NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

COMPARISON OF A DISTRIBUTED OPERATIONS FORCE TO A TRADITIONAL FORCE IN URBAN COMBAT

by

Michael Babilot

September 2005

Thesis Advisor:	Thomas Lucas
Second Reader:	Robert Armstrong

Approved for public release; distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** September 2005	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE Comparison of a Distributed Operations Force to a Traditional Force in Urban Combat			**5. FUNDING NUMBERS**
6. AUTHOR(S) Michael Babilot			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the US Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release, distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

Two motivations drove this study of the Distributed Operations Platoon (DO) in urban combat: (1) the Marine Corps Warfighting Lab (MCWL) is developing the concepts to apply to a DO in the Sea Viking 2006 experiment and (2) Marines are engaged daily in urban combat in support of the Iraq reconstruction efforts.

This thesis explores whether a DO is suitable for urban combat operations by analyzing the results of simulations created in Map Aware Non-uniform Automata (MANA). The employment of a DO is compared to employment of a traditional Marine infantry platoon in an urban combat scenario based upon data obtained from Operation al-Fajr, conducted in Fallujah, Iraq, in November 2004. The study also examines the effects caused by varying the terrain to that of Range 200, constructed at the Marine Air Ground Training Command, Twentynine Palms, California. Modeling insights, obtained by surveying Marines with urban combat experience in Iraq, tie into the research effort.

This research indicates that the DO is marginally more effective than a Traditional Platoon in urban combat. DO also shows a greater sensitivity to combat outcomes due to urban density, and produced significantly better results in terrain with a lesser density of urban structures.

14. SUBJECT TERMS agent-based models, MANA, Project Albert, design of experiment, urban combat, Military Operations on Urban Terrain (MOUT)			**15. NUMBER OF PAGES** 188
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited.

COMPARISON OF A DISTRIBUTED OPERATIONS FORCE TO A TRADITIONAL FORCE IN URBAN COMBAT

Michael J. Babilot
Captain, United States Marine Corps
B.S., Clarkson University, 1992

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 2005

Author: Michael J. Babilot

Approved by: Thomas Lucas
Thesis Advisor

Robert Armstrong
Second Reader

James N. Eagle
Chairman, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Two motivations drove this study of the Distributed Operations Platoon (DO) in urban combat: (1) the Marine Corps Warfighting Lab (MCWL) is developing the concepts to apply to a DO in the Sea Viking 2006 experiment and (2) Marines are engaged daily in urban combat in support of the Iraq reconstruction efforts.

This thesis explores whether a DO is suitable for urban combat operations by analyzing the results of simulations created in Map Aware Non-uniform Automata (MANA). The employment of a DO is compared to employment of a traditional Marine infantry platoon in an urban combat scenario based upon data obtained from Operation al-Fajr, conducted in Fallujah, Iraq, in November 2004. The study also examines the effects caused by varying the terrain to that of Range 200, constructed at the Marine Air Ground Training Command, Twentynine Palms, California. Modeling insights, obtained by surveying Marines with urban combat experience in Iraq, tie into the research effort.

This research indicates that the DO is marginally more effective than a Traditional Platoon in urban combat. DO also shows a greater sensitivity to combat outcomes due to urban density, and produced significantly better results in terrain with a lesser density of urban structures.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I would like to start by thanking God for the strength and opportunity to do this work. In addition, I thank my Mom for bringing me up to use my mind as well as my back to get the most out of life, no matter what I choose to do.

Next, I would like to thank my thesis team. Thanks to Professor Lucas for your extensive statistical knowledge, practical insights, repeated cautions and bottomless reservoir of understanding. You were instrumental in taking a general concept, molding it into something meaningful, and the research travels you facilitated made this a better product. Colonel Lesnowicz, I thank you for your efforts and generosity in providing personal experiences and insights to many of the issues faced in the course of this research. Thanks to Ron Russell, your responsiveness, quality suggestions and attention to detail, ensured that the final product was of the caliber it deserves.

