4645	0.1071	23.0077	0.0000
13	DO use rate shot at	-0.1582	0.0080	-19.7502	0.0000
14	DO use rate contact	-0.3653	0.0080	-45.3892	0.0000
15	(Resupply Speed (kph)-187.922)*(Resupply Speed (kph)-187.922)	0.0003	0.0000	18.6513	0.0000
16	(Rapid Request Setup time (hrs)-3.00354)*(Resupply Speed (kph)-187.922)	0.0260	0.0008	30.9594	0.0000
17	(Rapid Request Setup time (hrs)-3.00354)*(Rapid Request Setup time (hrs)-3.00354)	-0.3726	0.0544	-6.8467	0.0000
18	(DOS(days)-3.54669)*(Resupply Speed (kph)-187.922)	-0.0110	0.0009	-11.6990	0.0000
19	(DOS(days)-3.54669)*(Rapid Request Setup time (hrs)-3.00354)	0.8123	0.0529	15.3573	0.0000
20	(DOS(days)-3.54669)*(DOS(days)-3.54669)	-0.7373	0.0797	-9.2481	0.0000
21	(DOS(days)-3.54669)*(DO use rate contact-25.5311)	0.0593	0.0067	8.8302	0.0000
22	(DO use rate contact-25.5311)*(Resupply Speed (kph)-187.922)	0.0016	0.0001	15.2163	0.0000
23	(DO use rate contact-25.5311)*(Rapid Request Setup time (hrs)-3.00354)	-0.0915	0.0062	-14.6540	0.0000
24	(DO use rate contact-25.5311)*(DO use rate contact-25.5311)	0.0047	0.0009	5.1975	0.0000

Figure 25. This is the regression model on the Full Scenario data with data from both experiments combined. Notice how closely the predictions follow the actual data in the plot in the upper left.

Figure 26 shows the two most explanatory logistical factors, rapid request setup time and resupply speed. Both charts show that better performance in the logistical factor corresponds to better performance in the MOE with generally less volatility. Figure 27 shows the same plots for both DOS and usage rate in enemy contact.

One thing to keep in mind about the nature of these plots is that a large amount of the variability in the prediction formula in the plots is due to the nature of the experimental design. Although the model generally predicts the simulation output well, there is quite a lot of volatility in a one way slice of the data due to the way parameters are varied in the Nearly Orthogonal Latin Hypercube (NOLH). For example, resupply speed was varied simultaneously with other factors in an exploratory fashion so not all possible combinations were observed. It is possible that spike in the MOE in a region where the MOE is in a downtrend is due to another parameter that was varied simultaneously. Since humans are limited to visualizing in only two or three dimensions, trend lines in the plots were computed holding all other factors constant at their median values to illustrate the effect of the parameter alone. A major goal of the experimental design is to examine interactions, leading to the next set of plots.

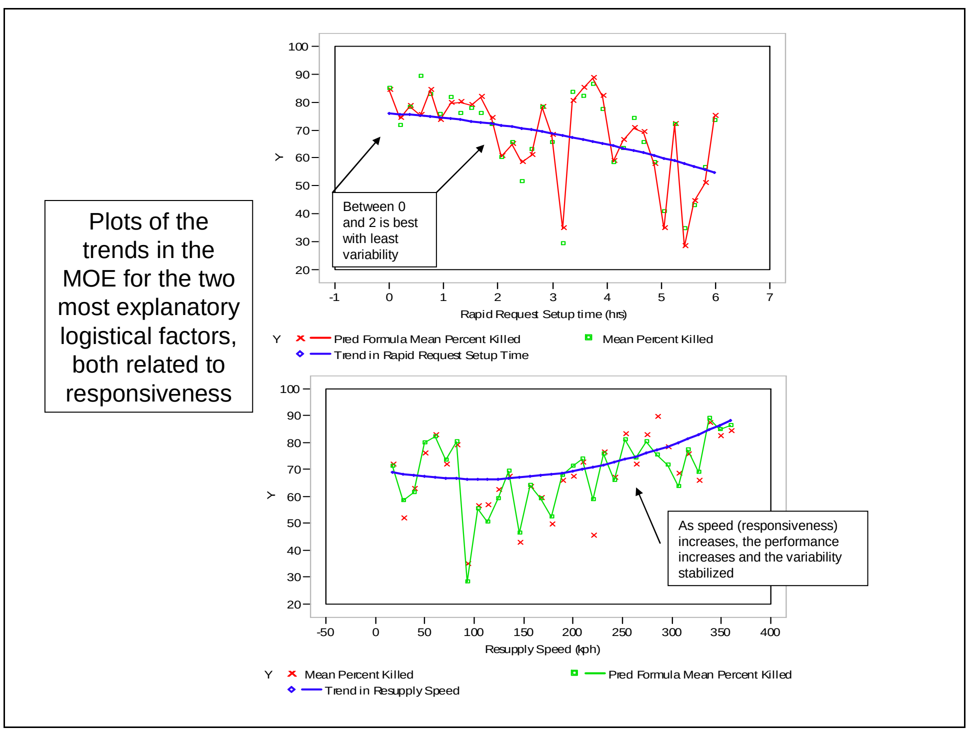


Figure 26. This figure shows the trends in the MOE for the two most explanatory logistical factors: rapid request setup time and resupply speed. [Best viewed in color]

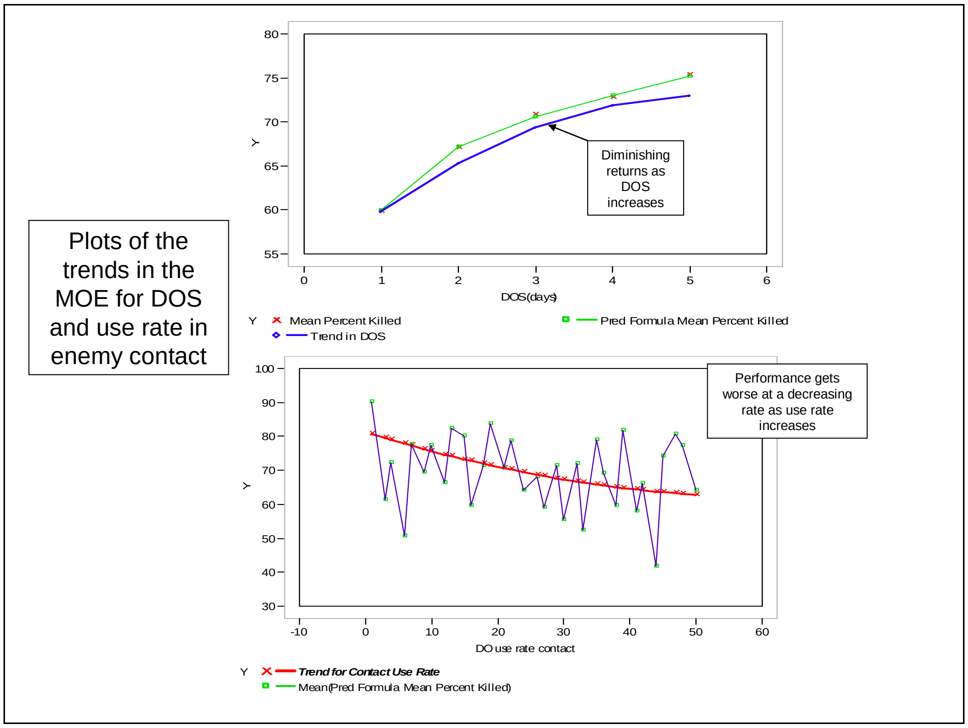


Figure 27. This figure shows the predicted trends in the MOE for DOS and usage rate in enemy contact. [Best viewed in color]

Figure 28 shows interaction plots of all the interacting parameters included the regression model. To maintain model simplicity, only interactions between the four main logistical factors were entered into the model. The captions are self explanatory; however, several points will be emphasized. The plot itself shows the four terms in the model that have interactions. An interaction means that the change in the MOE caused by varying one parameter is dependent upon another parameter. The trellis plot containing the interactions shows the high and low levels of the factor on the row and the trend in the MOE by changing the factor in the column. The diagonal is a mirror where the axes are reversed. For example, the bottom left and upper right plots show the interaction between DOS and resupply speed. In the upper right version, the high and low values of DOS are each shown with the trend in the MOE as Resupply Speed changes. In the lower left version, the high and low values of Resupply Speed are shown with the trend in the MOE as DOS changes.

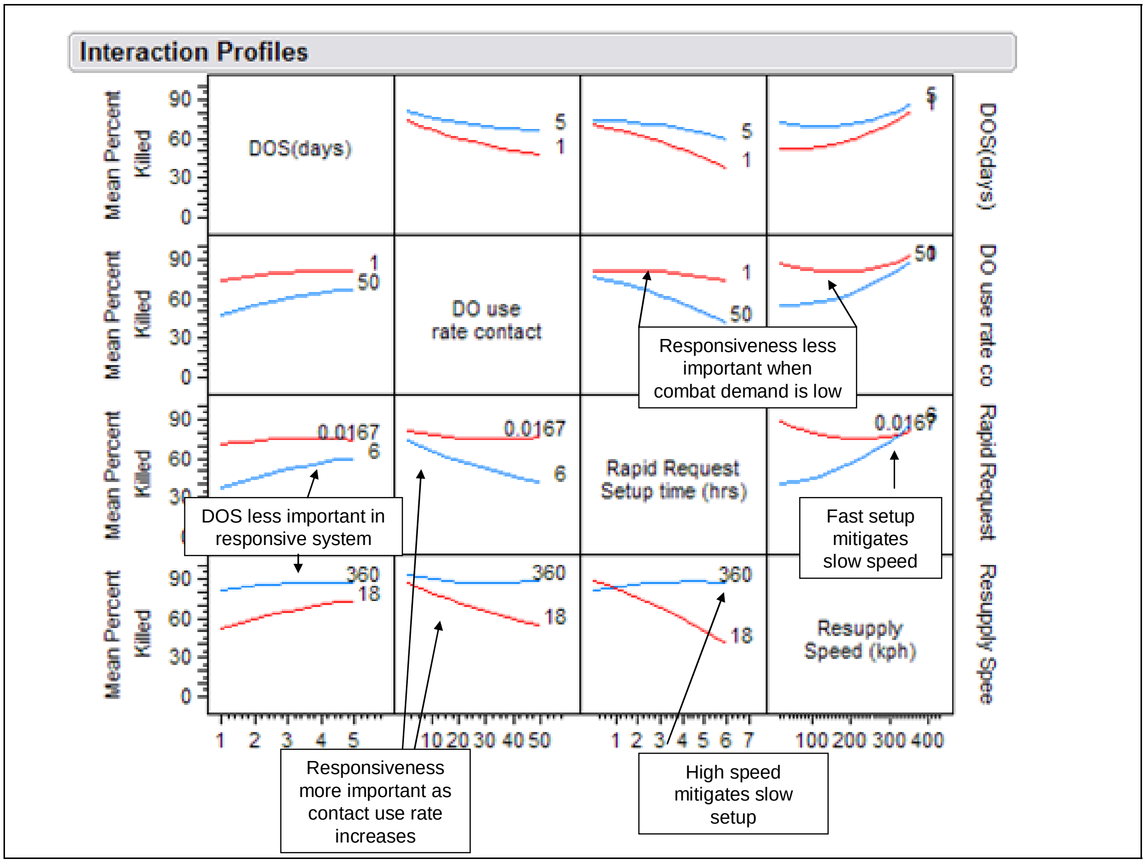


Figure 28. Interaction plots of the four most significant logistical factors. Each cell of the plot shows how the MOE changes (left axis) across the range of one factor (label on diagonal is for the columns, levels on bottom) for two levels of an interacting factor (right axis) with the low and high values listed inside the cell.

Notice in the bottom right hand corner of Figure 28 that the interaction between rapid request setup time and resupply speed is the most dramatic. Interpreting this into real world terms, this means that a system that is inherently slow to react to demands can make up for it by being either very close to the customer or having very fast delivery vehicles. Conversely, a quick reacting system can afford to have a less efficient delivery system or to be further from the battlefield. For example, in bad weather, delivery speed may be reduced. This could be mitigated by having resupply aircraft and logistics packages on standby to reduce response time. Additionally, the plots provide evidence that responsiveness is more important when combat usage rates are higher and that DOS is less important with a responsive system. While these results are in many ways intuitive, they lend credibility to the model and provide support to the decision making this simulation is used to support.

e. Summary

In summary, this section identified the most critical logistical factors pertaining to supporting a DO platoon in the Full scenario, which was the best performing scenario overall. Since this scenario represents a challenging long term mission, these factors should be incorporated into the planning of logistical support for any DO mission. Recommendations on how best to support the DO platoon from the MEU are in the next chapter. To conclude this section on critical factors, all of the experimental factors are listed below in Figure 29 with comments on their effect on the MOE in the Full scenario. Figure 30 shows graphically the trends in the MOE for the various input factors in the regression model.

	Decsion Factors	
	Term	**Interpretation**
1	Rapid Request Setup time (hrs)*	Decreasing Rapid Request Setup Time improves MOE
2	Resupply Speed (kph)*	Increasing Speed improves MOE
3	DO use rate contact*	Decreasing Usage Rate improves MOE
4	DOS(days)*	Adding DOS (how many DOS the platoon can carry) improves MOE
5	DO use rate shot at	Decreasing the casualty rate improves the MOE
6	Friendly IO Contact Persist (min)	Has marginal effect on MOE in this scenario
7	Resupply Sensor Range (m)	Has marginal effect on MOE in this scenario
8	Resupply conduct time (min)	Has marginal effect on MOE in this scenario
9	SR Lead(hrs)	Has marginal effect on MOE in this scenario
10	Resupply Stealth	Has marginal effect on MOE in this scenario
11	Controlled Supply Rate (CSR) (days)	Has marginal effect on MOE in this scenario

	Noise Factors	
	Term	**Interpretation**
12	Enemy Squad Size	Increasing enemy squad units by one decreases MOE by 1.75%
13	EN Hits to kill	Increasing each enemy agent's available hit points by one decreases MOE by 7.8%
14	Enemy Sensor Range (m)	Increasing enemy senor range by 1000 meters causes a 5% decrease in MOE
15	Enemy Organic Contact Persistence	Has marginal effect on MOE in this scenario

* indicates factors which have interactions with other factors and/or nonlinear effects

Figure 29. List of all the experimental factors and their impact on the Full scenario simulation model based on regression analysis. The list is divided into decision and noise factors and then sorted by explanatory power in the regression model.

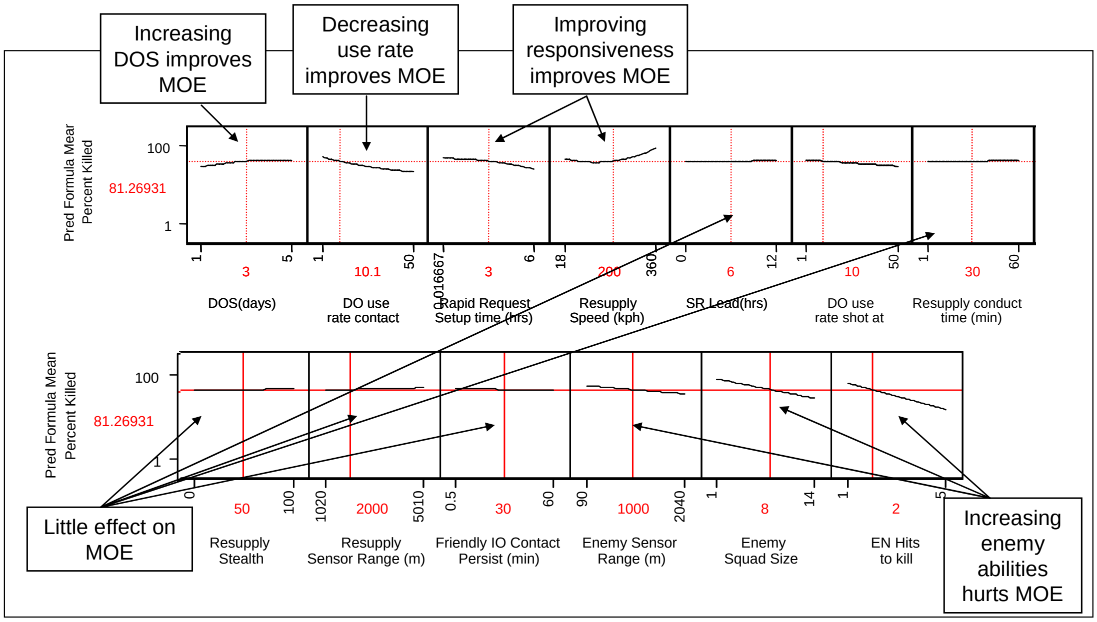


Figure 30. Graphic display of the trends in the MOE when changing one factor with other factors held constant based on the regression model from this section.

2. Critical Capabilities

The purpose of this section is to use the simulation data in order to determine some of the critical capabilities required for logistically supporting a DO platoon. For this analysis, all of the data from all five scenarios is considered. Using the critical factors from the previous section as a guide, this section determines acceptable ranges for all of the controllable parameters that can then be used to generate a support plan in the next chapter. This section makes heavy use of classification and regression trees, which, according to Cornell University's Office of Statistical Consulting, "...provide a simple rule for classification or prediction of observations... handle interactions among variables in a straightforward way... can easily handle a large number of predictor variables, and ...do not require assumptions about the distribution of the data." (Cornell University Office of Statistical Consulting Website, August 2005) Essentially the regression tree process uses the nature of the data itself to decide how to sub-categorize the data and accounts for interactions implicitly. In order to make decisions that are not unduly sensitive to the enemy threat level, the data was summarized across the range of noise factors for each unique set of decision factors.

a. Scenario

Figure 31 shows a regression tree on the data considering only partitions on the five scenarios. Interpreting the tree model is simple. Factors at the top of the tree are most important. Splits to the right are for improvements in the MOE. To use the tree as a prediction tool, one reads it from the top down following the appropriate branches for the case which is being considered. As stated in the previous section, the full scenario seems to be the best; however, all three top performing models have rapid request systems. Additionally, adding a surveillance capability to the resupply aircraft produces the two top performing scenarios. From this, it is reasonable to conclude that the best support system for a DO platoon must have the capability to receive, process, and respond to rapid requests. Additionally, aerial surveillance can considerably improve the performance of the platoon in a mission designed interdict an enemy who does not want to be found.

These conclusions give rise to the following question, "What general conditions must be met for the DO platoon to be comparably successful on average under the two least desirable scenarios?" For the Scheduled Resupply Only (SchedOnly) scenario, a tree model suggests that for the platoon to have comparable success, it must have a high resupply speed, a usage rate in contact that is no more than double the rate out of contact, and have the capacity for at least three DOS. For the Sense and Respond Only (NoRR) scenario, to have comparable performance all that is required is a high resupply speed and a usage rate in contact no more than three times the normal rate. The upper bound on usage rate is not important if there is a long lead time in the sense and respond system and the resupply conduct time can be kept short.

What this means is that for sense and respond logistics alone to work as well on average as the Full scenario with sense and respond and rapid request, it must travel quickly, anticipate requirements more than six hours in advance, have a low casualty rate (or alternative means for medical evacuations), and deliver efficiently. An exclusive scheduled resupply policy works well when demand and casualty rates are very low and the platoon can carry at least three DOS. This might work in a very permissive environment where the risks involved are more similar to those of border patrol agents. The ultimate conclusion of this section is that while it is possible to have success with several logistics policies, the policies that contain rapid request seem to be the most robust across all battlefield parameters, are not as sensitive to usage rates, and can be made more robust by improving responsiveness.