I would like to thank my "other" team as well. Thanks to Captain Matt Bain, whenever there was a technical point of confusion on my part, you clarified the situation, showed me the light, and many times gave me the "trick" to getting it to work. Thanks to Captain Todd Sanders, you took the time to bring into my work the "Grunts" perspective and provide a relevancy and reality to my work that would otherwise have been lacking.

I would also like to acknowledge the support received by Project Albert and the folks at MITRE especially Dr. Gary Horne, Matt Koehler, and Steve Upton. Thank you for the support, the opportunities and the surprises you helped create.

Finally, I would like to thank my wife Teri. You were invaluable as my assistant, aide, sounding board and sanity check. Your patience with the many long hours and your willingness to jump in and perform mind-numbing data entry at "crunch-time" are the main reasons this is as good as it is. Without your love and support this product would be only a shadow of what it has turned out to be. The same is true of me. I love you.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Distributed Operations and Urban Combat are two key issues facing the United States Marine Corps of today and the future. Scenarios, based upon data from Operation al-Fajr, conducted in Fallujah, Iraq, in November 2004, explore the applicability of the Distributed Operations Platoon to urban combat operations. The terrain of Range 200, Marine Air Ground Task Force Training Command, Twentynine Palms, California, is used as a comparative terrain to examine the effects of different urban environments on the outcomes of urban combat. The United States Marine Corps Combat Development Command is exploring and developing Distributed Operations doctrine. Distributed Operations and Military Operations on Urban Terrain training facility development are intended to benefit from this research

This thesis entailed the modeling of 12,400 agent-based urban combat experiments to answer the following questions:

(1) Is there a difference in battle outcomes due to the substitution of Distributed Operation forces for Traditional Infantry forces?

(2) Does the nature of the urban terrain affect the outcome?

The United States Marine Corps Distributed Operations infantry platoon, under conceptual and doctrinal development, could be a force suitable for combat in an urban environment. The primary null hypothesis of this research addresses the forces employed in urban combat. This hypothesis states that the Distributed Operations infantry platoon is as capable in urban combat as the traditional infantry platoon.
and terrain modeled.

The following graphic (Figure S1) depicts the principal elements of the combat models; specifically, the forces.

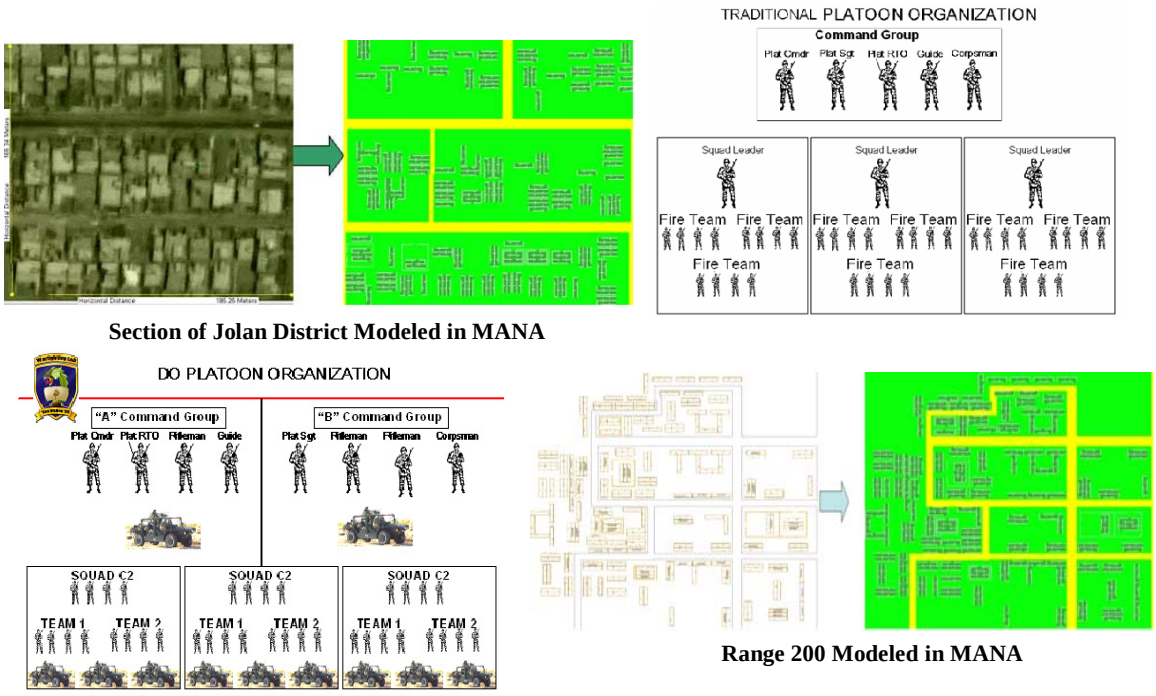


Figure S1 The Terrains and Blue Forces Modeled in the Scenarios

A secondary null hypothesis concerns urban terrain, namely whether Range 200 Military Operations on Urban Terrain Training Facility located at Twentynine Palms, Ca, affects urban combat with the same similitude of a comparably sized section of the Jolan District of Fallujah, Iraq.

Creating agent-based models is an ideal vehicle to explore both null hypotheses. Therefore, this thesis generated a model of Distributed Operations and Traditional Platoons on urban terrains and the opposing insurgent forces. The model is created in the Map Aware Non-Uniform Automata (MANA) modeling environment. The simulation focuses on the actions of the individual agents who comprise the platoon, attachments, insurgents and non-combatants.

An experimental design is incorporated into the research to examine the hypotheses. Parametric testing was examined. Elements of the data are found to violate the assumptions required for a parametric analysis. Consequently, the data are examined with non-parametric methods. The results indicate that there is only a 0.1% chance of seeing similar results (or values that are more discordant) if the data are all from the same

population. The analysis of the different scenarios shows that there is a statistically significant difference between each of the models.

As modeled, the findings are:

- There is a difference in outcomes attributable to the type of forces employed and the nature of the urban battlefield terrain,
- The terrain effect is more pronounced in the Distributed Operations Force,
- The increased density of the Military Operations on Urban Terrain training facility terrain led to lower performance of the Distributed Operations Platoon when compared to the Traditional infantry Platoon,
- The Distributed Operations Platoon attained a higher measure of effectiveness than the Traditional Platoon in the reduced density of the urban terrain of Fallujah,
- For each unit, the performance was notably higher when the attacks occurred on the Fallujah terrain than on the Military Operations on Urban Terrain training facility terrain,
- Above all other factors examined, the ability of the forces to be able to classify their enemy had the greatest influence on the outcome of the battle.

These finding in retrospect are sensible and confirm what is expected from a realistic simulation of these events. Visual assessments of multiple runs of the simulation appear to explain the relationship of terrain to the effectiveness of the Distributed Operations Platoon. In denser terrain, the enhance situational awareness of the Distributed Operations Platoon, appears to draw agents to the known threats on the battlefield. This, in turn, exposes them to fire from threats that exist but are at the time unknown.

Combat Marines from the Marine Air Ground Task Force Training Command at Twentynine Palms, California were surveyed for their opinions and observations from urban combat in Iraq and the Military Operations on Urban Terrain training received as

compared to their combat experiences. The Marines interviewed responded that Military Operations on Urban Terrain training facilities were large enough and sufficient to prepare them for urban combat. However, a preponderance of those surveyed reported that interior and exterior realism was less than satisfactory. The information gained from the survey was applied to enhance the model design and analysis.

The insights and findings of this research have been provided to the following commands: Marine Corps Combat Development Command—Operations Analysis Directorate, Marine Corps Warfighting Laboratory—Project Albert, Marine Corps Training and Education Command, and Marine Air Ground Task Force Training Command to assist in concept and doctrine development.