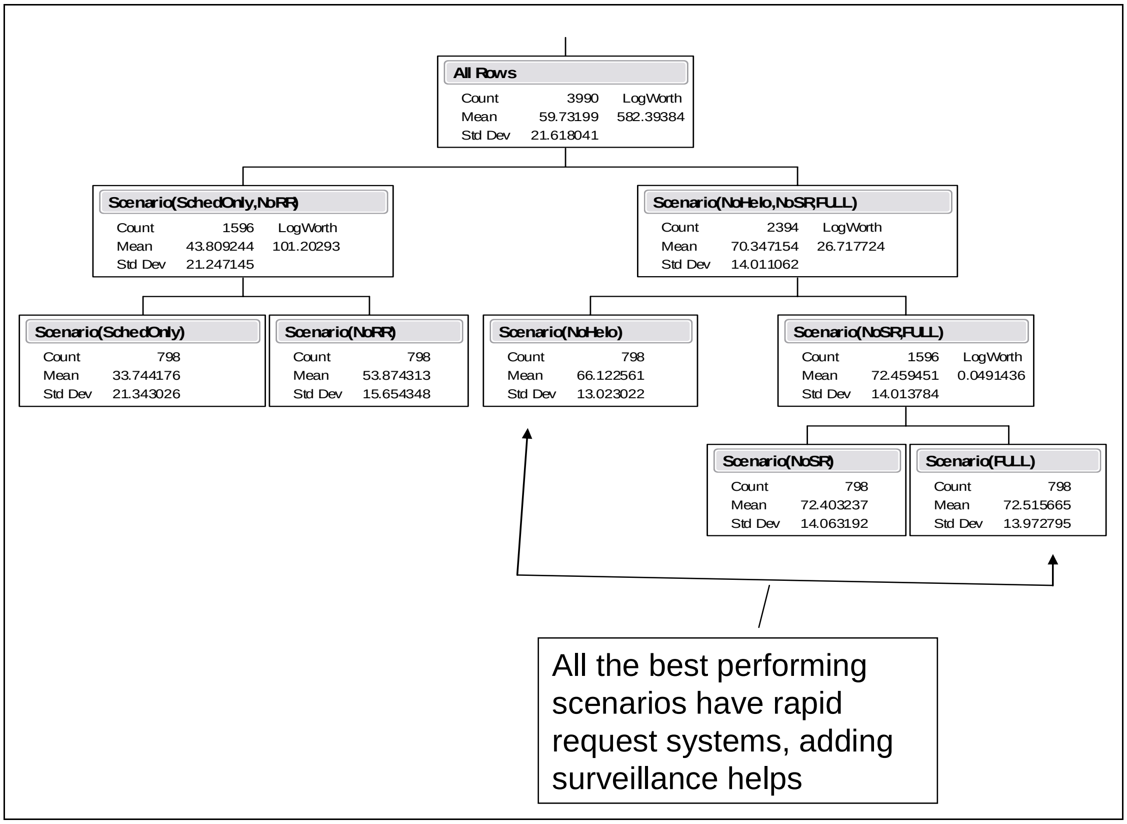


Figure 31. Regression tree considering only scenarios. The best performing scenarios all have rapid request systems.

b. Logistical Parameters

Since the purpose of this section is to identify capabilities, the selection of critical logistical capabilities is made as independently of the scenario as possible. This gives the logistician the best mix of capabilities to use across a range of possible concepts of support. The factors addressed here are those that are most amenable to control through technological, organizational, or doctrinal means. They are resupply speed, rapid request setup time, sense and respond lead time, DOS, controlled supply rate (CSR), resupply conduct time and resupply stealth.

In order to better identify the effect of sense and respond lead time and CSR, another simple simulation experiment was done, this time with the DO platoon performing its mission for fourteen days using the Full scenario. This experiment consisted of five levels of DOS (1 through 5) crossed with five levels of CSR (1 through 5), crossed with two levels of lead time (0 and 12 hours), crossed with two levels of enemy squad size (7 and 13 enemies per squad). All other parameters were set at nominal values contained in Appendix B. This resulted in 100 design points which were run ten times each for a total of 1000 data points. An interesting thing happened in this experiment. The combat demands were so stable across the experiment that the sense and respond logistics system dominated. Scheduled resupply missions never occur in this experiment. However, as Figure 32 shows, three DOS is a natural split between high and low performance. Additionally, a long sense and respond lead time is most important when the capacity in DOS is small, but a long sense and respond lead time stabilizes performance over the range of DOS. As a result, it is recommended that the DO platoon have the capacity to carry three DOS and that the supporting agency be prepared to launch push packages at least twelve hours in advance of anticipated need. These general conclusions are also supported by the seven day experimental data with all five scenarios aggregated.

The next thing that needs to be addressed is the CSR. If the DO platoon carries three DOS, how often should scheduled delivery missions take place? The data analysis thus far and the contour plots in Figure 33 show that three and four DOS give about the same effectiveness, so long as scheduled resupply missions are less than or equal to DOS. A contour plot is a way to visualize the MOE as a function of two factors, DOS and CSR in this case. The color shows the average value of the MOE at the values of the factors on the axes. It is therefore recommended that a preliminary conclusion from the MCWL DO Wargame I Analysis Report, which suggests that the DO platoon carry three DOS and be resupplied every two days, be implemented as a capability.

The next two capabilities to be addressed are resupply speed, and rapid request setup time. Since these factors interact, they will be looked at together and only in those scenarios where rapid request was active. Figure 34 shows that setup time is less important when there is fast delivery speed and more important with slow delivery speed. The regression tree split at 231 kilometers per hour corresponds to between 10 and 15

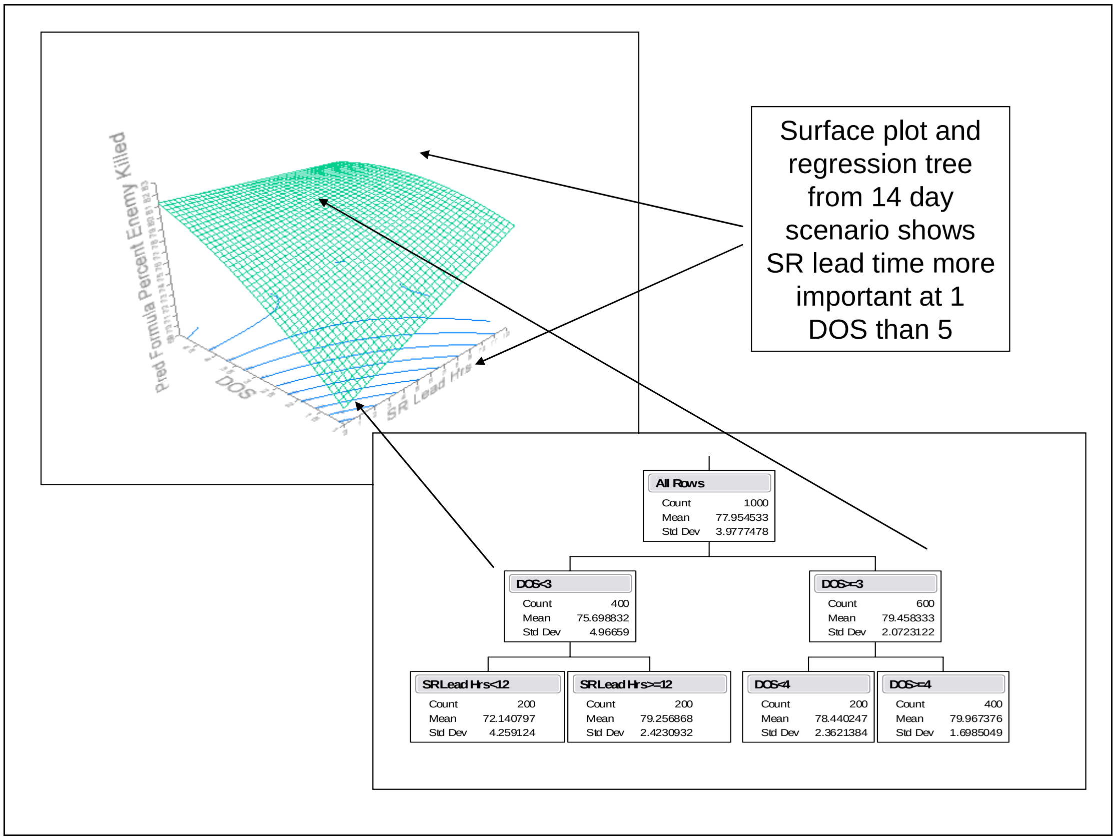


Figure 32. Surface plot and regression tree showing the effects of DOS and sense and respond lead time in the 14 day mission experiment.

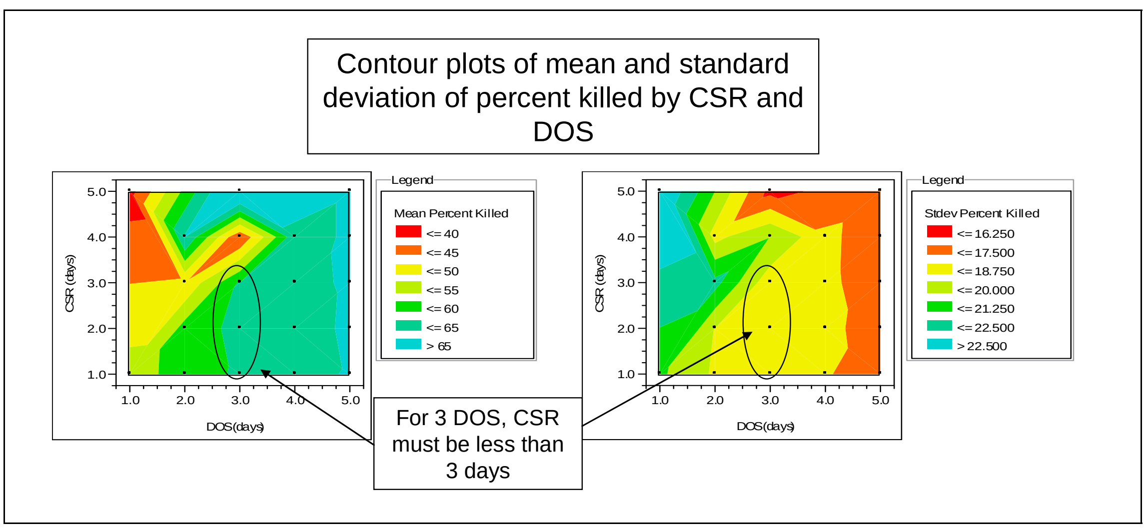


Figure 33. Contour plots show that CSR must be less than DOS, which is intuitive. Going to five DOS can reduce volatility, but it is likely too much to carry. [Best viewed in color]

minutes transit time by resupply aircraft. Since responsiveness, represented by these two factors, is critical to success, it is recommended that the agency supporting the DO platoon have the capacity to do both well. For example, when supporting a mission far away or in bad weather, the combat service support (CSS) agency could make up for the loss in delivery speed by having resupply packages and medical evacuation on standby alert to minimize setup time. In a more complex and austere operational environment, where having supplies and aircraft on standby is not feasible, the supporting agency must either be near the DO platoon, or have very fast delivery means. In either case, the CSS agency must have good communications with the DO platoon, easy access to the delivery aircraft, and sufficient battlefield intelligence to conduct a safe delivery.

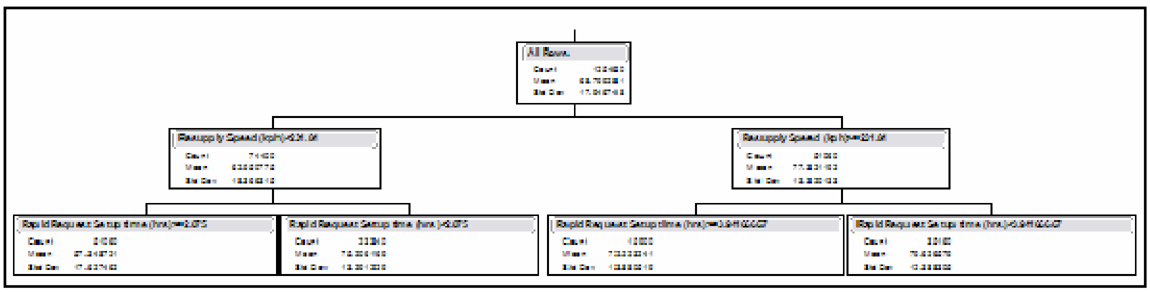


Figure 34. Regression tree considering only rapid request setup time and resupply speed in those scenarios where rapid request was used. It shows the interaction between the two factors.

Lastly, resupply conduct time and resupply stealth are addressed. Recall that resupply conduct time is the amount of time it takes to execute a delivery or medical evacuation once the delivery craft arrives at the DO platoon's location, and resupply stealth is the sensor signature of the delivery vehicles to the enemy. In the simulation model, these factors do not have a great deal of explanatory power. However, some insights can be gleaned from the data. In the No Helicopter Intelligence scenario (No Helo) these two factors can be addressed since detection of a resupply event by the enemy is not mitigated by aerial over watch. Figure 35 graphically illustrates the interaction between these factors. The general trends indicate that if the resupply conduct time is longer, then it must be conducted with more stealth or with over watch. In terms of capabilities, this would translate into stealthy delivery methods, such as night air drop, or providing armed escorts to the delivery aircraft, such as Cobra attack helicopters. Another option would be to provide the DO platoon with organic unmanned aerial vehicles. However, since adding these capabilities would likely be expensive, it is nice to know that improving responsiveness factors by small amounts has a much greater overall impact on the MOE. It is important to note here, that due to model limitations, the enemies are unable to attack resupply aircraft, so the effects of stealth and resupply conduct time are likely underestimated by the simulation model for an enemy with the ability and the will to attack U.S. aircraft.

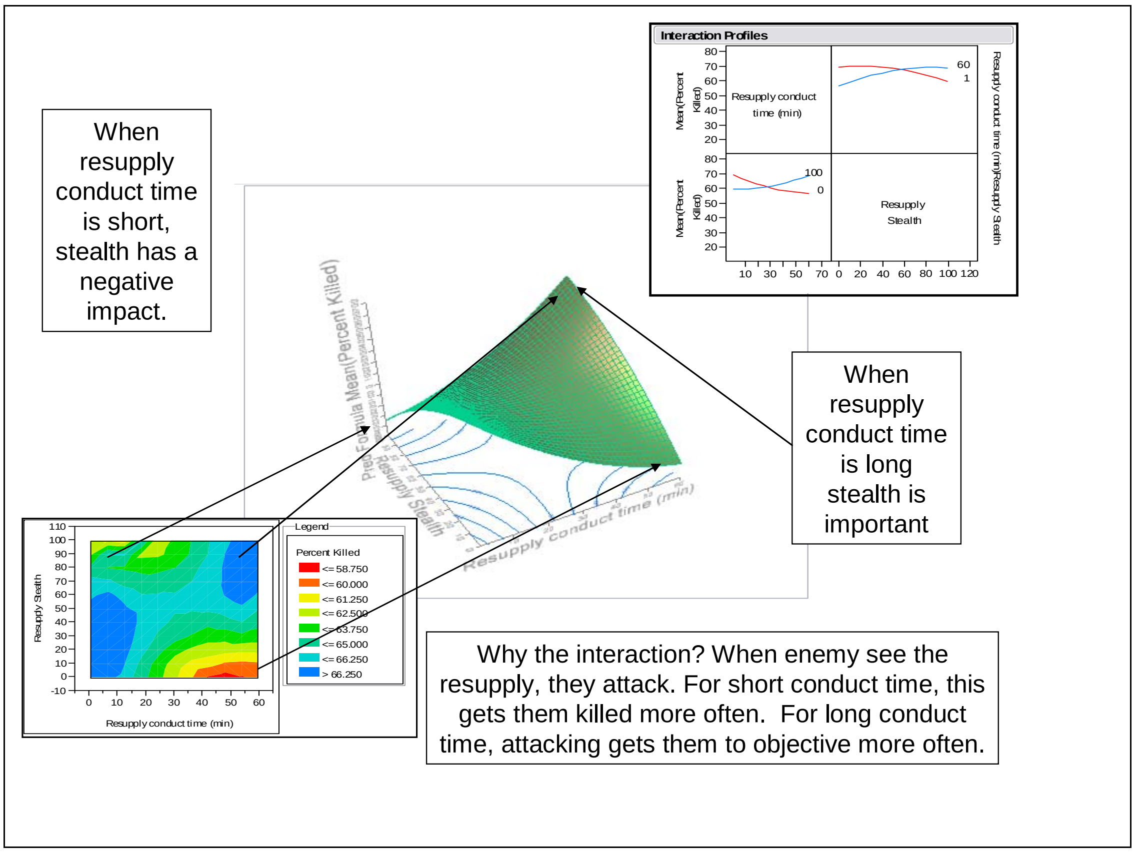


Figure 35. The interaction between stealth and resupply conduct time in the NoHelo scenario. [Best viewed in color]

c. Summary

In this section, critical factors were translated into critical capabilities by analyzing the simulation output data. In summary, the CSS supporting agency must have a great deal of flexibility in its responsiveness through solid communications, intelligence, access to aircraft, and pre-planned resupply packages. The DO platoon should be able to carry three DOS and be resupplied no less frequently than every two days. A sense and respond or push logistics system should plan on launching resupply missions twelve hours in advance of an anticipated stock-out or system failure. Finally, the exchange of supplies with the DO platoon on the ground must be conducted quickly, with great stealth, or with over watch.

C. FURTHER INSIGHTS

This section captures some further insights gathered from the data analysis but are not directly related to the research questions. The two major areas that will be covered here are the concept of stability versus instability and the importance of intelligence to a CSS agency.

1. Stability versus Instability

It is intuitive that responsive logistics is more important when the combat is more unstable. Using regression trees to identify some natural criteria for stability and instability, all the seven day data was divided into two general categories, "STABLE" and "UNSTABLE". An unstable situation is defined as very high usage rates and very capable enemies. The unstable situation corresponds to about three percent of the data, or 5600 total runs. Since the stable situation contains 97% of the data, which has already been analyzed, there are no additional insights to be gained from looking at it separately. However, looking at the unstable situation separately leads to some interesting insights.

For the unstable scenario, resupply speed and stealth are the two most important parameters. Having high speed resupply increases effectiveness by 150 percent in the unstable scenario. Since the majority of the scenarios include surveillance from the aircraft, lower stealth resupply missions attract more enemy and thus create more fire support missions. For a low stealth setting, the unstable situation improves by 60 percent. This relates two key points. First, fire support and aerial surveillance are much more critical when combat is unstable. Secondly, and perhaps, most importantly, responsiveness remains the most important logistical factor. Not only does this suggest the need for a dedicated aerial surveillance platform for the DO platoon, but it also shows that the CSS agency needs to know what kind of fight the platoon might be in, in order to design and execute its support plan.

2. CSS Intelligence

As the data analysis has shown, especially the interaction plots in Figure 27, there are times when increasing speed can make up for slow response time. There is also an interaction with stealth and resupply conduct time. The natural splits in rapid request set up time in the regression tress correspond directly to the expected time between enemy attacks. The CSS agency must be able to determine where to allocate scarce resources. Perhaps it is necessary that deliveries are stealthy or speedy for a particular mission. The resupply mission must respond to demands before the enemy can launch its next attack. It may be necessary to locate the CSS agency closer to the DO platoon, or limit the distance at which the platoon can be employed. Helicopters might need to be in direct support for a dangerous mission, but placed in general support for a more routine one. Essentially, the CSS agency must have intelligence equal to the maneuver commander in order to effectively develop a supporting concept. Additionally, sufficient intelligence is required to determine resupply locations, escort requirements, and numerous other issues. While this is certainly true of all logistics operations, it seems to be particularly true for distributed operations, especially given the MEU's limited resources. It is recommended that logisticians supporting a DO platoon have access to full intelligence during the planning of the operation and have continuous intelligence updates or access to the common operational picture throughout execution to ensure that logistics operations support the DO platoon rather than constrain it.

D. CONCLUSIONS FROM THE SIMULATION EXPERIMENT

There are many insights to be gained from analyzing the data from the simulation experiment, and many that this research simply does not have time to address. However, the whole data analysis leads directly to one conclusion. Responsiveness is the key logistical criteria for success for long term DO platoon operations. The most critical logistical factors are responsiveness, combat usage rate, and DOS. The critical capabilities are as follows:

- The DO platoon must have the capacity to carry three DOS.
- The CSS agency must have the ability to sustain scheduled resupply deliveries every two days.