LIST OF KEYWORDS, ACRONYMS AND ABBREVIATIONS

ABM	Agent-based Models
ANOVA	Analysis of Variance
AoA	Analysis of Alternatives
CA	Combined Arms
CNA	Center for Naval Analysis
CMC	Commandant of the US Marine Corps
CROP	Common Relevant Operational Picture
DoD	Department of Defense
DO	Distributed Operations
EPW	Enemy Prisoner of War
FACD	Final Analysis and Capabilities Document
FMFRP	Fleet Marine Force Reference Publication
FMFM	Fleet Marine Force Manual
GUI	Graphical User Interface
LOS	Line of Sight
MAGTF	US Marine Air-Ground Task Force
MAGTFTC	MAGTF Training Command
MARADMIN	US Marine Corps Administrative Notice
MCCDC	US Marine Corps Combat Development Command
MCDP	US Marine Corps Doctrinal Publication
MCWL	USMC Warfighting Laboratory
MHPCC	Maui High Performance Computing Center
MITRE	MIT Research and Engineering
MOUT	Military Operations in Urbanized Terrain
OPORD	Operations Order
RPG	Rocket Propelled Grenade
SMAW	Shoulder Launched Multipurpose Assault Weapon
SMEAC	Five paragraphs of OPORD (Situation, Mission, Execution, Administration and Logistics, Command and Signal)
SOP	Standard Operating Procedure
TECOM	US Marine Corps Training and Education Command
USMC	United States Marine Corps

THIS PAGE INTENTIONALLY LEFT BLANK

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 logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

> Fallujah is a significant example of what we're going to face in the future. It's about individual Marines with small arms going house to house killing.
>
> We are on a Distributed Ops battlefield right now. That's how the enemy is fighting us.
>
> Distributed Operations builds upon our philosophy and themes introduced by the "three-block war."
>
> While ever ready to respond to major combat operations, the future holds a greater likelihood of irregular wars fought in urban environments, against thinking enemies using asymmetric tactics. Thus, we will adapt our tactics, techniques, and procedures as well as technology to enhance our capabilities to succeed in these environments.
>
> —General Michael Hagee, Commandant, United States Marine Corps

A. PROBLEM STATEMENT

Distributed Operations (DO) and Urban Combat are two key issues facing the United States Marine Corps (USMC) of today and the future. Handling these issues will significantly affect the 21st century Marine Corps. These two elements may determine whether the USMC will "remain the world's foremost expeditionary warfighting organization." The USMC DO infantry platoon, under conceptual and doctrinal development, has the potential to be a force suitable for combat in an urban environment. A DO Platoon may be better suited to the urban task than a traditional USMC infantry Platoon. Yet, to date, the effectiveness of a DO Platoon in an urban environment has yet to be quantitatively examined.

This issue serves as the basis for the principal hypothesis of this research. A hypothesis represents a theory that is a basis for argument. Statistical hypothesis testing deals with an argument that has the potential to be true, called the null hypothesis. It also concerns an argument that is statistically supported if the null hypothesis is rejected. This is called the alternative hypothesis.

For the purpose of this research, the primary null hypothesis addresses the forces employed in urban combat. This hypothesis states that the USMC DO infantry platoon (or "DO Platoon") is as capable in urban combat as the traditional USMC infantry platoon (referred to as the "Traditional Platoon"). The alternative to the null hypothesis is that the DO Platoon is more or less capable than a Traditional Platoon in conventional urban combat.

A secondary null hypothesis concerns urban terrain, namely whether Range 200 Military Operations on Urban Terrain Training Facility ("MOUT terrain") located at Twentynine Palms, Ca, affects urban combat with the similitude of a comparably sized section of the Jolan District of Fallujah, Iraq.

Creating agent-based models (ABM) is an ideal vehicle to explore both null hypotheses. Analyzing the data from the models will determine if sufficient statistical evidence exists to reject the null hypotheses and accept the alternative hypotheses.