- The CSS agency must be assigned dedicated responsive, high speed delivery means.
- The CSS agency must have pre-staged resupply packages at the CSS area.
- The CSS agency must have good communications with the DO platoon.
- An anticipatory (or sense and respond) logistics system should launch missions twelve hours ahead of a predicted stock out or equipment failure.
- Resupply deliveries must be accomplished quickly, stealthily, or with heavy security (or a combination of all three).
- The CSS agency must have accurate, up to date intelligence on the DO platoon's operations.
- Logistical responsiveness, intelligence, aerial surveillance, and fire support are critical for unstable or extremely dangerous missions.
- The best performing logistics system (based on those modeled and analyzed) combines rapid request, fast delivery, aerial surveillance, a scheduled resupply rate, three or more DOS capacity, and a sense and respond logistics capability.

This summarizes the lessons learned from the analysis of the data from the simulation experiment. In the next chapter, the physical requirements of the DO platoon will be analyzed with the goal of determining how sustainable supporting it is from the MEU platform.

V. DEVELOPING A CONCEPT OF SUPPORT

This chapter of the research is dedicated to answering the final research question and tying all the research insights together into coherent advice for logistical planners. This final question is, "What is the supportability of the distributed operations (DO) platoon across the range of missions?" This is a very broad question with a quite simple answer: It depends. Depending on the mission, the enemy, and the environment, supporting a DO platoon will be more or less taxing on a Marine Expeditionary Unit's (MEU) resources, which will affect the MEU's capabilities as a whole. The goal of this chapter is to first answer the question, "How much?" and secondly to answer the question, "How?" This portion of the analysis begins with an assessment of the logistical requirements of the DO platoon for a typical mission, like the one analyzed through simulation. After this, a concept is developed that supports these requirements, taking into account the conclusions from the data analysis. Finally, this chapter ends with advice on developing a logistical estimate of supportability based on the results of this research. Ultimately, this chapter answers the final question by giving the reader an appreciation for the resources necessary to sustain the DO platoon and general advice for developing a logistical estimate. With this chapter in hand, a Marine logistician should be able to begin to assess the supportability of a DO platoon across the range of missions.

A. REQUIREMENTS DETERMINATION

Determining logistical requirements is not the exact science that it might seem, and it becomes more inexact as a logistician attempts to predict what a small unit might need over the course of a day. Planning factors work well for large units in traditional engagements, but are difficult to apply to a DO platoon operating in new ways with new equipment. As a result of these difficulties, the author used a combination of operational experience from supporting infantry and armored units in Operation Iraqi Freedom and standard Marine Corps logistical planning factors. These planning factors are published in "A Logistician's Reference," a compact disc published by the Combat Service Support Section of the MAGTF Staff Training Program as a compilation of all Marine Corps logistical planning factors. This section progresses through each of the various supply classes and determines how much would be required for a one day resupply of the DO platoon for a mission like that presented in Chapter II. Classes VI (personal demand items), VII (major end items), and X (civil support) are not considered since they would not be part of a typical tactical resupply mission for a mobile DO platoon. This section concludes with an assessment of the total weight and volume of supplies required to support the platoon as a function of days of supply (DOS).

1. Class I: Subsistence

There are two components of Class I: rations and water. While demand for food is quite simple, water can be complex. People use different amounts of water based on environmental factors and activity levels.

a. Rations

The DO platoon will need to be supplied with three MREs for each DOS carried. Three MREs weigh a total of 5.58 pounds and occupy 0.386 cubic feet of space.

b. Water

The DO platoon will use approximately three gallons of water per man per day in a temperate environment and five gallons per man per day in a hot environment, based on standard planning factors. During OIF, the author used a planning factor of four gallons per man per day to support a mechanized infantry company in combat during the Iraqi spring with good success. As a result, four gallons per man per day is a good general planning factor for an unknown environment which allows a Marine to have plenty of drinking water if he conserves it carefully. However, it must be noted that water consumption can be drastically higher during intense combat operations for infantrymen who must exert themselves physically for long periods of time. This fact can contribute to uncertainty in the water requirement. As the simulation results indicate, having a high or uncertain demand rate beyond the normal planning factors can have an adverse impact on the mission unless the support system is highly responsive. Four gallons of water weighs 33.38 pounds and takes up 0.535 cubic feet of space. Since carrying more than two gallons of water in individual equipment is awkward, the additional water would have to be carried on the ITV or stored in five gallon jugs at a patrol base. Using strict water conservation measures, the daily requirement for an individual Marine could be reduced to as low as two gallons per day if mission requirements dictate.

2. Class II: General Supplies

General supplies are essential items that are often overlooked in planning. These include administrative supplies, tools, replacement canteens, toilet paper, chemical lights and hundreds of other items. It is nearly impossible to determine exactly which items will be required, but for a DO platoon there are several items that should be on hand. These include chemical lights, especially the infrared variety, toilet paper, heavy duty tape, map pens, waterproof paper and acetate, parachute cord (also 550lb test cord), rope, and replacement personal equipment. High priority for replacement equipment is water and fuel carrying containers and canteens which are easily damaged by shrapnel and accident. The standard planning factor for Class II is 3.6 pounds per day per person, with the volume depending entirely on what type of items are required. A good thumb rule is that 3.6 pounds of dry goods is about two MREs or 0.138 cubic feet. These items are usually provided based on rapid requests, but certain items, including chemical lights and toilet paper, should be considered continuous demand items that will need to be provided routinely.

3. Class III: Fuel and Lubricants

There are two aspects of Class III: fuel to run equipment and lubricants to maintain it.

a. Fuel

For many missions, the DO platoon will be employed with eleven total internally transportable vehicles (ITV). The ITV is currently in later stages of development, but exact fuel planning factors were not available for this analysis at this time. As a result, the planning factors for the High Mobility, Multi-purpose, Wheeled Vehicle (HMMWV) are used. Since the ITV is much smaller and lighter than a HMMWV, it will likely use less fuel per hour of operation, but it may be used more intensively by a more distributed force. The infantry HMMWV planning factor is for eight hours a day of operation using 1.7 gallons per hour. This equates to about 13.6

gallons of fuel per day per vehicle weighing 90.5 pounds and occupying 1.82 cubic feet of space.

b. Lubricants

Lubricants, like Class II, are critical, yet often overlooked. For a long term operation, an infantry unit in an expeditionary environment will have to conduct preventive maintenance on weapons and vehicles. CLP (stands for Cleaning, Lubricant, and Preservative), the standard cleaning and maintenance oil for infantry weapons, will need to be planned for and supplied continuously. Lubricants for standard preventive maintenance will need to be included for the ITV as well. An operational lesson learned by the author in combat is to take empty liter sized plastic water bottles and fill them with engine oil, brake fluid, and transmission fluid and store them on the vehicle. Having a vehicle fail in a firefight over a slow transmission leak is not an option. Typically, resupply of lubricants is done in response to a need for a specific type, but small quantities of all major types, including those already mentioned, should be on hand during a routine resupply. The planning factor is about approximately half a pound per man per day. This is about 0.06 gallons or 0.008 cubic feet. These items, other than a small bottle of CLP, should be carried on board the ITV.

4. Class IV: Barrier and Construction Materials

Class IV materials are typically used by infantrymen to construct prepared defenses. Included in this class are sandbags, concertina wire, metal stakes, and lumber. This class may or may not be required, depending on the mission, but the DO platoon should always deploy with empty sandbags. Several strands of concertina wire and metal stakes should be included if vehicle space allows. Concertina wire, stakes, and sandbags allow the hasty construction of checkpoints, prisoner holding areas, and prepared defenses. The standard planning factor for Class IV for defensive purposes is 4.29 pounds per man per day. For the whole platoon this amounts to 188 pounds. Since these items are really mission dependent and may not be required for many DO missions, specific requirements will not be computed as part of the basic load or routine resupply mission. However, it is recommended that a relatively small number of empty sandbags (about 100) are included in each routine resupply mission. Obviously, strands of concertina wire would only be supportable in the event that the platoon is employed with ITVs.

5. Class V: Ammunition

There are two components to supplying Marines with ammunition. The first component is the basic combat load, which is the total amount of ammo that the unit would carry into a single engagement. It could also be considered the unit's ammunition carrying capacity. Since in typical combat, some areas are typically more heavily engaged than others, planning factors are skewed lower due to the low usage rate of command and support troops. Individual units will typically not need ammunition resupply until they have an engagement, and after the engagement they will need more ammunition than typical planning factors indicate. A basic combat load for the DO platoon is identified based on an infantry threat and a resupply package is developed based on basic assumptions about a typical engagement. Figure 36 shows the weapon mix of the platoon.

TAMCN	NOMENCLATURE	TOTAL WEAPONS
E0892	LAUNCHER GRENADE 40MM M203	9
E0960	M249 (SAW)	9
E0984	MACHINE GUN 50 CAL, M2	4
E0989	MG 7.62MM M240G	3
E0994	MACHINE GUN MK19 40MM	4
E1250	PISTOL 9MM	2
E1441	RIFLE 5.56MM	35

Figure 36. This figure shows the individual weapons of the DO platoon. The TAMCN is the reference number of the weapon on the Table of Authorized Material.

a. Basic Combat Load

Figure 37 shows a basic combat issue of ammunition for the DO platoon based on infantry threat planning factors. Signal pyrotechnics and grenade quantities were increased to account for the dispersed nature of platoon operations. Thermite grenades were added for each ITV in case vehicles had to be abandoned in an emergency. The total size of the basic combat load is nearly 3,300 pounds and 77 cubic feet.

DODIC	Nomenclature	WPN TAMCN	Rounds Per Weapon	Total Rounds	Total Weight	Total Cube
A059	CTG, 5.56MM BALL	E1441	350	12,250	502	12
A063	CTG, 5.56MM TRACER	E1441	10	350	17	1
A064	CTG, 5.56MM 4 & 1 LINKED	E0960	800	7,200	439	14
A131	CTG, 7.62MM 4 & 1 LINKED	E0989	800	2,400	242	5
A363	CTG, 9MM BALL	E1250	30	60	4	0
A576	CTG, CAL .50 4 & 1 LINKED	E0984	400	2,000	790	12
B504	CTG, 40MM GREEN STAR PARACHUTE	E0892	0.3	5	5	0
B505	CTG, 40MM RED STAR PARACHUTE	E0892	0.3	5	5	0
B506	CTG, 40MM RED SMOKE GROUND	E0892	0.25	5	5	0
B508	CTG, 40MM GREEN SMOKE GROUND	E0892	0.5	5	5	0
B509	CTG, 40MM YELLOW SMOKE GROUND	E0892	0.25	5	5	0
B535	CTG, 40MM WHITE STAR PARACHUTE	E0892	2	18	19	0
B542	CTG, 40MM HEDP LINKED FOR MK19	E0994	288	1,152	864	23
B546	CTG, 40MM HEDP FOR M79/M203	E0892	18	162	119	3
G881	GRENADE, HAND FRAGMENTATION	INDIV	1 PER INDIVIDUAL	44	75	2
G900	GRENADE, HAND INCENDIARY TH3	INDIV	1 PER ITV	11	32	1
G930	GRENADE, HAND SMOKE HC	INDIV	1 PER SQUAD OR HQ	5	13	0
G940	GRENADE, HAND SMOKE GREEN	INDIV	1 PER SQUAD OR HQ	5	13	0
G945	GRENADE, HAND SMOKE YELLOW	INDIV	1 PER SQUAD OR HQ	5	13	0
G950	GRENADE, HAND SMOKE RED	INDIV	1 PER SQUAD OR HQ	5	13	0
G955	GRENADE, HAND SMOKE VIOLET	INDIV	1 PER SQUAD OR HQ	5	13	0
L306	SIGNAL, ILLUM GROUND RSC	INDIV	1 PER SQUAD OR HQ	5	8	0
L307	SIGNAL, ILLUM GROUND WSC	INDIV	1 PER SQUAD OR HQ	5	8	0
L311	SIGNAL, ILLUM GROUND RSP	INDIV	1 PER SQUAD OR HQ	5	8	0
L312	SIGNAL, ILLUM GROUND WSP	INDIV	1 PER SQUAD OR HQ	5	8	0
L314	SIGNAL, ILLUM GROUND GSC	INDIV	1 PER SQUAD OR HQ	5	8	0
L323	SIGNAL, SMOKE GROUND RP	INDIV	1 PER SQUAD OR HQ	5	8	0
L324	SIGNAL, SMOKE GROUND GP	INDIV	1 PER SQUAD OR HQ	5	8	0
L495	FLARE, SURFACE TRIP	INDIV	1 PER SQUAD OR HQ	5	9	0
				Total	3,258	77

Figure 37. A potential basic combat ammunition load for the DO platoon against an infantry threat. The DODIC is the Department of Defense Identification Code of each particular ammunition type.

b. Resupply

As mentioned in the introduction to this section, small units cannot be resupplied ammunition by planning factor. Either they have been in a fight or not. The resupply package shown in Figure 38 is based on 15% of the combat load. This amount is based on the assumption that an individual squad would use less than half of its basic load of ammunition in a fire fight before it is reinforced or breaks contact. Half of one squad's ammunition comprises about 15% of the total platoon load. It is recommended that several resupply packages of this type be prepared in advance for rapid delivery to the DO platoon. At 489 pounds and 12 cubic feet, it is a fairly manageable resupply package, but it should be tailored to the mission.

DODIC	Nomenclature	WPN TAMCN	15% Rounds	Total Weight	Total Cube
A059	CTG, 5.56MM BALL	E1441	1,838	75	2
A063	CTG, 5.56MM TRACER	E1441	53	3	0
A064	CTG, 5.56MM 4 & 1 LINKED	E0960	1,080	66	2
A131	CTG, 7.62MM 4 & 1 LINKED	E0989	360	36	1
A363	CTG, 9MM BALL	E1250	9	1	0
A576	CTG, CAL .50 4 & 1 LINKED	E0984	300	119	2
B504	CTG, 40MM GREEN STAR PARACHUTE	E0892	1	1	0
B505	CTG, 40MM RED STAR PARACHUTE	E0892	1	1	0
B506	CTG, 40MM RED SMOKE GROUND	E0892	1	1	0
B508	CTG, 40MM GREEN SMOKE GROUND	E0892	1	1	0
B509	CTG, 40MM YELLOW SMOKE GROUND	E0892	1	1	0
B535	CTG, 40MM WHITE STAR PARACHUTE	E0892	3	3	0
B542	CTG, 40MM HEDP LINKED FOR MK19	E0994	173	130	3
B546	CTG, 40MM HEDP FOR M79/M203	E0892	24	18	0
G881	GRENADE, HAND FRAGMENTATION	INDIV	7	11	0
G900	GRENADE, HAND INCENDIARY TH3	INDIV	2	5	0
G930	GRENADE, HAND SMOKE HC	INDIV	1	2	0
G940	GRENADE, HAND SMOKE GREEN	INDIV	1	2	0
G945	GRENADE, HAND SMOKE YELLOW	INDIV	1	2	0
G950	GRENADE, HAND SMOKE RED	INDIV	1	2	0
G955	GRENADE, HAND SMOKE VIOLET	INDIV	1	2	0
L306	SIGNAL, ILLUM GROUND RSC	INDIV	1	1	0
L307	SIGNAL, ILLUM GROUND WSC	INDIV	1	1	0
L311	SIGNAL, ILLUM GROUND RSP	INDIV	1	1	0
L312	SIGNAL, ILLUM GROUND WSP	INDIV	1	1	0
L314	SIGNAL, ILLUM GROUND GSC	INDIV	1	1	0
L323	SIGNAL, SMOKE GROUND RP	INDIV	1	1	0
L324	SIGNAL, SMOKE GROUND GP	INDIV	1	1	0
L495	FLARE, SURFACE TRIP	INDIV	1	1	0
				489	12

Figure 38. A squad half load which could be used as a standard resupply package.

6. Class VIII: Medical Supplies

The planning factor for medical supplies is 1.22 pounds per man per day. Since this factor includes dental supplies, veterinary supplies, repair parts for medical equipment, and numerous other things that would be of no concern to a DO platoon, the factor for this research is assumed to be 0.5 pounds per man per day. Typical things included for the DO platoon might be field dressings, compression bandages, tourniquets, water purification tablets, anti-malarial medication, antibiotics, pain killers, et cetera. The battalion surgeon for the MEU's battalion landing team should be consulted to determine what a routine resupply package in this area should look like. Based on the size of an MRE, 0.5 pounds of medical supplies would be approximately 0.019 cubic feet.

7. Class IX: Repair Parts and Batteries

Repair parts and batteries fall into the hard to define category. Planning factors for weight exist, but they do not help a logistician determine whether the next resupply mission will need to carry a spare tire or a new gun barrel. While autonomic logistics technologies will help in this area to some degree by providing feedback on equipment as it wears out, it will not be able to predict the next flat tire or fire fight. The DO platoon carries a tremendous amount of sensors and radios which will certainly require frequent battery resupply. The planning factor for a lightly engaged mechanized unit is 3.43 pounds/man/day. If this amount was converted directly into AA sized batteries, which can be used to power much of the current field technology, it would be about 54 AA batteries per day. Assuming half the planning factor weight is used for actual replacement parts for vehicles, weapons, and radios, this would amount to 22 AA batteries per man per day. This is roughly four batteries per gadget per day for each member of the DO platoon. This factor seems reasonable, although some batteries should be rechargeable using the ITV and a battery charger. Based on this assessment, 3.43 pounds per man per day seems to be a reasonable upper bound planning factor for the platoon. This amounts to approximately 0.016 cubic feet.

8. Total DO Platoon Requirements

Figure 39 summarizes the daily supply requirement for each Marine and each ITV. The basic combat load of ammunition per Marine is about 35 pounds. Each vehicle's combat ammunition load is approximately 150 pounds. Each ITV would have to carry the balance of each fire team's water requirement, which is 8 gallons for the first day and 16 gallons for each additional day. A Marine's individual load bearing equipment can carry 120 pounds and about 3.4 cubic feet. (Marine Corps Systems Command Website, 2005) Adding days of supply increases the amount of supplies required for all listed classes of supply except ammunition. Figure 40 shows the daily requirements as a function of days of supply. Notice that for an individual Marine, three

DOS utilizes the full volume capacity of the load bearing equipment. In the next section, a support concept will be developed based on a three DOS policy.

		Weight requirement (pounds)	Cubic Feet Requirement	Weight/Marine	Cube/Marine	Weight/ITV	Cube/ITV
Class I							
	MRE	5.58	0.39	5.58	0.39		
	Water	33.36	0.54	16.68	0.27	66.72	1.07
Class II		3.60	0.14	3.60	0.14		
Class III	(vehicles only)						
	Lubricants	2.00	0.55			2.00	0.55
	Fuel	90.50	1.82			90.50	1.82
Class V	(basic load)						
	Marines	36.45	0.95	36.45	0.95		
	Vehicles	150.36	3.18			150.36	3.18
Class VIII							
	Medical Supplies	0.50	0.02	0.50	0.02		
Class IX							
	Batteries/Repair Parts	3.43	0.02	3.43	0.02		
			Individual Total	**66.24**	**1.78**	**309.58**	**6.62**
			Platoon Total	**2,914.76**	**78.37**	**3,405.42**	**72.86**
			Platoon Total less Ammunition	**1,310.76**	**36.37**	**1,751.42**	**37.86**

Figure 39. This figure shows the total supply requirement (excluding Class IV), for each Marine and ITV for one day.

DOS	**Weight/Marine (lbs)**	**Cube/Marine (cu ft)**	**Weight/ITV (lbs)**	**Cube/ITV (cu ft)**	**Weight/Platoon (lbs)**	**Cube/Platoon (cu ft)**	**Routine Resupply Weight**	**Routine Resupply Cube**
1	66	2	310	7	6,320	151	3,062	74
2	79	3	469	10	8,648	225	5,390	148
3	92	3	628	14	10,977	300	7,719	223
4	106	4	787	17	13,305	374	10,047	297
5	119	5	946	20	15,633	448	12,375	371

Figure 40. This shows the supply requirement as function of days of supply. A routine resupply does not include ammunition. Three DOS is highlighted as the maximum volume that an individual Marine can carry.

B. DEVELOPING A SUPPORT CONCEPT

This section develops a support concept based on the scenario, from Chapter II, the simulation results from Chapter IV, and the logistical requirements identified in the previous section. Since the platoon will be resupplied by aviation assets, the typical aviation mix of a MEU is listed below:

- 12 CH-46 medium lift helicopters (Sea Knight)
    - Scheduled for replacement by the MV-22 (Osprey) medium lift tilt rotor aircraft

- 4 CH-53E heavy lift helicopters (Super Stallion)
- 2-4 UH-1N light utility helicopters (Huey)
- 4 AH-1W light attack helicopters (Super Cobra)
- 6 AV-8B VTOL fixed wing light attack aircraft (Harrier)
- 2 KC-130 tanker/cargo aircraft (not embarked on ships)

This information was compiled from the Federation of American Scientists Website (fas.org), and the GlobalSecurity.org website in August 2005, as well as the author's operational experience.

1. Transportation Requirements

The scenario in Chapter II describes a DO platoon operating in an austere, mountainous environment without secure ground lines of communication. As a result, aircraft lift capacity is diminished by higher altitude operations. Additionally, due to the importance of speed of transit, and the requirement for maneuverability and survivability, external lift should be ruled out. Figure 41 shows the internal lift capacities of MEU cargo helicopters at 4000 feet elevation in a hot climate for a 30 nautical mile round trip mission, which provides a conservative estimate. These were derived from military standards on transportability (MIL-STD-1366D, 1998).

Aircraft	Internal Payload Useful Volume (cu ft)	Internal Load (lbs) (at 4000ft, 90 degress F)	Internal Load Max Speed (knots)	Max Internal Load (lbs)
CH-46	603	3,890	145	6,000
MV-22	398	8,000	240	13,850
CH-53	1,386	18,600	130	35,000

Figure 41. Internal payload capacity for MEU cargo helicopters for a 30 nautical mile round trip at 4000ft and 90 degrees Fahrenheit. (after MIL-STD-1366D, 1998).

From Figure 40, a three DOS resupply mission, without ammunition, is about 7,700 pounds and 220 cubic feet. To lift this would require the full capacity of two CH-46 aircraft, without leaving any room for an ammunition load. Assuming a typical ammunition resupply is three squad half loads (Figure 38), the ammunition adds an additional 1,467 pounds and 36 cubic feet. Two CH-46 aircraft could not carry three DOS with three squad half loads to 4,000 feet on a hot day, but could carry the load under more ideal conditions. For the mission in this scenario, a three DOS resupply mission with ammunition, would require four CH-46 helicopters since Marine aircraft always fly in pairs (Mislick, 2005). Two MV-22 aircraft could easily handle the weight requirements for three DOS with ammunition at the given conditions and provide considerable additional flexibility since it is much faster, has additional range, can be refueled in flight, and can fly at much higher altitudes (Federation of American Scientists Website, 2005). The CH-53 is capable of carrying five DOS for the entire platoon with a basic load of ammunition in one aircraft. Using the CH-53 seems to be overkill for a platoon mission, but since the MV-22 has not yet been fielded, it may be required for certain missions requiring higher altitude operations, such as those in Operation Enduring Freedom in Afghanistan. It should be noted that the C-130 aircraft could air drop the platoon's required supplies, which may be useful, especially when a clandestine night airdrop is important to the mission. However, since resupply by C-130 cannot evacuate casualties or prisoners, it is ruled out for this mission.

2. Employment

Based on a controlled resupply rate (CSR) of every two days, a pair of CH-46 helicopters could carry the required 5,400 pounds of supplies plus four squad half loads of ammunition at a total weight of 7,350 pounds. This would require the MEU to dedicate two CH-46 aircraft to remain in direct support of the DO platoon throughout its operation. In order to provide security for the resupply missions, each resupply flight would need to be escorted by two AH-1W Super Cobra helicopters. The Cobras could loiter over landing zones and provide surveillance, coordinate fire missions, and engage enemies while the platoon is engaged in receiving supplies from the CH-46 helicopters.

Since responsiveness is the most critical supporting factor, supplies should be pre-staged and separated into fire team sized packages. A two day package (without ammunition) would weigh about 500 pounds. This would allow for quick on and off loading, as well as reducing the amount of time it takes the platoon to internally distribute supplies. Having the Cobra over watch would allow the CH-46's the security to deliver to each squad individually rather than requiring internal redistribution over a large area.

The helicopters will also pick up casualties and enemy prisoners and return them to the MEU.

Based on the results from the data analysis, the aircraft transit time should be limited to less than 15 minutes combined with a mission setup time of less than 4 hours. Based on Figure 41, which shows airspeed as a function of distance and flight time, to be supported by the CH-46, the platoon must be no further than 30 nautical miles or 55 kilometers from the supporting agency. The introduction of the MV-22 will increase the range to over 100 kilometers, but makes using the Cobra as an escort infeasible. In order to keep mission setup time less than four hours, helicopters and flight crews must be on hand in addition to having pre-staged supply and ammunition packages. Keeping response time short will also require the CSS agency to have constant communications with the DO platoon in order to effectively anticipate its requirements and react to problems. The following list summarizes a support concept for the DO platoon for the scenario in this thesis:

- The DO platoon carries 3 DOS and combat ammo load
- Two CH-46 assigned in direct support transporting supplies internally
- Two AH-1W assigned for escort and landing zone security
- 2 DOS resupply packages pre-staged and organized into fire team sized packages
- CSS agency located within 55 kilometers of the DO platoon
- Pilots, aircraft, and supply and ammunition packages on standby to keep response time less than four hours
- CSS agency in continuous contact with DO platoon in order to track requirements and respond to demands

Assuming that at any given time, approximately 20% of MEU aircraft are not available due to maintenance (based on maintenance planning factors), supporting the DO platoon with this concept would leave the MEU with an average of eight CH-46 and two AH-1W helicopters to support the rest of the MEU’ s missions. Depending on the priority of the DO platoon’s mission in the context of MEU operations as a whole, and the degree of risk involved, this supporting concept may or may not be feasible for the MEU. If it is not feasible, great care must be taken to assess the risks associated with a particular DO mission and other potential concepts of support. Additionally, consideration must be given to insertion and extraction of the DO platoon and its vehicles, which is beyond the scope of this research. In the next section, some guidelines based on this research are developed to help assess the supportability of the DO platoon from the MEU.

Distance		Flight Time									
Kilometers	Nautical Miles	2 min	4 min	6 min	8 min	10 min	12 min	14 min	16 min	18 min	20 min
5	3	81 kt	41 kt	27 kt	20 kt	16 kt	14 kt	12 kt	10 kt	9 kt	8 kt
10	5	162 kt	81 kt	54 kt	41 kt	32 kt	27 kt	23 kt	20 kt	18 kt	16 kt
15	8	243 kt	122 kt	81 kt	61 kt	49 kt	41 kt	35 kt	30 kt	27 kt	24 kt
20	11	324 kt	162 kt	108 kt	81 kt	65 kt	54 kt	46 kt	41 kt	36 kt	32 kt
25	14	405 kt	203 kt	135 kt	101 kt	81 kt	68 kt	58 kt	51 kt	45 kt	41 kt
30	16	486 kt	243 kt	162 kt	122 kt	97 kt	81 kt	69 kt	61 kt	54 kt	49 kt
35	19	567 kt	284 kt	189 kt	142 kt	113 kt	95 kt	81 kt	71 kt	63 kt	57 kt
40	22	648 kt	324 kt	216 kt	162 kt	130 kt	108 kt	93 kt	81 kt	72 kt	65 kt
45	24	729 kt	365 kt	243 kt	182 kt	146 kt	122 kt	104 kt	91 kt	81 kt	73 kt
50	27	810 kt	405 kt	270 kt	203 kt	162 kt	135 kt	116 kt	101 kt	90 kt	81 kt
55	30	891 kt	446 kt	297 kt	223 kt	178 kt	149 kt	127 kt	111 kt	99 kt	89 kt
60	32	972 kt	486 kt	324 kt	243 kt	194 kt	162 kt	139 kt	122 kt	108 kt	97 kt
65	35	1053 kt	527 kt	351 kt	263 kt	211 kt	176 kt	150 kt	132 kt	117 kt	105 kt
70	38	1134 kt	567 kt	378 kt	284 kt	227 kt	189 kt	162 kt	142 kt	126 kt	113 kt
75	41	1215 kt	608 kt	405 kt	304 kt	243 kt	203 kt	174 kt	152 kt	135 kt	122 kt
80	43	1296 kt	648 kt	432 kt	324 kt	259 kt	216 kt	185 kt	162 kt	144 kt	130 kt
85	46	1377 kt	689 kt	459 kt	344 kt	275 kt	230 kt	197 kt	172 kt	153 kt	138 kt
90	49	1458 kt	729 kt	486 kt	365 kt	292 kt	243 kt	208 kt	182 kt	162 kt	146 kt
95	51	1539 kt	770 kt	513 kt	385 kt	308 kt	257 kt	220 kt	192 kt	171 kt	154 kt
100	54	1620 kt	810 kt	540 kt	405 kt	324 kt	270 kt	231 kt	203 kt	180 kt	162 kt

Feasible MV-22 and CH-46
Feasilbe MV-22

Figure 42. This table shows the required airspeed in knots to achieve a particular flight time at a particular distance. Blue cells indicate speeds feasible for the MV-22. Yellow indicates feasible for the CH-46 and MV-22. [Best viewed in color]

C. DEVELOPING AN ESTIMATE OF SUPPORTABILITY FOR A DISTRIBUTED OPERATIONS PLATOON

The goal of this research is not to provide a boiler plate supportability estimate for a DO platoon. Its purpose is to provide simulated experience to decision makers through analysis of the problem. Since a DO platoon has not been employed operationally, there are no logisticians in the Marine Corps with operational experience supporting one. This analysis provides a surrogate for that experience which planners can use to begin to address the logistical challenges of supporting a DO platoon.

Determining the supportability of the DO platoon will be based on many factors, including the degree of risk which the commander is willing to accept. A time honored way for Marines to asses these factors during mission analysis is to conduct a METT-TSL analysis where the acronym stands for: "Mission, Enemy, Terrain and Weather, Troops and Fire Support Available, and Time, Space, and Logistics." Using the lessons learned during this analysis, each one of these areas is addressed with a focus on the effect it has on the supportability of the DO platoon.

1. Mission

The mission of the DO platoon is the most important consideration when developing an estimate of supportability. Figure 43 lists the additive capabilities of the DO platoon. Recall that the mission of the DO platoon in this thesis research utilized many of these capabilities, but focused on holding key terrain, interdicting enemy forces and controlling avenues of approach — all at extended range. This mission requires the platoon to operate independently for a long period of time, creating a high risk situation far from friendly lines of communication. Shorter term missions, like a long range mounted patrol, may not need any resupply. For this type of mission, the platoon could depart on a two day patrol mission aboard their ITVs and carry three DOS with them. The only logistical support that may be required during the mission would be casualty evacuation, which could be accomplished as part of an overall casualty evacuation plan for the MEU.

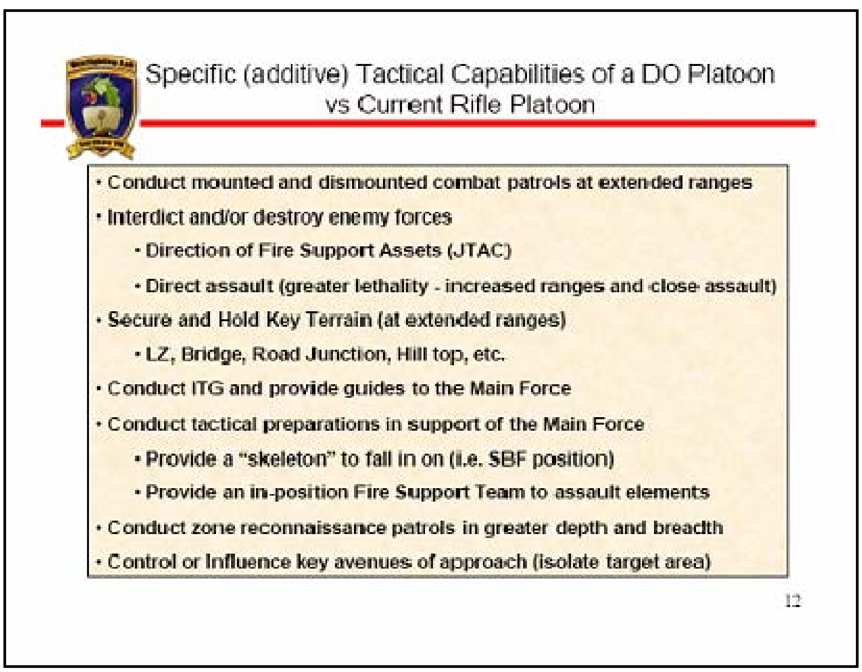


Figure 43. Reproduction of the list of additive capabilities of the DO platoon from Chapter 1. (from *Sea Viking 06 Distributed Operations Live Force Experimentation 25 Feb*

In summary, when analyzing the supportability of the DO platoon, a logistician should consider how far the mission will take the platoon from established lines of communication and support bases and for how long. Figure 42 gives some rough guidance of the risk associated with operating at a range of distances by computing the expected flight time at a given airspeed. Additionally, if the platoon's mission has a high probability of direct action against the enemy, the ability of the support agency to respond to emergency requests must be greater.

2. Enemy

The enemy's mission and capabilities are critical when determining a support concept for the DO platoon. Enemy factors were some of the most critical in the simulation. If the enemy has a robust air defense capability, resupply by helicopter may be difficult or impossible. For this situation, air drop by C-130 may be a possible alternative using recently developed GPS guided parachutes that are capable of landing supplies within 200 meters of their intended target (Lisbon, 2004). These parachutes have been successfully tested in Operation Iraqi Freedom. Conducting such air drops at night could prevent the loss of friendly helicopters and prevent the compromise of the DO platoon's position. If the enemy is not seen as a threat to aircraft and landing zone security is not an issue, then combat escorts may not be required for resupply helicopters. In a situation where compromising the platoon's position creates a threat to the DO platoon, but helicopter delivery is the only acceptable means of sustainment, serious consideration should be given to including escort aircraft to provide added protection for the platoon while it is receiving a resupply. Ultimately, when evaluating the supportability of the DO platoon, the logistician must consider the ability to protect both the resupply assets and the Marines who are made vulnerable by receiving them.

3. Terrain and Weather

The terrain between the MEU and the DO platoon and the terrain in which the platoon operates are critical factors. If the elevation is high, the CH-46 might not be able to fly a resupply mission. If the weather is very bad, low flying aircraft may not be able to provide support, forcing a ground resupply mission or causing a long delay in response. If a resupply mission had to fight its way to support the DO platoon over the ground, are there sufficient roads and combat assets to accomplish the mission? A major risk of a mission that depends on aviation support is that it is highly susceptible to weather. A logistician should fully understand the terrain and weather that the DO platoon may encounter over the length of the mission, in order to ensure that alternative means to sustain it over the length of the mission are available. A good historical example to keep in mind is the recent loss of a CH-47 helicopter full of Navy SEALs in Afghanistan who were flying to the aid of a recon team under fire in Kunar province. (Gordon and Boylan, 2005) Against a determined foe in rugged terrain, the mission may be as risky for the resupply as it is for the DO platoon.

4. Troops and Fire Support Available

The supportability of the DO platoon will depend heavily on the ability to provide the necessary security to resupply missions. The availability of escort aircraft and fire support to suppress enemy air defenses will be critical. Additionally, escort aircraft can coordinate ground and air fire support for the DO platoon when it is most vulnerable. For example, if the platoon takes casualties, it may not have the strength in numbers to continue an intense fight while providing security for an evacuation landing zone. Providing extra fire support during resupply missions could help mitigate this threat, as evidenced by the results of the simulation experiment. An additional concern will be the logistical support of a fire support agency if it is not co-located with the combat service support area. If the MEU has to provide logistics support to an artillery battery by air as well as the DO platoon, its resources to support other missions may be severely limited. The fielding of the MV-22 and the Expeditionary Fire Support System will greatly increase the MEU's flexibility in this area.

5. Time, Space, and Logistics

Of all the factors considered, perhaps the most important to the logistician are the temporal and logistical constraints on the DO platoon's mission. How long will the platoon operate? How quickly must resupply missions be executed? Does the MEU have sufficient supplies on hand to sustain the DO platoon for the duration of the mission? Does the CSS agency have the option of setting up a forward support base or a forward arming and refueling point nearer to the DO platoon in order to provide quicker response or longer range? The watchword of logistics is responsiveness. When considering the supportability of the DO platoon, the physical constraints of the MEU's limited resources will always impact the achievable level of responsiveness. There will always be a way to support one platoon, but if the level of responsiveness is not adequate to the risk of the mission, then it is not supportable.

D. SUMMARY

In summary, this chapter analyzes the requirements of the DO platoon and uses them in conjunction with lessons learned from the simulation experiment to generate a support concept and guidance for developing an estimate of supportability. This chapter provides the means to answer the third research question: What is the supportability of the DO platoon across the range of missions? With the supply requirements along with the MEU's support capabilities analyzed and tabulated in this chapter, a MEU logistician should be able to asses the supportability of the DO platoon for any mission. As most logisticians realize, supporting a single infantry platoon is generally not complicated. Supporting a DO platoon is made complicated by the risk to both the platoon and the resupply assets caused by the lack of secure lines of communication and the distances involved. In order for the MEU to effectively support the DO platoon, it must be willing to dedicate a significant portion of its assets to ensure that resupply is responsive and secure.

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VI. CONCLUSIONS

A. RESEARCH SUMMARY

This research set out to explore the logistical implications of the Marine Corps' distributed operations (DO) platoon concept which is being developed by the Marine Corps Warfighting Lab (MCWL). Through the development of a realistic scenario and simulation based on MCWL's DO Wargame, a thorough experiment and analysis, and a determination of the support requirements and a support concept, this thesis produced a detailed quantitative analysis of the challenges of supporting a DO platoon. The simulated operational experience generated by this analysis will form a strong foundation for the further development of the DO concept and will be useful to any logistician in a position to support a DO platoon.

B. RESEARCH QUESTIONS

The goal of this research was to answer three questions:

- What are the critical logistical factors relating to mission success for the DO platoon in the missions envisioned in MCWL's Wargame Scenarios?
- What are the critical logistical capabilities of the MEU that will enable it to provide continuous sustainment to a distributed force?
- What is the supportability of a DO platoon across the range of missions?

In this section, the answers to these questions are briefly summarized.

1. Critical Factors

The simulation experiment results are analyzed using multiple regression to identify critical factors. The two most critical logistical factors for supporting the DO platoon are tied directly to responsiveness. They are the time it takes to setup a resupply mission and the time it takes to deliver it. The analysis results suggest that if setup time can be kept less than four hours and resupply flight time is less than 15 minutes, then the platoon's average mission performance is better overall. The number of days of supply (DOS) is also important and three DOS is the threshold value for better performance. Adding more days of supply increases performance, but logistical analysis suggests that more than three DOS is too much for an individual Marine to carry. Also critical is the usage rate of supplies in a fight. The amount of supplies that a Marine uses in an engagement can be much higher than normal planning factors suggest, especially for fuel, water, ammunition, and medical supplies. The statistical analysis suggests that if this usage rate deviates significantly from the planned factors, then a more responsive request system is required to maintain effectiveness. Overall, enemy capabilities are incredibly significant since a more powerful enemy introduces greater instability in the usage of supplies and ammunition and in the casualty rate.

2. Critical Capabilities

The critical capabilities that are required to support a DO platoon are also defined through analysis of the simulation results using regression and classification trees combined with data visualization. Based on the scenarios that were explored in the experiment, the most effective logistical support system includes autonomic, rapid request, and scheduled support missions. This system is made more effective by providing aircraft that can provide surveillance over the DO platoon's landing zones during resupply missions. An autonomic logistics system works well for combat usage and casualty rates that are low and relatively stable, but a rapid request system is much more robust over the range of possible combat environments. Stealth is a potentially important component of low risk resupply missions.