B. PURPOSE

> We must build forces that draw upon the revolutionary advances in the technology of war … one that relies more heavily on stealth, precision weaponry, and information technologies.
>
> —President George W. Bush

The purpose of this thesis is to create an agent-based simulation to serve as a foundation for future work in developing the DO concept and for examining urban combat. A model of a DO and Traditional Platoon, urban terrains, and opposing insurgent forces is the focus of this thesis. The model is created in the Map Aware Non-Uniform Automata (MANA) modeling environment. The simulation focuses on the actions of the individual agents who comprise the platoon, attachments, insurgents and non-combatants. Thus, the primary intent is to study the effects of the DO concept and

terrain on a unit's ability to accomplish an assault on a defended urban area. The insights and findings of this research will be provided to the sponsoring commands to assist in concept and doctrine development:

- Marine Corps Warfighting Laboratory (MCWL)—Project Albert
- Marine Corps Concept Development Command (MCCDC)
  - Operations Analysis Directorate (OAD)
  - Marine Corps Training and Education Command (TECOM)
  - Marine Air Ground Task Force Training Command (MAGTFTC)

C. MOTIVATION AND GOALS

> Units trained in distributed operations would be very useful in urban environments or counter insurgency scenarios.
>
> —Brigadier General Schmidle, Director, Expeditionary Force Development Center

MCWL has been tasked by the MCCDC to prepare a DO Platoon to deploy in an experimental capacity with a US Marine Expeditionary Unit (Special Operations Capable) (MEU (SOC)) for use in Marine Air Ground Task Force (MAGTF) operations in the Sea Viking experiment scheduled for 2006. (Distributed Operations 2006 Capabilities and Enhancements Report, Dec 2004) Experiments and studies have begun in order to develop DO doctrine in response to the tasking. Although MCCDC acknowledges that DO may have a place in urban warfare, current plans do not explore the application. The intention is to "examine DO in an urban setting in follow-on experimentation." (Questions and Answers about Distributed Operations, 2005)

MCWL's Project Albert is a research and development effort that uses high performance computing to model, examine, and understand issues and concepts in order to address decision-makers' questions. (Project Albert, 2005) There has been growing interest in the defense community regarding the modeling and simulation of urban

combat, and Project Albert has been involved in numerous vanguard efforts (see Appendix A for a detailed list of agencies involved in modeling and simulation of the urban environment.)

Marine Corps Training Commands are not prone to waiting in the wings for doctrine to be handed to them. The commands strive to develop concepts and doctrine. TECOM's mission is "to develop, coordinate, resource, execute, and evaluate training and education concepts, policies, plans, and programs to ensure Marines are prepared to meet the challenges of present and future operational environments." (http://www.tecom.usmc.mil/)

MAGTFTC's (of Marine Corps Air Ground Combat Center, Twentynine Palms, California) mission is to develop, conduct, and administer the Combined Arms Training Program. (www.29palms.usmc.mil) Emphasis on developing concepts is readily apparent in the joint efforts of MAGTFTC and TECOM in studying the options and requirements for construction of a large-scale Military Operations in Urban Terrain (MOUT) facility. MAGTFTC has begun constructing the USMC Urban Warfare Training Center in order to enhance urban training significantly throughout the Marine Corps. (Statement by Brigadier General Joseph F. Weber to the House Armed Services Committee, 2002) Operations officer for MOUT Training at 29 Palms, Col James Seaton III, says "We're trying to help blend what's worked very well in the past … to make it (MOUT training) more realistic." (Mega MOUT, 2005)

Marines gain experience for urban engagements in pre-deployment MOUT training. Many combat-experienced Marines from Iraq noted the difference between the Marine Corps' relatively simple and limited MOUT training facilities and the actual urban environment encountered in Iraq. This perceived difference has gained the interest of Brigadier General Zlimer, Commanding General, MAGTFTC, and he has requested an exploration of the issue.

The research goals are to evaluate the applicability of the DO Platoon to urban combat; explore the comparable effect of real-world terrain to the USMC Urban Warfare Training Center MOUT facility; and to gain valuable training insights for application to MOUT to support the missions of the above agencies.

D. SCOPE

Battles have and will potentially be fought on a vast number of urban terrains. There are also immense permutations of tactics, assaulting forces, enemy dispositions, and arrangement of non-combatants that could be experienced in an urban environment. This thesis focuses on two different assaulting platoon types, two specific urban terrains, a single tactic for each terrain, an identical attachment of supporting arms, a single enemy disposition for each terrain and a single non-combatant presence. The modeling environment adds a stochastic element to the placement and actions of the agents so no two runs are identical. This creates comparable urban operating environments to generate numerous data points that represent a wide range of possible outcomes of employing the DO or Traditional Platoons. In all, there are four vignettes: DO Platoon on Fallujah Terrain; Traditional Platoon on Fallujah Terrain; DO Platoon in a MOUT facility; Traditional Platoon in a MOUT facility.