3. Supportability

An effective logistical support system for the mission in the DO wargame scenario is sustainable from the current MEU. Two CH-46 and two AH-1 helicopters in direct support can provide the DO platoon with its required support by flying scheduled (every two days) and rapid request missions from a location within 50 kilometers of the DO platoon. Three DOS is the recommended combat load of supplies for the platoon and is within their carrying capacity. Carrying more than three DOS would be very difficult without some very strict economy measures. These measures might include water reclamation and purification technologies, battery chargers, and strict fuel economy standards. Developing an estimate of supportability for a DO platoon mission requires looking at the MEU's overall support commitments and the time, distance, and intensity of the platoon's mission.

C. ADDITIONAL INSIGHTS

This research identifies several additional insights as a by-product of the analysis into the research questions. The three most significant of these are summarized below.

1. Instability

This research examines critical factors under unstable combat conditions. Instability is defined as a very capable enemy force which results in large uncertainties in combat usage rates. In the unstable situation, high resupply speed and low resupply stealth were the most important contributors to success. This shows that responsiveness and fire support are critical to the DO platoon. In the scenario analyzed, resupply missions also serve as close air support missions since the resupply aircraft provide targeting information. As a result, this research concludes that quick response for both supplies and fire support are critical to the success of the DO platoon, especially when faced with great uncertainty.

2. Intelligence

Tactical intelligence is critical to the combat service support agency when supporting DO. The threat to resupply vehicles in a dispersed environment without secure lines of communication increases the risks to all involved. The supporting agency must be able to respond to support requests before the next enemy attack. Resupply missions must have appropriate escorts to ensure safe delivery and return of vehicles. Combat service support takes on a much more tactical character when supporting DO. This makes intelligence much more critical when planning a resupply mission, both in determining the execution and timeline of the mission and in preparing the support that may be required for the next mission.

3. Simulated Operational Experience

Usually lessons learned and significant factors are not identified until many mistakes are made in the field operationally. In this research, computer modeling allows hundreds of thousands of simulated combat missions to be executed. By exploring the ranges of factors in this simulated combat, there are both mistakes made and things done well. Statistical analysis of the results is like an operational hot wash, where key players in an operation meet to discuss the lessons learned from an operation or exercise. When developing new doctrine and tactics, such as DO, there is precious little operational experience to draw on to determine what works well and what does not. While the lessons learned from simulation analysis do not automatically translate into operational success, they give a good foundation of simulated experience for live operational testing and experimentation. The author of this thesis participated in a Project Albert sponsored experiment in which agent-based simulations and data farming were used as part of the course of action development phase of the planning process. During this process, the experiment staffs were able to gain a surrogate for operational experience in the tactical problem they were working on which helped to improve the quality of their planning. A brief synopsis of the author's participation in this experiment is contained in Appendix D. In summary, computer simulation and data farming is a valuable way to gain a foundation of experience in operational problems.

D. RECOMMENDATIONS

Based on the conclusions of this thesis, several recommendations are made below:

1. Supporting a DO platoon

- Water is the biggest limiting factor in increasing DOS for the DO platoon. It is recommended that research be done into ways to reduce the water requirement by reclaiming waste water and capturing the water in engine exhaust.
- The DO platoon could be resupplied by air delivery provided it is in range of casualty evacuation aircraft. It is recommended that technologies for precision airdrop from the C-130 or MV-22 be explored for delivering tactical resupply packages to DO units in a clandestine manner.

- The risk of a DO platoon operation increases with the length of time it takes for supporting aircraft to reach it. This research estimates that a 15 minute or less time of flight is effective and gives an operational radius of approximately 50 kilometers using the CH-46. Poor flight conditions or bad weather may limit this radius. It is recommended that operational constraints for DO be developed that account for the travel time of aircraft carrying critical supplies or performing medical evacuation.
- Aerial surveillance of the DO platoon's area during resupply deliveries proved to be very valuable in the simulation model. It is recommended that a tactical unmanned aerial vehicle be considered for employment with the DO platoon.
- Autonomic logistics was useful in supporting the DO platoon in the simulation, but a rapid request system was more critical overall in responding to high demand variability. It is recommended that intelligence and communications assets of the supporting agency be tailored to provide the maximum amount intelligence on usage rates and enemy activity in order to provide the supporting agency maximum flexibility in executing both push and pull logistics.

2. Methodological

- The use of data farming and simulation analysis of the problem before identifying physical logistical constraints allowed a direct assessment of the tradeoffs among factors and policies before preconceived ideas of support constraints were established in this research. It is recommended that simulation studies in logistics freely explore factors and policies that are not feasible in the real world in order to assess the cost of mistakes and the value of good policy.
- This simulation study helped to develop a surrogate for operational experience in a new tactical concept that is critical to USMC transformation. It is recommended that the methodology of this thesis be applied to other USMC and Department of Defense transformation efforts in order to guide the development of new doctrine, tactics, equipment, training, and live experimentation.

E. FOLLOW-ON WORK

The following is a list of follow-on research of value that could be accomplished utilizing this work:

- More detailed data analysis of the results of each of the five scenarios in the simulation
- Focused analysis over the key parameters and ranges identified including more factorial experiments

- Repeat analysis using a scenario from an actual DO platoon operational exercise
- Analysis of the effects of enemy attack on resupply aircraft
- Analysis of effects of the terrain in the model
- Analysis of the effects of different enemy characteristics and arrival rates on the results of the simulation
- Analysis of the utility of adding unmanned aerial vehicles to the DO platoon equipment list
- Analysis of the effect of imperfect communication with the CSS agency in the simulation
- Analysis of the effect of incomplete resupply missions on the effectiveness of the DO platoon in the simulation
- A more detailed analysis of the effect of distance on the supportability of the DO platoon

The following is a list of follow-on research of value stemming from this research:

- Validation/comparison of the MANA simulation results and recommendations with the results and recommendations of MCWL's live experiments
- Development of a model exploring the potential casualty rates sustained by the DO platoon and their relationship to logistical support
- Further research into the utility of using simulation to develop synthetic operational experience in new doctrine and tactics
- Human factors study of the effects of carrying heavy loads of supplies on the effectiveness of the DO platoon
- Comparison of MANA simulation results in this thesis with a similar scenario created in a different combat modeling environment
- Analysis of the utility of stealth precision air delivery methods in support of the DO platoon

The two highest priority research areas for follow-on work are as follows:

1. Dispersed Logistics

In the development of DO and other future tactics, secure lines of communication are becoming rarer. Most current logistical systems are based on throughput, which puts security in a secondary role. This research addresses the risk to the mission of the DO platoon caused by poor logistics. Since poor logistics can cripple a distributed force, it is important that supply deliveries operate securely and safely. An important follow on study for this research would be to assess the consequences of enemy action against logistics assets in support of distributed forces.

2. Data Farming and Logistics

Traditionally, combat logistical problems have been addressed by trying to find the optimal allocation of assets mathematically. In a distributed environment, the threats to logistical assets are much more uncertain, as are the best ways to support a particular mission. An optimal allocation of logistics assets may not work well across an uncertain battlespace. An important follow on study for this research would be to use data farming techniques to develop robust logistical support concepts for other transformational concepts, including DO at higher echelons.

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APPENDIX A. EQUIPMENT LISTS

	Billet	Equipment	Description	Technology	Range
A Command					
	Plt Commander				
		M16A4	5.56 rifle w/ rifleman suite		800m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	7-10mi
	Plt Radio Operator				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	7-10mi
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms		500-1000m
	Guide				
		M-16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
		PRC 150	Platoon to HHQ comms OTH (logistics)	HF/HFDigital	30+ miles
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	ITV		Internally Transportable Vehicle	Can be transported inside MV-22	
		PAS-13H	Optic for .50 caliber MG		
		M-2HB	.50 Caliber Machine Gun		1830m
		Medical Kit	Standard First Aid Supplies		
B Command	Plt Sergeant				
		M16A4	5.56 rifle w/ rifleman suite		800m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	7-10mi
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	7-10mi
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman				
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Corpsman				
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		Adv. Medkit	Corpman emergency trauma kit		
	ITV		Internally Transportable Vehicle	Can be transported inside MV-22	
		PAS-13H	Optic for Mk-19		
		MK-19	Automatic 40mm Grenade Launcher		1500m
		Medical Kit	Standard First Aid Supplies		

M16A4 Rifleman suite consists of:
PRR, Bayonet, Bipod, Compass, White/IR Light, Suppressor, Bayonet, Collapsable Stock, Day RCO, Night RCO

This is the equipment list for the two DO platoon headquarters sections.

Squad Organization (3 per platoon)

	Billet	Equipment	Description	Technology	Range
Squad C2					
	Squad Leader		SGT		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		ETCS/Voice	Expeditionary Tactical Comm System	Low Earth Orbit Sattelite	Worldwide
	Automatic Rifleman				
		M249 SAW	5.56 Machine Gun w/ spare barrel		1000m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	ITV				
		M240G	7.62 Machine Gun		1800m
		PVS-17	Night Sight		
		PRC 117	Squad-Plt-HHQ , CAS, Firecontrol - digital	VHF(7-10mi)/UHF(LOS)/Sattelite (WW)	
		GLTD II	Ground Laser Target Designator	10x magnification	20km
		Medical Kit	Standard First Aid Supplies		
Team 1					
	Team Leader		CPL		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4			
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Automatic Rifleman		PVT-LCPL		
		M249 SAW	5.56 Machine Gun w/ spare barrel		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	ITV				
		M-2HB	.50 Caliber Machine Gun		1830m
		PAS-13H	Optic for M-2		
Team 2					
	Team Leader		CPL		
		M16 w/ M203	5.56 rifle w/ rifleman suite and 40mm grenade launcher		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		PRC 148	Platoon C2 and Close Air Support	UHF(line of sight)/VHF (7-10mi)	
		PEQ-2	Aiming / Pointing Laser	Class 3b Laser	Unknown
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
		IZLID	Infrared Zoom Laser Illuminator/Designator	Class 4 Laser	10km
	Automatic Rifleman		PVT-LCPL		
		M249 SAW	5.56 Machine Gun w/ spare barrel		1000m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	Rifleman		PVT-LCPL		
		M16A4	5.56 rifle w/ rifleman suite		800m
		PRR	Personal Role Radio Intra Team Comms	UHF	500-1000m
	ITV				
		MK-19	Autmatic 40mm Grenade Launcher		1500m
		PAS-13H	Optic for Mk-19		

This is the equipment list of an individual DO squad.

APPENDIX B. MANA SIMULATION PARAMETER DATA

This appendix contains the spreadsheets used to develop and document the simulation parameters used in this research. For a copy of the source code of the simulation, contact Dr. Tom Lucas, Associate Professor of Operations Research at the Naval Postgraduate School in Monterey, California. His email address is twlucas@nps.edu.

Days in Scenario	Hours In Scenario	Minutes In Scenario	Minutes per time step	total time steps of scenario
14	336	20160	0.5000	40320
			(30 seconds)	

m on X axis of Terrain Map	m on Y axis of Terrain Map	Total sq meters in Map
6000	6000	36000000

meters per grid squad	Grid Squares on X axis of	Grid Squares on Y axis of Terrain	Total Grid Squares in
30	200	200	40000

speed	kph	1	2	3	4	5	100
	m/s	0.277777778	0.555555556	0.833333333	1.111111111	1.388889	27.77778
	m/ time step	8.333333333	16.66666667	25	33.33333333	41.66667	833.3333
	grid / step	0.277777778	0.555555556	0.833333333	1.111111111	1.388889	27.77778
	mana speed	27.77777778	55.55555556	83.33333333	111.1111111	138.8889	2777.778

General Simulation parameters

Time Step 30 Seconds

MAP SCALE

	X	Y	JUSTIFICATION
Number of Cells	200	200	6000mx6000m corresponds to Bridgeport region used in Sea Viking DO Wargame 1 Scenario 2
Real World Min (m)	0	0	Aggregation into 200x200 cells is to allow simulation to run faster out to a simulation time of 14 days to simulate logistics system
Real World Max	6000	6000	
Add new contacts	By Agent ID		Faster, works well (no significant difference in MOE)
Shoot SA Map Contacts By	Location on SA map		Faster and results similar to removing by underlying contact ID (difference not significant)
LOS Mode	Advanced		take into account terrain effects of mountains
Contact Resolution Radius	1		Default Setting 1 Cell is 30 meters. Increasing has significant effects. Contacts 30+ meters apart would be considered different for targeting purposes
Number of Cells used in Terrain Calcs	5		Tried several parameters, this seems to work as well as larger numbers for the aggration level of this model. This amounts to a 150m sample out of 1000m

Move Selection	Stephen Algorithm	default, not explored
Best Move	Precision	default for ground forces, not explored
Move Precision	Varies	

Genral Movement Settings

NO	Multiple Agents in Cell (blue agents)
YES	Multiple Agents in Cell (red agents)
YES	Diagonal Motion Correction
YES	Navigate Obstacles
NO	Squad Moves Together
YES	Going affects speed / except aviation units

MANA DO Scenario Comm Architecture			
Entity	**Passes Information to:**	**(Real World)**	**Explanation**
DO Fireteams	All Squad Members / Squad HQ	Voice, PRR, VHF, UHF, Sattelite	Squad has a common picture based on internal communication using voice, signals, and personal role radios
DO Rifle Squads	Platoon HQ, Squad Members	PRR, VHF, UHF, Sattelite	Reports squad situational awareness (SA) to platoon.
DO Platoon HQ (A&B)	MEU Cdr, Fire Support, Squads, Combat Service Support Agency (Log Sensor)	VHF, UHF, Sattelite	Consoliodates and reports squad SA from three squads. Relays platoon SA to squads and Higher.
Blue Re-supply Agents	Blue Plt Headquarters (A&B), Other Resupply Agents	UHF / VHF	Pass mission tasking to each other to coordinate launch. Pass battlefield awareness to ground forces obtained from their vantage point.
Blue Fire Support	Implicit Communication with requesting agency	PRR, VHF, UHF, Sattelite	Fire support agency receives targets from blue squads via a common operating pictures. Fires are controlled to avoid fratricide.
Blue Logistic Sensor (CSSA)	Resupply Agents (passes taskings and requests)	internal lines (ship or CSSA)	An agent senses when friendlies are out of fuel and sends a message to resupply agents triggering a mission
Enemy Forces	internal to small groups (Squad SA only) and refueling used to trigger hiding	VHF, commercial radios, cell phone, sattelite phones	Small groups trying to infiltrate cross country (terrorists)

Communication settings in MANA model

min link Rank	low	
Inorganic Threat Persistance	30	equates to 15 minutes (parameter for data farming)
Fuse Unknowns on Inorg map	No	slows down model, with perfect sensors and comm, should be no unknowns
Outbound Comm Link	Only blue forces have explicit external comms	

Blue DO Squads (squads 1-3)

Squad	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery	Remarks
4	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	
5	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	

Blue HQ A&B (squads 4-5)

Squad	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery	Remarks
1	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	
2	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	
3	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	
4	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	(4 links to 5 and vice versa, all others same)
5	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F	(4 links to 5 and vice versa, all others same)
9	1000	10	10	0	1	100	100	-1	High	SFUNETC	Guaranteed	
10	1000	10	10	0	1	100	100	-1	High	SFUNETC	Guaranteed	

Blue Resupply Agent (Squad 6-8)

Squad	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery
4	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F
5	1000	10	10	0	1	100	100	-1	High	SFUNETC	F-N-F

Blue force squads and state changes

Squad ID	Name of Agent	State		Summary	JustificationDetail	duration	Fallback To
1-3	Blue DO Infantry Squad	1	Default State	Start state and Default fallback state	Patrol		
		5	Shot At (Pri)	Agent state when shot at by an enemy's primary weapon (may not have been hit)	Suppressed	6	Squad En Contact
		15	Squad En Contact	Squad state when enemy contact (observation) has been made	Active	20	
		26	Fuel Out	Agent state when an agent's fuel runs out (fuel <= 0 & was +ve)	Waiting for resupply	40320	
		28	Refuelled by Anyone	Agent state while being refuelled by any agent	refueled	1	Spare 1
		30	Refuel By Friend	Agent state while being refuelled by a friend	refueled	1	Spare 1
		49	Spares 1	Left empty for use as intermediate fallback states	Resupply conduct time	30	
4-5	Blue Infantry Plato	1	Default State	Start state and Default fallback state	Patrol		
		5	Shot At (Pri)	Agent state when shot at by an enemy's primary weapon (may not have been hit)	Suppressed	6	Squad En Contact
		15	Squad En Contact	Squad state when enemy contact (observation) has been made	Active	20	
		26	Fuel Out	Agent state when an agent's fuel runs out (fuel <= 0 & was +ve)	Waiting for resupply	40320	
		28	Refuelled by Anyone	Agent state while being refuelled by any agent	refueled	1	Spare 1
		30	Refuel By Friend	Agent state while being refuelled by a friend	refueled	1	Spare 1
		49	Spares 1	Left empty for use as intermediate fallback states	Resupply conduct time	30	
6-8	Blue Resuppl	1	Default State	Start state and Default fallback state	movement		
		2	Reach Waypoint	Agent state when any waypoint is reached	Delivers supplies	12	
		31	Refuel By Neutral	Agent state while being refuelled by a neutral	mission triggered by Log Sensor	2	
		35	Reach Final Waypoint	Agent state when final waypoint is reached	scheduled time btwn missions	5760	
		36	Run Start	Squad state at the beginning of a run (can be used as delay)	delay	1	Reach Final Waypoint
9	Blue Fire Suppor	1	Default State	Start state and Default fallback state	Shoots at targets on IO SA map		
10	Blue Logisitcs Sens	1	Default State	Start state and Default fallback state	Tracks fuel 1 / time step		
		26	Fuel Out	Agent state when an agent's fuel runs out (fuel <= 0 & was +ve)	triggers resupply	49000	
		28	Refuelled by Anyone	Agent state while being refuelled by any agent	refuell	1	
		43	Inorg SA En Contact 1	Squad state when a new low enemy threat (level 1) appears on the Inorganic SA map	track DO usage	20	
		47	Inorg SA Ne Contact	Squad state when a new neutral contact appears on the Inorganic SA map	track DO rapid request	1	Spare 1
		49	Spares 1	Left empty for use as intermediate fallback states	time to set up rapid request	240	Spare 2
		50	Spares 2	Left empty for use as intermediate fallback states	trigger resupply	2	Fuel Out

Blue force movement preferences by squad and state

19	Types			Agent SA																	
Squad ID	Name of Agent		State	Enemies	Combat	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Ideal Enemy	En. Class	Uninjured Friends	Injured Friends	Cluster	Neutrals	Next Waypoint	Advance	Alt. Waypoint	Easy Going	Cover	Concealment	Line Center
1-3	Blue DO Infantry Squad	1	Default State								-30				30						
		5	Shot At (Pri)	-20							20				20						
		15	Squad En Contact								-30				30						
		26	Fuel Out	-20							20				20						
		28	Refuelled by Anyone																		
		30	Refuel By Friend																		
		49	Spares 1	-20							20				20						
4-5	Blue Infantry Plato	1	Default State								-10				10						
		5	Shot At (Pri)	-20							20				20						
		15	Squad En Contact								-10				10						
		26	Fuel Out	-20							20				20						
		28	Refuelled by Anyone																		
		30	Refuel By Friend																		
		49	Spares 1	-20							20				20						
6-8	Blue Resuppl	1	Default State												100						
		2	Reach Waypoint								100	100									
		31	Refuel By Neutral												100						
		35	Reach Final Waypoint												100						
		36	Run Start												100						
9	Blue Fire Suppor	1	Default State																		
10	Blue Logisitcs Sen	1	Default State																		
		26	Fuel Out																		
		28	Refuelled by Anyone																		
		43	Inorg SA En Contact 1																		
		47	Inorg SA Ne Contact																		
		49	Spares 1																		
		50	Spares 2																		

Blue force ranges

19	Types			Ranges																
Squad ID	**Name of Agent**		**State**	Icon	Allegiance	Threat	Agent Class	Movement Speed	No Hits to kill	Stealth	Armour Thickness	Waypoint Radius	Sensor Class Range	Sensor Detect Range	Sensor Height	Fuel Usage Rate	Refuel Trigger Range	Prob Refuel Enemy	Prob Refuel Friend	Prob Refuel Neutral
1-3	Blue DO Infantry Squad	1	Default State	1	1	3	0	111	1	0	100	2	34	34	2	1				
		5	Shot At (Pri)	3	1	3	0	0	1	0	100	2	3	3	2	3				
		15	Squad En Contact	2	1	3	0	111	1	0	100	2	34	34	2	2				
		26	Fuel Out	3	0	3	0	20	1	0	100	2	3	3	2	0				
		28	Refuelled by Anyone	1	1	3	0	100	1	0	100	2	167	167	2	0	167	0	100	100
		30	Refuel By Friend	1	1	3	0	100	1	0	100	2	167	167	2	0	167	0	100	100
		49	Spares 1	3	1	3	0	0	1	0	100	2	3	3	2	1				
4-5	Blue Infantry Platoo	1	Default State	1	1	3	0	111	1	0	100	2	34	34	2	1	0	0	0	0
		5	Shot At (Pri)	3	1	3	0	0	1	0	100	2	3	3	2	3	0	0	0	0
		15	Squad En Contact	2	1	3	0	111	1	0	100	2	34	34	2	2	0	0	0	0
		26	Fuel Out	3	0	3	0	20	1	0	100	2	3	3	2	0	0	0	0	0
		28	Refuelled by Anyone	1	1	3	0	100	1	0	100	2	167	167	2	0	167	0	100	100
		30	Refuel By Friend	1	1	3	0	100	1	0	100	2	167	167	2	0	167	0	100	100
		49	Spares 1	3	1	3	0	0	1	0	100	2	3	3	2	1	0	0	0	0
6-8	Blue Resuppl	1	Default State	8	1	1	0	550	1	0	10	2	167	167	100	0	10	0	100	100
		2	Reach Waypoint	83	1	1	0	50	1	0	10	2	167	167	2	0	40	0	100	100
		31	Refuel By Neutral	8	1	1	0	550	1	0	10	2	167	167	100	0	34	0	100	100
		35	Reach Final Waypoint	58	1	1	0	0	1	0	10	2	0	0	2	0	0	0	0	0
		36	Run Start	8	1	1	0	550	1	0	10	2	34	34	100	0	0	0	0	0
9	Blue Fire Suppor	1	Default State	13	1	3	0	0	1	100	10	2	0	0	2	0	0	0	0	0
10	Blue Logisitcs Sens	1	Default State	12	1	3	0	0	1	0	100	2	34	34	255	1	0	0	0	0
		26	Fuel Out	37	0	3	0	0	1	0	100	2	50	50	255	0	10	0	100	0
		28	Refuelled by Anyone	12	0	3	0	0	1	0	100	2	0	0	255	0	0	0	0	0
		43	Inorg SA En Contact 1	12	1	3	0	0	1	0	100	2	0	0	255	2	0	0	0	0
		47	Inorg SA Ne Contact	12	1	3	0	0	1	0	100	2	34	34	255	0	0	0	0	0
		49	Spares 1	14	1	3	0	0	1	0	100	2	34	34	255	10000	0	0	0	0
		50	Spares 2	14	0	3	0	0	1	0	100	2	34	34	255	10000	100	0	100	0

Blue force weapons

19	Types			Weapon 1																			Squad SA					Inorganic SA				
Squad ID	**Name of Agent**		**State**	Type	Ammo	Range	Prob Hit	Range	Prob Hit	Range	Prob Hit	NonTarget Class	NonTarget Class	NonTarget Class	Max Targets/Step	Penetration	Targets Unknowns Pause	Min Targetr Treat Level	Max Target Threat Level	Max SA Target Age	Protect Contact Types	Using Map:	Intra-Squad Comms Delay	Squad Threat Persistence	Fuse Unknowns	Fuse Time	Fuse Radius	Min Link Rank	Inorganic Threat Persist	Fuse Unknowns on Inorg M	Fuse Time	Fuse Radius
1-3	Blue DO Infantry Squad	1	Default State	KE/ASA	1000000	4	1	17	0.5	33	0.12					0	-1	0	3	100	All	All	0	30				L	30			
		5	Shot At (Pri)																													
		15	Squad En Contact	KE/ASA		4	1	17	0.5	33	0.12					0	-1	0	3	100	All	All										
		26	Fuel Out																													
		28	Refuelled by Anyone																													
		30	Refuel By Friend																													
		49	Spares 1																													
4-5	Blue Infantry Plato	1	Default State	KE/ASA	1000000	4	1	17	0.5	33	0.12					0	-1	0	3	100	All	All	0	30				L	30			
		5	Shot At (Pri)	(primary)																												
		15	Squad En Contact	KE/ASA		4	1	17	0.5	33	0.12					0	-1	0	3	100	All	All										
		26	Fuel Out	(primary)																												
		28	Refuelled by Anyone																													
		30	Refuel By Friend																													
		49	Spares 1																													
6-8	Blue Resuppl	1	Default State																				0	30				L	1			
		2	Reach Waypoint																													
		31	Refuel By Neutral																													
		35	Reach Final Waypoint																													
		36	Run Start																													
9	Blue Fire Suppor	1	Default State	HE / IO SA (S	1000000	1	0.22	2	0.02							1	-1	0	500	100	All	IO	0	30				L	30			
10	Blue Logisitcs Sens	1	Default State																				0	30				L	30			
		26	Fuel Out																													
		28	Refuelled by Anyone																													
		43	Inorg SA En Contact 1																													
		47	Inorg SA Ne Contact																													
		49	Spares 1																													
		50	Spares 2																													

Red force agent states and state changes

ID	Name of Agent		State	Summary	Justification	duration	Fallback To
11-80	Red Insurgent	1	Default State	Start state and Default fallback state	Infiltration tactics		
		5	Shot At (Pri)	Agent state when shot at by an enemy's primary weapon (may not have been hit)	Shot at by direct fire	15	Default State
		6	Shot At (Sec)	Agent state when shot at by an enemy's secondary weapon (may not have been hit)	Shot at by indirect fire	15	Default State
		8	Enemy Contact 1	As for "Enemy Contact" but only for enemies of threat 1	Sees resupply	15	Default State
		10	Enemy Contact 3	As for "Enemy Contact" but only for enemies of threat 3	Sees DO platoon agent	15	Default State
		19	Injured	Agent state when injured (shot at and hit)	Lost first hit point	1	Spare 1
		28	Refuelled by Anyone	Triggered into hiding state	Told to hide	1	Spare 1
		35	Reach Final Waypoint	Hides permanently at final waypoint	Reached objective	infinite	none
		36	Run Start	Delay for 500 + (squad# -10)*500 time steps	Arrival rate	varies	Default State
		49	Spares 1	Hiding state, invisible and invincible	Hiding	250	Default State

Red force movement preferences

Name of Agent		State	Enemies	Combat	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Ideal Enemy	En. Class	Uninjured Friends	Injured Friends	Cluster	Neutrals	Next Waypoint	Advance	Alt. Waypoint	Easy Going	Cover	Concealment	Line Center
Red Insurgent	1	Default State	-30							50				80			100			
	5	Shot At (Pri)	-50															50	50	
	6	Shot At (Sec)	-50															50	50	
	8	Enemy Contact 1												100			100			
	10	Enemy Contact 3	-50															50	50	
	19	Injured	-30														50	100		
	28	Refuelled by Anyone	-30											50						-100
	35	Reach Final Waypoint												50						
	36	Run Start												50						
	49	Spares 1												50						

Red force range parameters

ID	Name of Agent		State	Icon	Allegiance	Threat	Agent Class	Movement Speed	No Hits to kill	Stealth	Armour Thickness	Waypoint Radius	Sensor Class Range	Sensor Detect Range	Sensor Height	Fuel Usage Rate	Refuel Trigger Rate	Prob Refuel Enemy	Prob Refuel Friend	Prob Refuel Neutral
11-80	Red Insurgent	1	Default State	26	3	3	1	111	1	20	0	17	34	34	2	0	0	0	0	0
		5	Shot At (Pri)	101	3	3	1	222	1	20	0	17	34	34	2	0	0	0	0	0
		6	Shot At (Sec)	101	3	3	1	222	1	20	0	17	34	34	2	0	34	0	95	0
		8	Enemy Contact 1	101	3	3	1	222	1	20	0	17	34	34	2	0	34	0	95	0
		10	Enemy Contact 3	101	3	3	1	222	1	20	0	17	34	34	2	0	34	0	95	0
		19	Injured	26	3	3	1	111	1	20	0	17	17	17	2	0	0	0	0	0
		28	Refuelled by Anyone	26	3	3	1	111	1	100	100	17	17	17	2	0	0	0	0	0
		35	Reach Final Waypoint	112	3	3	1	0	1	100	100	2	0	0	2	0	0	0	0	0
		36	Run Start	117	2	3	1	0	1	100	100	2	17	17	2	0	0	0	0	0
		49	Spares 1	117	1	3	1	0	1	100	100	2	17	17	2	0	0	0	0	0

Red individual weapons are the same as blue DO squads

APPENDIX C. EXPERIMENTAL DESIGNS

The following are the factors and maximum ranges that are explored in the simulation experiments. Decision factors are in yellow.

Factor	Value Range	Explanation
DO Platoon Days of Supply	1..5	The amount of supplies, in days, carried into initial deployment
Scheduled Resupply Days	1..5	The number of days between scheduled resupply missions
Consumption rate when in enemy contact (fuel/step)	1..100	Consumption rate of blue squads when in contact with the enemy
Consumption rate when shot at (fuel / step)	1..100	Consumption rate of blue squads when in direct contact (i.e. in a fire fight with the enemy)
Rapid request setup time (min)	1..360	Time, in minutes, from time of request to time of resupply unit departure from combat service support area
Time to conduct resupply (min)	1..60	Time, in minutes, to execute the transfer of supplies and casualties when the resupply unit arrives at DO platoon
Resupply speed (m/s)	5..100	Movement speed, in meters per second, of the Resupply force
Resupply stealth (rate per time step)	0..100	Concealment rate of resupply force per time step
Resupply sensor range	34..167	Sensor detection and classification range, in meters, of resupply force
Inorganic sensor persistence friendly (min)	1..120	Time, in minutes, a blue force sensor will maintain a previously reported track of an enemy agent
Sense and respond lead time (hrs)	0..12	The amount of lead time built into the sense and respond (autonomic logistics) system in hours
Enemy Sensor Range (m)	90..2040	Sensor range, in meters, of the enemy's sensors
Enemy Squad Size	1..20	Number of agents in an enemy squad
Contact Persistence Enemy (min)	1..120	Time, in minutes, enemy forces will continually track a blue agent
Enemy hits to kill	1..10	Number of weapon hits required to kill an enemy agent

1. DEBUGGING DESIGN

low level	1	1	1	1	2	2	50	0	34	1	3	1	3	1	1
high level	**5**	**5**	**100**	**100**	**720**	**120**	**1000**	**100**	**167**	**240**	**68**	**20**	**68**	**240**	**10**
Squad	1,2,3,4,5	6,7,8	1,2,3,4,5	1,2,3,4,5	10	1,2,3,4,5	6,7,8	6,7,9	6,7,8	1,..,9	11,…,90	11,…,90	11,…,90	11,…,90	11,…,90
Real Factor	DO Squad Days of Supply	Scheduled Resupply Days	Consumption rate En contact (fuel/step)	Consumption rate Shot at (fuel / step)	Rapid Request Setup time (min)	Time to conduct resupply (min)	Resupply Speed (m/s)	Resupply Stealth	Resupply Sensor Range	Inorganic sensor persistance Friendly (min)	Enemy Sensor Range (m)	Enemy Squad Size	Enemy Weapon Range (m)	Contact Persistance Enemy (min)	EN Hits to Kill
ANA Factor	Fuel tank	Reach final Waypoint time in state	En Contact state fuel rate	Shot At state fuel rate	Spare 1 time in state	Spare 1 time in state	Default State movement speed	Default State, reach waypoint stealth	Default State, reach waypoint stealth	Inbound Communication inoganic persistance	All states sensor range	num agents	All states weapon range	Squad SA contact persistance	default and EN ctc 1 and 2 states
ID1	4	1	37	33	92	92	807	48	163	173	39	19	15	150	8
ID2	5	4	12	43	249	32	570	75	130	221	53	10	18	83	4
ID3	5	2	95	23	215	103	198	45	88	139	55	18	33	124	3
ID4	4	5	72	46	47	52	302	27	51	236	62	13	8	50	9
ID5	5	3	20	3	69	20	288	61	115	117	7	17	45	143	7
ID6	3	5	24	49	114	79	184	86	152	27	29	16	61	16	3
ID7	4	2	54	4	182	41	896	42	55	106	25	18	65	177	2
ID8	4	4	92	32	271	111	718	2	67	76	4	13	50	8	6
ID9	4	1	3	81	294	74	421	9	140	72	58	8	24	57	6
ID10	5	4	49	77	2	35	926	38	123	1	47	2	30	203	1
ID11	3	1	97	54	148	54	347	69	36	57	50	5	17	12	3
ID12	5	3	69	92	125	9	406	81	76	91	38	6	32	139	9
ID13	3	2	33	64	282	59	228	28	161	229	12	2	67	42	7
ID14	4	3	43	89	193	116	95	0	103	128	19	7	37	162	5
ID15	3	2	78	95	316	28	495	94	53	199	3	9	66	72	6
ID16	4	3	55	72	103	114	1000	56	94	195	26	3	48	236	9
ID17	4	3	40	13	484	120	792	97	111	143	23	6	29	154	7
ID18	3	4	27	35	417	55	837	80	82	177	10	1	3	20	4
ID19	4	3	57	30	563	107	80	41	105	191	34	2	16	210	1
ID20	3	4	86	7	395	22	466	17	142	210	6	9	14	61	5
ID21	4	2	41	10	709	46	65	70	73	23	30	4	43	195	10
ID22	4	4	1	16	372	85	510	89	57	83	63	7	51	35	5
ID23	5	3	80	26	698	17	733	13	109	79	40	6	40	132	3
ID24	3	5	83	38	496	65	599	22	167	16	49	5	59	53	9
ID25	4	2	10	60	585	89	941	16	46	38	20	13	11	1	9
ID26	4	4	16	100	552	24	659	36	84	109	5	17	25	135	1
ID27	4	1	75	80	383	109	362	95	136	61	17	12	22	27	5
ID28	5	4	63	83	664	39	169	66	132	87	27	20	7	173	7
ID29	5	2	13	61	462	26	436	8	63	206	60	11	62	76	7
ID30	4	5	35	74	641	118	377	53	42	188	43	14	58	147	3
ID31	4	2	71	57	686	50	777	77	157	233	56	11	52	23	2
ID32	5	4	94	86	518	78	911	67	121	147	57	16	44	128	8
ID33	3	3	51	51	361	61	525	50	101	121	36	11	36	121	6
ID34	2	5	64	68	630	30	243	52	38	68	32	2	56	91	3
ID35	1	2	89	58	473	91	480	25	71	20	18	11	53	158	7
ID36	1	4	6	78	507	19	852	55	113	102	16	3	38	117	8
ID37	2	1	29	55	675	70	748	73	150	5	9	8	63	191	2
ID38	1	3	81	98	653	102	763	39	86	124	64	4	26	98	4
ID39	3	1	77	52	608	43	866	14	49	214	42	5	10	225	8
ID40	2	4	47	97	541	81	154	58	146	135	46	3	6	64	9
ID41	2	2	9	69	451	11	332	98	134	165	67	8	21	233	5
ID42	2	5	98	20	428	48	629	91	61	169	13	13	47	184	5
ID43	1	2	52	24	720	87	124	63	78	240	24	19	41	38	10
ID44	3	5	4	47	574	68	703	31	165	184	21	16	54	229	8
ID45	1	3	32	9	597	113	644	19	125	150	33	15	39	102	2
ID46	3	4	68	37	440	63	822	72	40	12	59	19	4	199	4
ID47	2	3	58	12	529	6	955	100	98	113	52	14	34	79	6
ID48	3	4	23	6	406	94	555	6	148	42	68	12	5	169	5
ID49	2	3	46	29	619	8	50	44	107	46	45	18	23	5	2
ID50	2	3	61	88	238	2	258	3	90	98	48	15	42	87	4
ID51	3	2	74	66	305	67	213	20	119	64	61	20	68	221	7
ID52	2	3	44	71	159	15	970	59	96	50	37	19	55	31	10
ID53	3	2	15	94	327	100	584	83	59	31	65	12	57	180	6
ID54	2	4	60	91	13	76	985	30	128	218	41	17	28	46	1
ID55	2	2	100	85	350	37	540	11	144	158	8	14	20	206	6
ID56	1	3	21	75	24	105	317	88	92	162	31	15	31	109	8
ID57	3	1	18	63	226	57	451	78	34	225	22	16	12	188	2
ID58	3	4	91	41	137	33	109	84	155	203	51	8	60	240	2
ID59	2	3	85	1	170	98	391	64	117	132	66	4	46	106	10
ID60	2	5	26	21	339	13	688	5	65	180	54	9	49	214	6
ID61	1	2	38	18	58	83	881	34	69	154	44	1	64	68	4
ID62	1	4	88	40	260	96	614	92	138	35	11	10	9	165	4
ID63	2	1	66	27	81	4	673	47	159	53	28	7	13	94	8
ID64	2	5	30	44	36	72	273	23	44	8	15	10	19	218	9
ID65	2	2	7	15	204	44	139	33	80	94	14	5	27	113	3

2. EXPLORATORY DESIGN

Here is the debugged factor list:

Factor Number	Decision Factors	Squads	Low Level	High Level	Mana factor	Mana Low	Mana High
1	DO Squad Days of Supply	1,2,3,4,5,10	1	5	Fuel tank	2880	14400
2	Scheduled Resupply Days	6,7,8	1	5	Reach final Waypoint time in state	2880	14400
3	Consumption rate En contact (fuel/step)	1,2,3,4,5	1	50	En Contact state fuel rate	1	50
4	Consumption rate Shot at (fuel / step)	1,2,3,4,5	1	50	Shot At state fuel rate	1	50
5	Rapid Request Setup time (min)	10	1	360	Spare 1 time in state	2	720
6	Time to conduct resupply (min)	1,2,3,4,5	1	60	Spare 1 time in state	2	120
7	Resupply Speed (m/s)	6,7,8	50	1000	Default State movement speed	50	1000
8	Resupply Stealth	6,7,9	0	100	Default State, reach waypoint stealth	0	100
9	Resupply Sensor Range	6,7,8	34	167	Default State, reach waypoint stealth	34	167
10	Inorganic sensor persistance Friendly (min)	1,2,3,4,5, 10	1	120	Inbound Communication inoganic persistance	1	120
	Noise Factors						
11	Enemy Sensor Range (m)	11,…,90	90	2040	All states sensor range	3	68
12	Enemy Squad Size	11,…,90	1	20	num agents	1	14
13	Contact Persistance Enemy (min)	11,…,90	1	120	Squad SA contact persistance	1	120
14	EN Hits to Kill	11,…,90	1	10	default and EN ctc 1 and 2 states	1	5

The final exploratory design is the Cartesian product of the two NOLH's listed below for a total of 561 excursions.

Decsion Factors										
low level	**1**	**1**	**1**	**1**	**2**	**2**	**50**	**0**	**34**	**2**
high level	**5**	**5**	**50**	**50**	**720**	**120**	**1000**	**100**	**167**	**120**
unit	**days**	**days**	**fuel/30sec**	**fuel/30sec**	**30 sec**	**31 sec**	**grid/step**	**hide rate/step**	**30m**	**30 sec**
factor name	DO Squad Days of Supply	Scheduled Resupply Days	Consumption rate En contact (fuel/step)	Consumption rate Shot at (fuel / step)	Rapid Request Setup time (min)	Time to conduct resupply (min)	Resupply Speed (m/s)	Resupply Stealth	Resupply Sensor Range	Inorganic sensor persistance Friendly (min)
1	5	1	22	10	630	76	703	47	167	83
2	5	5	7	19	339	24	763	31	155	54
3	5	3	45	9	24	72	733	3	76	116
4	3	5	50	21	675	20	822	6	92	13
5	5	1	24	12	496	87	436	56	42	17
6	5	5	16	15	316	28	198	88	38	65
7	4	3	48	13	2	79	406	91	150	2
8	3	4	47	18	653	32	258	100	105	113
9	4	2	12	27	518	39	50	19	113	72
10	4	4	15	35	159	65	139	38	146	24
11	4	2	38	48	249	9	169	16	84	76
12	4	4	33	47	541	116	495	41	63	20
13	3	2	10	29	428	17	970	78	80	35
14	4	3	19	44	114	68	941	72	67	94
15	4	2	42	45	271	2	673	75	130	43
16	4	4	30	50	585	109	584	66	142	91
17	3	3	26	26	361	61	525	50	101	61
18	1	5	29	41	92	46	347	53	34	39
19	1	1	44	32	383	98	288	69	46	68
20	2	3	6	42	698	50	317	97	125	6
21	3	2	1	30	47	102	228	94	109	109
22	1	5	27	39	226	35	614	44	159	105
23	1	1	35	36	406	94	852	13	163	57
24	2	3	3	38	720	43	644	9	51	120
25	3	2	4	33	69	91	792	0	96	9
26	2	4	39	24	204	83	1000	81	88	50
27	2	2	36	16	563	57	911	63	55	98
28	2	4	13	3	473	113	881	84	117	46
29	2	2	18	4	182	6	555	59	138	102
30	3	4	41	22	294	105	80	22	121	87
31	2	3	32	7	608	54	109	28	134	28
32	3	4	9	6	451	120	377	25	71	79
33	2	3	21	1	137	13	466	34	59	32

Noise Factors				
low level	**3**	**1**	**2**	**1**
high level	**68**	**14**	**120**	**5**
factor name	Enemy Sensor Range (m)	Enemy Squad Size	Contact Persistance Enemy (min)	EN Hits to Kill
1	23	14	98	3
2	7	4	105	3
3	11	7	9	2
4	15	9	39	5
5	52	13	54	2
6	68	5	46	4
7	44	3	120	2
8	40	12	91	5
9	36	8	61	3
10	48	1	24	4
11	64	11	17	3
12	60	8	113	4
13	56	6	83	1
14	19	2	68	5
15	3	10	76	2
16	27	12	2	4
17	31	3	32	1

3. LARGE SCALE EXPERIMENTAL DESIGN

Three levels of noise:

Enemy Sensor Range (m)	Enemy Squad Size	Contact Persistance Enemy (min)	EN Hits to Kill
68	3	30	2
68	7	30	2
68	13	30	2

Crossed with three levels of Sense and Respond Lead Time (720 = 6 hours):

SR Lead Time
0
720
1440

Crossed with fifteen levels of scheduled resupply policy:

DO Squad Days of Supply	Scheduled Resupply Days
1	1
2	1
2	2
3	1
3	2
3	3
4	1
4	2
4	3
4	4
5	1
5	2
5	3
5	4
5	5

Crossed with seventeen levels of other decision factors:

DO use rate contact	DO use rate shot at	Rapid request setup time	Resupply conduct time	Resupply Speed	Resupply Stealth	Resupply Sensor Range	Friendly IO Contact Persist
1	35	451	24	941	25	167	16
4	13	630	68	50	31	167	75
7	22	47	32	644	81	167	120
10	32	226	120	584	13	167	90
13	4	406	105	703	100	167	23
16	50	585	46	288	94	167	68
19	41	2	83	169	56	167	8
22	7	182	9	228	38	167	38
26	26	361	61	525	50	167	61
29	44	541	113	822	63	167	83
32	10	720	39	881	44	167	113
35	1	137	76	763	6	167	53
38	47	316	17	347	0	167	98
41	19	496	2	466	88	167	31
44	29	675	91	406	19	167	1
47	38	92	54	1000	69	167	46
50	16	271	98	109	75	167	105

Yields 2,295 total excursions. Notice that Resupply Sensor Range is no longer variable.

This is a sample of the processed output data:

Scenario	random_index	Excursion_Number	DOS(days)	CSR (days)	SR Lead Time	SR Lead(hrs)	DO use rate contact	DO use rate shot at	Rapid Request Setup time (hrs)	Resupply conduct time (min)	Resupply Speed (kph)	Resupply Stealth	Resupply Sensor Range (m)	Friendly IO Contact Persist (min)	Enemy Sensor Range (m)	Enemy Squad Size	EN Org Contact Persist (min)	EN Hits to kill	Total Enemy	Total Red Killed	Proportion Killed	Percent Killed	Full Prediction Formula
NoHelo	7	1103	4	4	0	0	19	41	0.0166667	41.5	60.84	56	5010	4	2040	7	15	2	280	227	0.810714286	81.07143	87.4915306
NoRR	6	85	1	1	720	6	16	50	4.875	23	103.68	94	5010	34	2040	13	15	2	520	244	0.469230769	46.92308	33.5507257
NoSR	2	1068	4	3	0	0	1	35	3.7583333	12	338.76	25	5010	8	2040	13	15	2	520	420	0.807692308	80.76923	82.3387375
NoSR	9	1908	5	3	720	6	38	47	2.6333333	8.5	124.92	0	5010	49	2040	7	15	2	280	198	0.707142857	70.71429	65.1432419
SchedOnly	8	2087	5	1	1440	12	13	4	3.3833333	52.5	253.08	100	5010	11.5	2040	13	15	2	520	236	0.453846154	45.38462	74.75654
SchedOnly	2	2273	5	5	1440	12	41	19	4.1333333	1	167.76	88	5010	15.5	2040	7	15	2	280	42	0.15	15	65.1800739
FULL	10	732	3	3	720	6	4	13	5.25	34	18	31	5010	37.5	2040	7	15	2	280	154	0.55	55	70.8910687
FULL	6	883	3	3	1440	12	22	7	1.5166667	4.5	82.08	38	5010	19	2040	3	15	2	120	103	0.858333333	85.83333	87.8655538
FULL	4	1230	4	3	720	6	32	10	6	19.5	317.16	44	5010	56.5	2040	3	15	2	120	108	0.9	90	87.4458941
FULL	11	1443	4	3	1440	12	19	41	0.0166667	41.5	60.84	56	5010	4	2040	3	15	2	120	109	0.908333333	90.83333	95.2180417
FULL	10	1824	5	1	720	6	50	16	2.2583333	49	39.24	75	5010	52.5	2040	13	15	2	520	320	0.615384615	61.53846	61.7105022
FULL	20	1844	5	2	720	6	26	26	3.0083333	30.5	189	50	5010	30.5	2040	3	15	2	120	93	0.775	77.5	80.0539399
FULL	14	2041	5	1	1440	12	4	13	5.25	34	18	31	5010	37.5	2040	3	15	2	120	111	0.925	92.5	86.6844489
FULL	18	2248	5	5	1440	12	38	47	2.6333333	8.5	124.92	0	5010	49	2040	3	15	2	120	80	0.666666667	66.66667	72.5253982
FULL	9	465	2	4	0	0	13	3	3.9416667	56.5	317.16	84	3510	23	1320	3	60	2	120	108	0.9	90	97.5431399
NoRR	19	526	2	3	0	0	32	7	5.0666667	27	39.24	28	4020	14	930	3	16	1	120	60	0.5	50	59.9489978
NoSR	10	546	2	3	0	0	21	1	1.1416667	6.5	167.76	34	1770	16	330	7	4.5	2	280	233	0.832142857	83.21429	84.3651231
SchedOnly	6	203	4	4	0	0	33	47	4.5083333	58	178.2	41	1890	10	930	3	16	1	120	60	0.5	50	77.9103647
SchedOnly	3	388	1	1	0	0	35	36	3.3833333	47	306.72	13	4890	28.5	90	10	38	2	400	127	0.3175	31.75	73.1522291

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APPENDIX D. SIMULATION IN COURSE OF ACTION ANALYSIS

Course of action (COA) development, wargaming, and analysis is one of the most critical portions of the Marine Corps Planning Process. Determining likely enemy tactics and creating friendly plans to exploit them provide the commander with a set of tactical options to accomplish his assigned mission. One could envision a virtually endless landscape of possible COAs from the simple to the ridiculous. History has shown that often it is the audacious or unexpected plan that leads to victory. The problem then becomes, with finite time to plan for seemingly infinite possibilities, how can a commander be sure that his staff has explored a wide range of potential COAs when they typically only have time to develop two or three? I recently participated in an experiment headed by Col Darryl Stanley from I MEF at the Project Albert International Workshop 10 in Stockholm, Sweden in May of 2005, where we explored a potential solution to this problem. The purpose of this paper is to briefly summarize this experience and then compare and contrast it with a more deliberate course of action analysis process that I participated in through the Wargaming Analysis class in the Operations Research Curriculum at the Naval Postgraduate School (NPS).

The experiment we conducted in Stockholm was designed to allow a red staff and a blue staff to quickly develop numerous COAs which were then input into a computer simulation model and explored in order to provide feedback to the staff in their decision making process. The model used was MANA (Map Aware Non-Uniform Automata), developed by the New Zealand Defense Technology Agency. The MANA model is relatively simple compared to some of the more detailed combat models like CASTFOREM or JCATS (Joint Conflict and Tactical Simulation), but it still attempts to capture the key aspects of combat, including terrain, communication, fire support, movement, and unit behaviors. The advantage of the MANA model is that model setup and runtime is relatively short compared to other highly detailed combat models. My role as part of the red cell was to model the various red COAs and use the model to help the red staff analyze the affects of key terrain and mobility issues. Over the course of the one week experiment, we were able to create and analyze seven different red COAs and compare them across seven blue COAs over numerous sets of battlefield conditions. The key insights gained by the staff during this process were an appreciation for key terrain, the time and space issues of battlefield maneuver, the value of armor and artillery support, and the dangers of assuming too much about enemy intentions. The goal of the simulation process was not to tell the staff which plan would work better in real life, but simply to help them through their decision process by challenging their intuition and allowing them to see the consequences of some of their planning assumptions.

In the Wargaming Analysis class (designator OA 4604) at NPS, we split the class into a red and blue staff in order to exercise the COA development and wargaming process, in preparation for a large scale, highly detailed, simulated wargame which we played in JCATS. The staff planning process was conducted in the traditional manner, using maps, intelligence summaries, enemy order of battler, et cetera. I was a member of the blue staff and we developed three courses of action and decided on one based on the results of a wargame that we played verbally on a map. The culmination of the course was for the red and blue staffs to put their forces into JCATS and conduct a live, human in the loop, wargame, red versus blue. In this process, the setup time was very long, and the learning curve on controlling the various entities in the model was slow. In the final execution of the game, individual operator error on the part of the students had as much affect on the outcome as did the number of infantry divisions, or the quality of the plans. Ultimately, the setup time (which was several days including training time) and the playing complexity limited the utility of game as a planning support tool.

I am not trying to downplay the utility of JCATS as a tool for training staff coordination or to advocate the use of MANA in the planning process, but my recent experience in this class and in Stockholm has led me to some conclusions about the utility and employment of simulations in support of COA development, wargaming, and analysis. Here they are in no particular order:

1) No simulation or wargame can tell the staff what will happen if a particular COA is chosen, but it can identify many of the strengths and weaknesses of a particular plan, as well as provide some assessment of the risk against various enemy COAs. It

must be kept in mind that there are limits to every model and combat simulations will not identify every risk, or make up for lazy staff work.

2) If the modelers and/or game controllers become too close to the staff, it is tempting to try to game the system by taking advantage of known model limits. It is, however, useful for model experts to be able to use the model to help the staff position forces and assess terrain and obstacles.

3) Building a robust combat model can be a time consuming and iterative process. The more that is done before the planning process begins, the more useful the simulation support will be to the staff.

4) A wargame is only one realization of the possible outcomes of a particular COA. Repeated simulations, which can be done in Project Albert's data farming environment, can give a better impression of the risks and benefits of a course of action.

5) If simulation is used as part of an iterative COA development process, the red cell order of battle (or set of possible orders of battle) should remain fixed (if possible) throughout the process. For example, it is hard to assess the advantage of changing friendly COAs or friendly order of battle if the enemy is constantly changing. One technique that could be used would be to develop the blue COA against a particular order of battle and then vary the numbers or combat power of the enemy force in order to assess the consequences of imperfect intelligence.

6) Game player skill and modeler ability level can have significant affects on the outcome of simulations and wargames and must be controlled by an umpire cell.

In summary, I would recommend that further research be done in this area. I believe that combat simulations can be an incredibly valuable part of the planning process, as long as it can be done relatively efficiently so as not to interfere with a time constrained process. Complex multiplayer wargames are useful for training the staff in the execution of the selected course of action, but simpler models, explored over many parameters, can be great tools to help the staff develop and analyze COAs. The result is a set of thoroughly explored and analyzed COAs which will help the commander to make better decisions.

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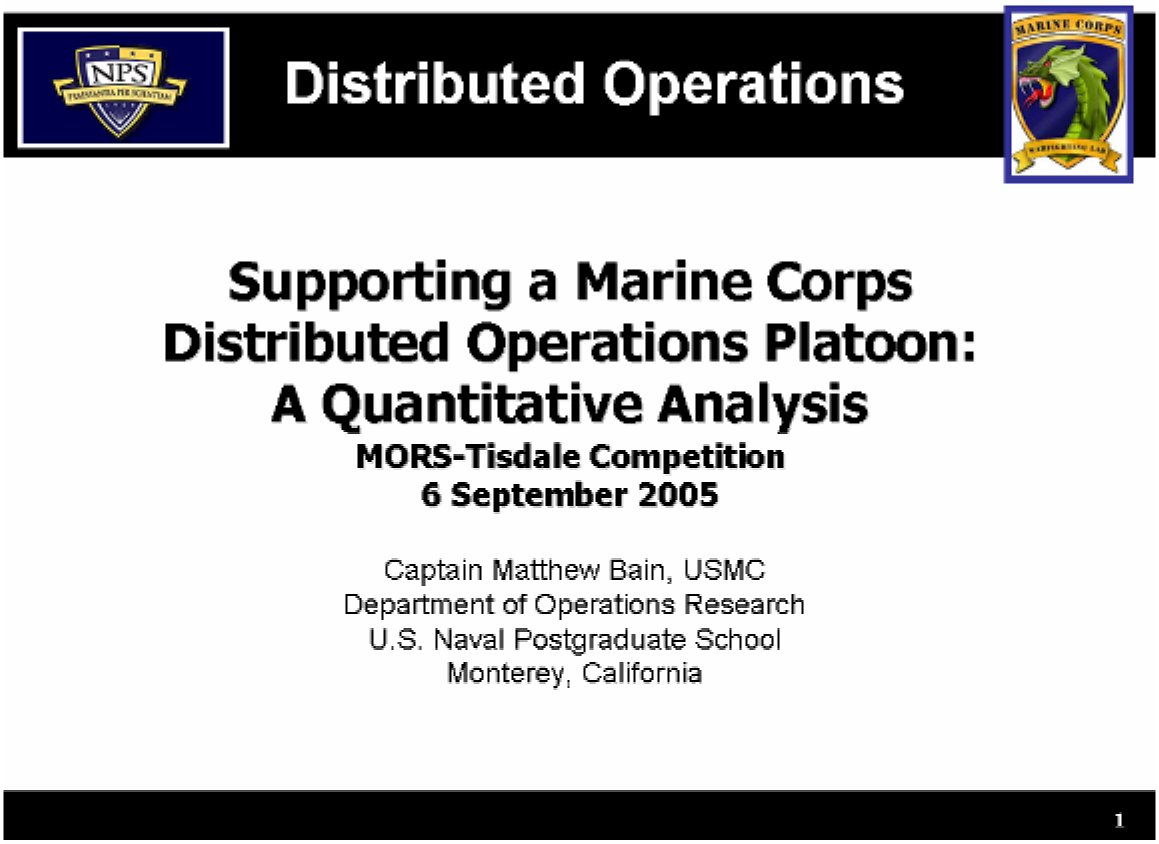
APPENDIX E. MILITARY OPERATIONS RESEARCH SOCIETY TISDALE COMPETITION PRESENTATION

The following are slides from a presentation of this research at the Naval Postgraduate School's Military Operations Research Society Tisdale Award Competition. This thesis was one of four finalists selected for the competition based on the potential for near term impact on the military.



What is DO?

- Transformational USMC initiative:
  - Directed by Gen Hagee, CMC
  - Further forward
  - Widely dispersed
  - Collecting intelligence, controlling fires, and shaping the battlespace
  - No secure ground lines of communication
  - Platoon deployed in 2006 with MEU
- It needs:
  - Capability to operate over extended periods of time
  - A support concept that maintains effectiveness in the face of higher risk
  - Currently no support concept exists

What's the Problem?

How am I solving it?

- Analyze logistical support of DO using:
  - Simulation, statistical analysis, and requirements determination
- In order to:
  - Identify the critical logistical factors, capabilities, and supportability of DO
  - Determine if current MEU can support DO in 2006
- And:
  - Establish a baseline of simulated operational experience

4

Who cares?

- <u>Customers – The people implementing DO</u>
  - Marine Corps Warfighting Lab
  - Mr. Nick Linkowitz, Logistics Vision & Strategy Center, HQMC I&L
  - Dr. Gary Horne, MCCDC (sponsor)
  - The Marine Infantryman
- <u>Briefing Customers this week in D.C.</u>
  - Above listed, plus Dr. George Akst and Col Greg Reuss, USMC at MCCDC

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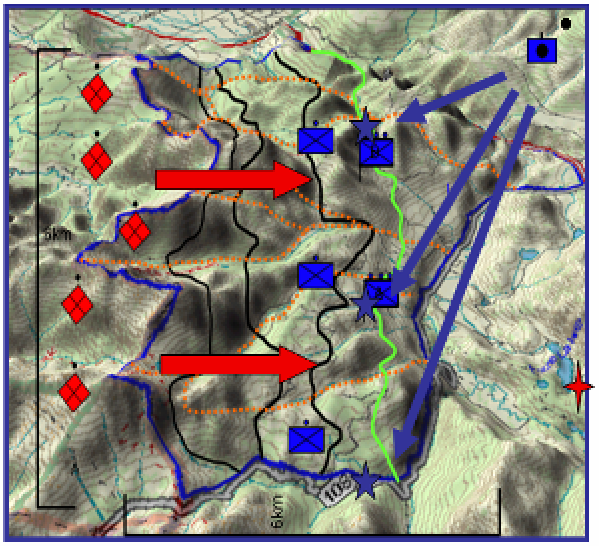
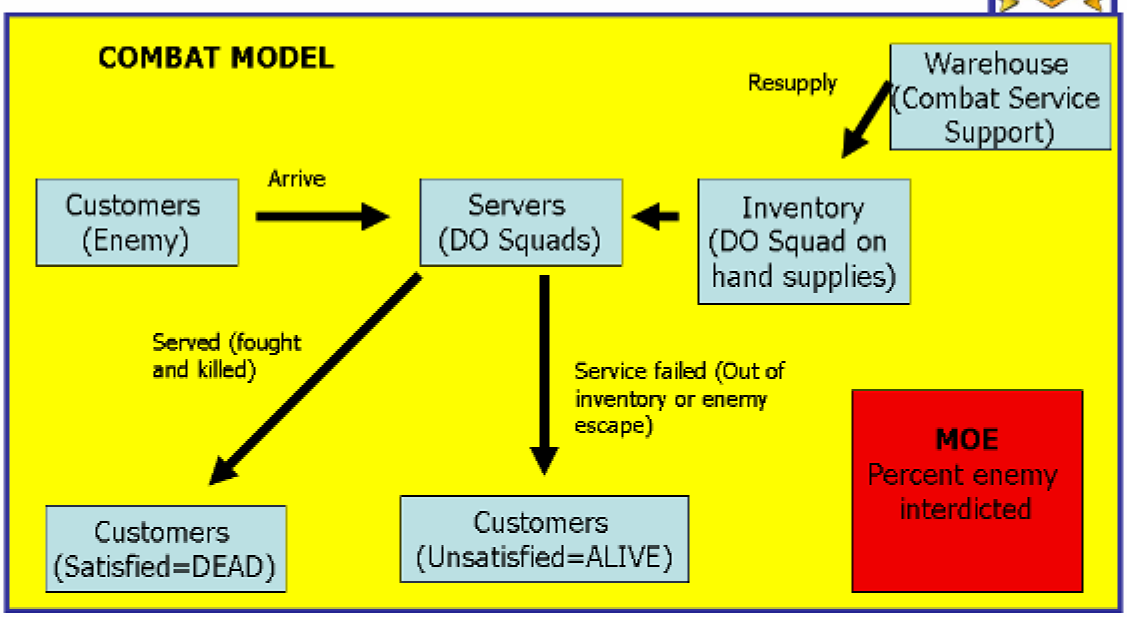
What is my model?



MANA Simulation

– Enemy attempt to reach red star
– Blue interdicts by fire support and close combat
– Resupply by air delivery
– Usage rates generated by combat interactions

What's my MOE?



What did I explore?

Factor	Range	Explanation
DO Platoon Days of Supply	1..5	The amount of supplies, in days, carried into initial deployment
Scheduled Resupply Days	1..5	The number of days between scheduled resupply missions
Consumption rate when in enemy contact (fuel/step)	1..100	Consumption rate of blue squads when in contact with the enemy
Consumption rate when shot at (fuel / step)	1..100	Consumption rate of blue squads when in direct contact (i.e. in a fire fight with the enemy)
Rapid request setup time (min)	1..360	Time, in minutes, from time of request to time of resupply unit departure from combat service support area
Time to conduct resupply (min)	1..60	Time, in minutes, to execute the transfer of supplies and casualties when the resupply unit arrives at DO platoon
Resupply speed (m/s)	5..100	Movement speed, in meters per second, of the Resupply force
Resupply stealth (rate per time step)	0..100	Concealment rate of resupply force per time step
Resupply sensor range	34..167	Sensor detection and classification range, in meters, of resupply force
Inorganic sensor persistence friendly (min)	1..120	Time, in minutes, a blue force sensor will maintain a previously reported track of an enemy agent
Sense and respond lead time (hrs)	0..12	The amount of lead time built into the sense and respond (autonomic logistics) system in hours
Enemy Sensor Range (m)	90..2040	Sensor range, in meters, of the enemy's sensors
Enemy Squad Size	1..20	Number of agents in an enemy squad
Contact Persistence Enemy (min)	1..120	Time, in minutes, enemy forces will continually track a blue agent
Enemy hits to kill	1..10	Number of weapon hits required to kill an enemy agent
Mission Length (days)	7, 14	One or two week mission
Support paradigm	1..5	Five different logistical support policies

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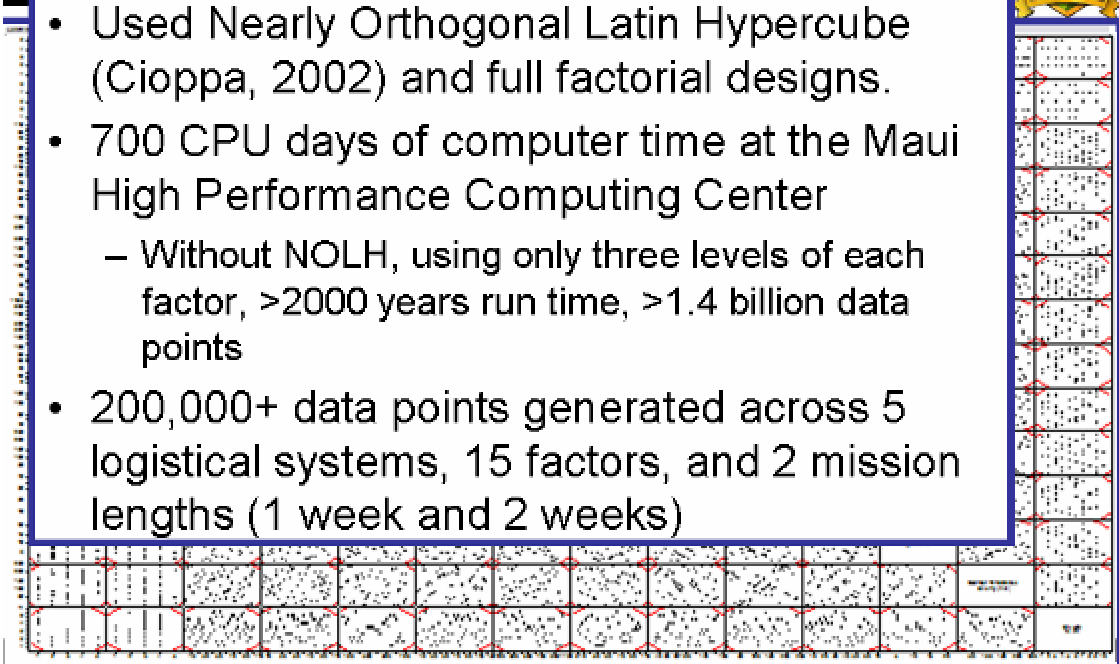
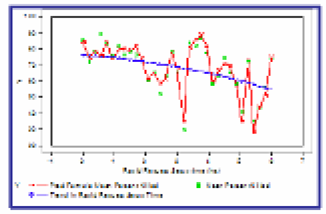
How did I do it?

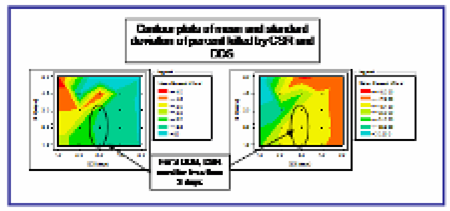
- Used Nearly Orthogonal Latin Hypercube (Cioppa, 2002) and full factorial designs.
- 700 CPU days of computer time at the Maui High Performance Computing Center
  - Without NOLH, using only three levels of each factor, >2000 years run time, >1.4 billion data points
- 200,000+ data points generated across 5 logistical systems, 15 factors, and 2 mission lengths (1 week and 2 weeks)

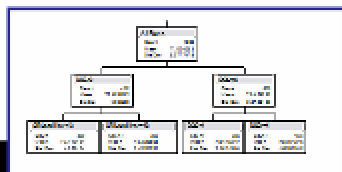


How did I analyze so much data?

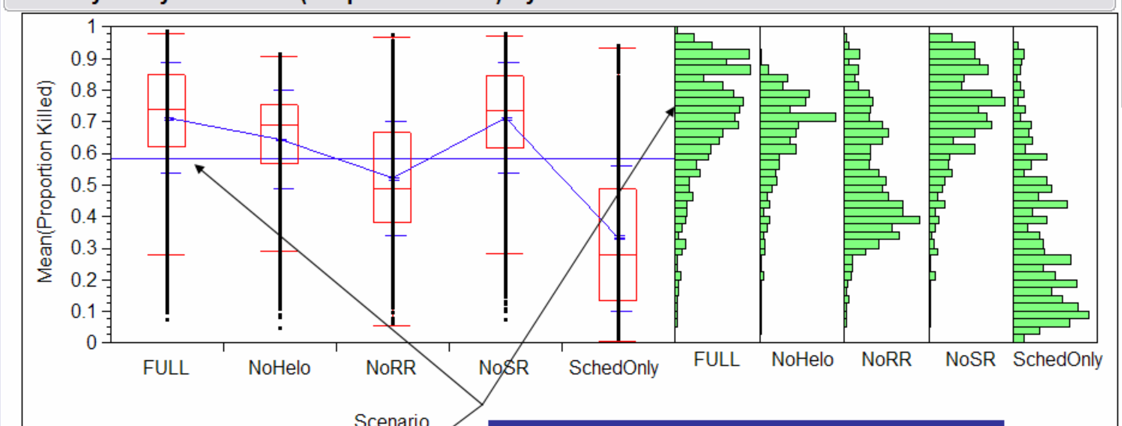
- Used multiple analysis techniques
  - One way analysis
  - Multiple regression
  - Classification trees
  - Data visualization







Oneway Analysis of Mean(Proportion Killed) By Scenario



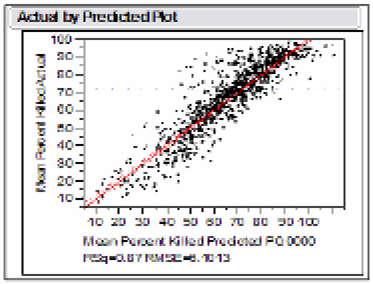
Means and Std Deviations

Level	Number	Mean	Std Dev	Std E
FULL	2856	0.712764	0.171633	0
NoHelo	2856	0.645988	0.154935	0
NoRR	2856	0.523165	0.181794	0
NoSR	2856	0.711885	0.171707	0
SchedOnly	2856	0.335328	0.230500	0

5 scenarios represent 5 support paradigms. The FULL scenario seems to provide the best performance for the DO platoon with surveillance of delivery sites, rapid requests, and scheduled resupply missions. Most general and robust support concept.

Removing Sense and Respond has little effect

Chosen Linear Regression Model



Whole Model

RSquare	0.87
RSquare Adj	0.87
Root Mean Square Error	6.10
Mean of Response	71.24
Observations	2570.00
Mallow's Cp	24.00
F Statistic	786.00
Prob(>F)	0.00
Model Degrees of Freedom	23.00
Error Degrees of Freedom	2546.00

	Term	[illegible]	Std Error	t Ratio	Prob>|t|
1	Intercept	[illegible]	1.2565	88.1337	0.0000
2	SR Lead(hrs)	[illegible]	0.0267	2.1476	0.0318
3	Resupply conduct time (min)	[illegible]	0.0067	2.3668	0.0180
4	Resupply Stealth	[illegible]	0.0040	2.0019	0.0454
5	Resupply Speed (kph)	[illegible]	0.0012	47.6084	0.0000
6	Resupply Sensor Range (m)	[illegible]	0.0002	3.5289	0.0004
7	Rapid Request Setup time (hrs [illegible]	[illegible]	0.0658	-53.9463	0.0000
8	Friendly IO Contact Persist (m [illegible]	[illegible]	0.0067	-4.0484	0.0000
9	Enemy Squad Size	[illegible]	0.0295	-58.6471	0.0000
10	Enemy Sensor Range (m)	[illegible]	0.0004	-13.4704	0.0000
11	EN Hits to kill	[illegible]	0.2012	-38.9161	0.0000
12	DOS(days)	[illegible]	0.1071	23.0077	0.0000
13	DO use rate shot at	-0.1582	0.0080	-19.7582	0.0000
14	DO use rate contact	-0.3653	0.0080	-45.3882	0.0000
15	(Resupply Speed (kph)-187.922)*(Resupply Speed (kph)-187.922)	0.0003	0.0000	18.6513	0.0000
16	(Rapid Request Setup time (hrs)-3.00354)*(Resupply Speed (kph)-187.922)	0.0260	0.0008	30.9584	0.0000
17	(Rapid Request Setup time (hrs)-3.00354)*(Rapid Request Setup time (hrs)-3.00354)	-0.3726	0.0544	-6.8467	0.0000
18	(DOS(days)-3.54669)*(Resupply Speed (kph)-187.922)	-0.0110	0.0009	-11.6990	0.0000
19	(DOS(days)-3.54669)*(Rapid Request Setup time (hrs)-3.00354)	0.0123	0.0529	15.3573	0.0000
20	(DOS(days)-3.54669)*(DOS(days)-3.54669)	-0.7373	0.0797	-9.2481	0.0000
21	(DOS(days)-3.54669)*(DO use rate contact-25.5311)	0.0593	0.0067	8.8382	0.0000
22	(DO use rate contact-25.5311)*(Resupply Speed (kph)-187.922)	0.0016	0.0001	15.2163	0.0000
23	(DO use rate contact-25.5311)*(Rapid Request Setup time (hrs)-3.00354)	-0.0815	0.0062	-14.0540	0.0000
24	(DO use rate contact-25.5311)*(DO use rate contact-25.5311)	0.0047	0.0009	5.1975	0.0000

Regression model explains 87% of the variability in the FULL scenario with less than 25% of the possible terms. It explained 87% of the variability in a test data set.

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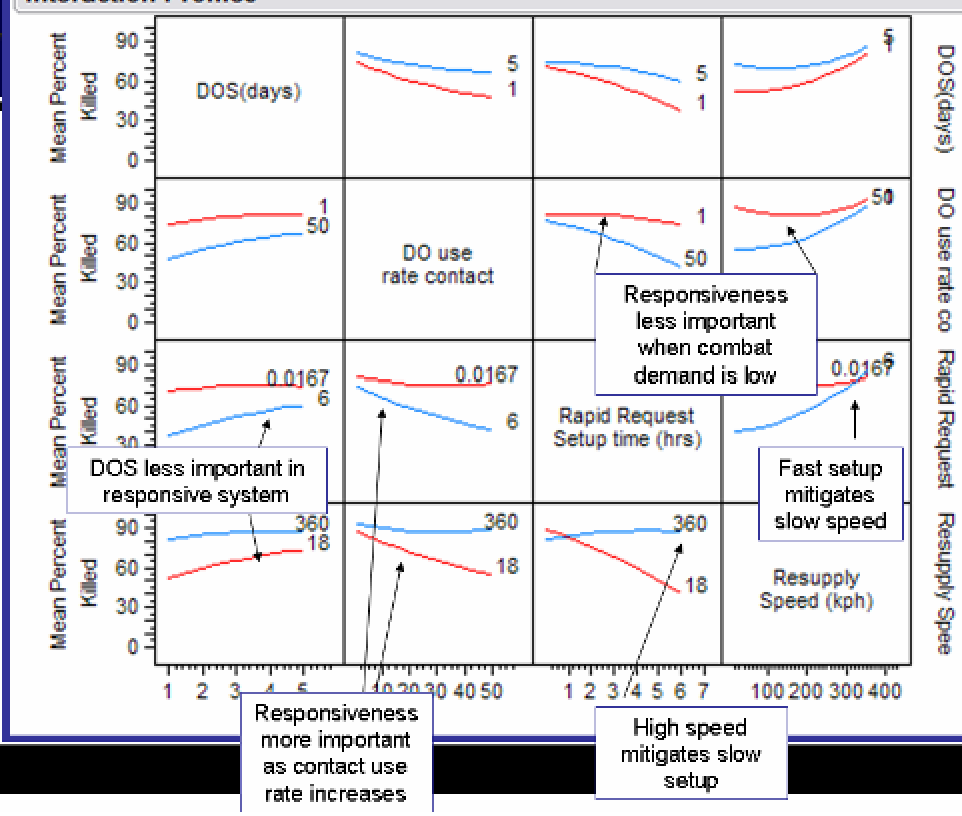
Interaction Profiles



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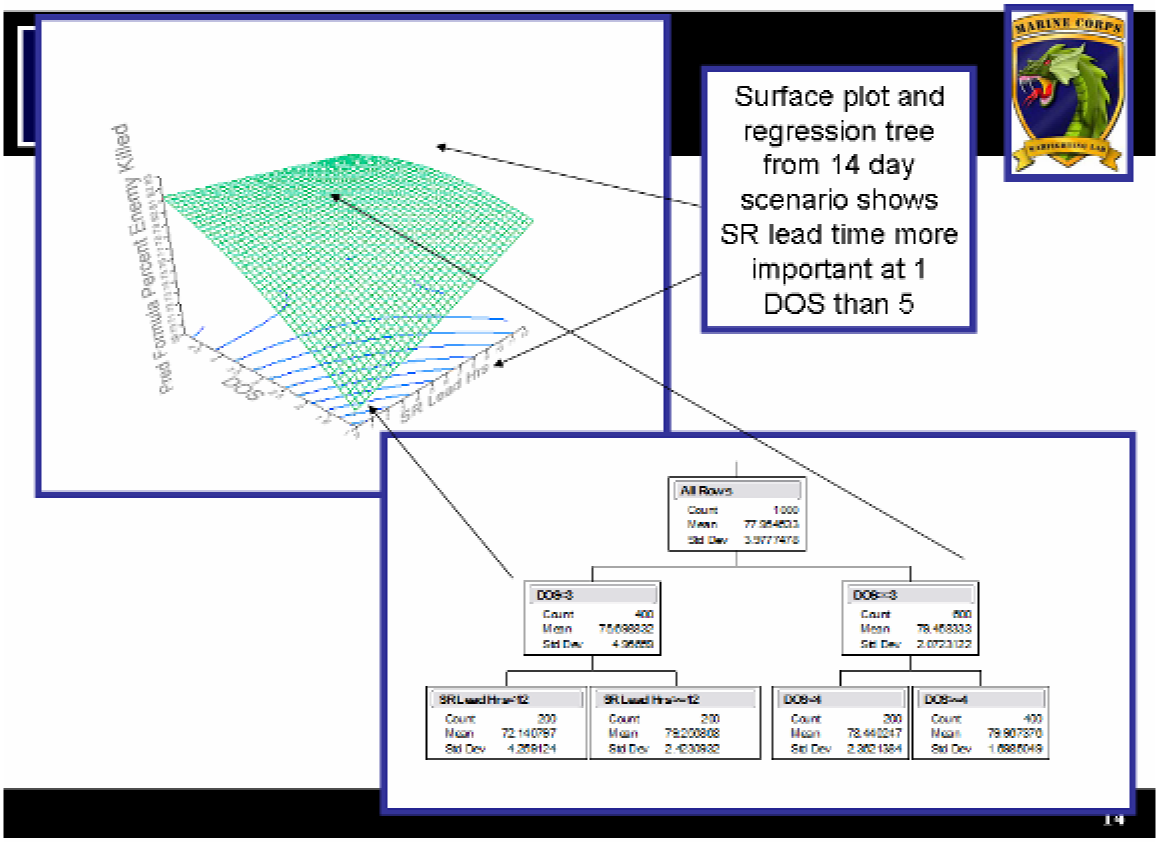

Building a Support Plan

- Requirements determination
  - Planning Factors
  - Ammunition based on infantry threat
  - Operational Experience
- Support Concept
  - Based on lessons from data analysis
  - Physically supportable by MEU
  - Constrained by requirements

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Weight on his back: As a function of DOS

- Three DOS appears to be the maximum volume a Marine can carry based on load carrying equipment
  - Economization is possible but water is a major constraint

DOS	Weight/Marine (lbs)	Cube/Marine (cu ft)	Weight/ITV (lbs)	Cube/ITV (cu ft)	Weight/Platoon (lbs)	Cube/Platoon (cu ft)	Routine Resupply Weight	Routine Resupply Cube
1	66	2	310	7	6,320	151	3,062	74
2	79	3	469	10	8,648	225	5,390	148
3	92	3	628	14	10,977	300	7,719	223
4	106	4	787	17	13,305	374	10,047	297
5	119	5	946	20	15,633	448	12,375	371

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Support Concept Based on Analysis

- The DO platoon carries:
  - Three DOS
  - Combat ammo load
- Two CH-46
  - In direct support, internal transport
- Two AH-1W
  - Escort & enemy suppression
  - Landing zone security
- Two DOS resupply packages
  - Pre-staged
  - Fire team sized packages

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How should we do this?

- Pilots, aircraft, & supply & ammo packages
  - On standby
  - Keep response time less than expected time to next engagement
- CSS agency
  - Within 55 kilometers of the DO platoon

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Conclusions

- Most Critical Logistical Factors
  - Resupply speed, rapid request setup time, days of supply
- Critical Capabilities
  - 3 DOS supply capacity, secure delivery and aerial surveillance of LZs, rapid response and anticipatory logistics, intelligence
    - Quick response dominates anticipatory logistics at platoon level
- Supportability
  - Mission is supportable from current MEU, range and terrain limited by MEU helicopters

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The Last Word

- "Truth is what stands the test of experience."
  – Albert Einstein
- Questions?

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