This analysis concentrates on an infantry platoon with attachments assaulting an area of urban terrain defended by insurgent forces with a noncombatant presence. Doctrine, unclassified reports, and real-world accounts were used to the maximum extent possible to define the scenarios and behaviors in the models. In the absence of information and data, experts and personal experience were used to create reasonable elements of the model. The desire to have the product remain unclassified resulted in a large amount of the information gathered from newsprint posted online, books, and articles by reputable authors with acknowledged combat experience, and websites of the USMC and GlobalSecurity.org. Works are cited in the text, and a complete reference list is provided at the end of the document. Joint Publications, CompanyCommander.com, Service Publications, Defense Advanced Research Projects Agency (DARPA), Defense Planning Guidance, and concept papers have influenced the development of ideas and even though not directly cited are indirectly responsible for the germination of some ideas contained in this thesis.

Much of the foundation of this research is based upon USMC doctrine and concepts under development. Specifics are provided in Chapters III and IV, but in summary:

- The structure for the Traditional Platoon, attachments, capabilities and basic assault tactics are from USMC doctrine.
- The DO Platoon structure and capabilities are based upon the concepts developed by MCWL in its Distributed Operations 2006 Capabilities and Enhancements Report.
- Terrain for the section of the Jolan District, Fallujah, Iraq is adapted from National Geospatial-Intelligence Agency (NGA) satellite imagery.
- Terrain for the MOUT terrain is adapted from site photography and schematic plans for the MAGTFTC Urban Warfare Training Center, Range 200, MOUT Training Facility, Twentynine Palms, Ca.
- Insurgent structure and behaviors are from news and first-hand reports of the events in Operation al-Fajr, November 2004.
- Non-combatant presence is in line with news and first-hand reports of the events in Operation al-Fajr, November 2004.
- Weapons are modeled after manufacturer specification of capabilities and interpolation of applicable probabilities to hit within the geographic ranges of the modeled terrain.

E. ORGANIZATION

The remaining portion of the thesis is organized into the following chapters:

- Chapter II: Background: This chapter identifies the elements of the problem being addressed and how a simulation model of urban combat at the platoon level can assist in evaluating DO. The section also

includes a brief summary of Operation al-Fajr and its importance to the approach used in developing this research.

- Chapter III: Scenarios: This chapter delves into the details of each of the four scenarios.
- Chapter IV: Model Development: The development of the terrain, agents, and weapons in the model is discussed.
- Chapter V: Analysis Methodology: The Design of Experiment (DOE) is explained along with the reasoning that led to the data generation. This chapter discusses the reasons these methods are appropriate for evaluating the applicability of DO in urban combat and the Measures of Effectiveness (MOEs). The survey of Marines with combat experience is presented.
- Chapter VI: Data and Data Analysis: The data are summarized, the analysis tools are introduced, and an analysis is performed using data plots, analysis of variance (ANOVA), and regression trees.
- Chapter VII: Findings, Insights and Conclusion: Specific findings and insights from the analysis are presented.
- Chapter VIII: Recommendations for Future Studies: This chapter briefly discusses future research opportunities based upon the current work and elements that could be explored due to time constraints.

THIS PAGE INTENTIONALLY LEFT BLANK

II. BACKGROUND

> If there is an enemy out there that wants to make a difference, he can only make a difference by getting us into a complex, chaotic, deadly environment that negates our technology, negates our strength, and capitalizes on their strengths. That place is called the cities.
>
> —General Charles Krulak, 31st Commandant, USMC

A. CITY STREETS: BATTLEFIELD OF THE FUTURE

As the above quote indicates, future battles will likely ensue on the city streets than on the conventional terrains of the past. Mogadishu, Somalia, Grozny, Chechnya, and Fallujah, Iraq were urban battles that might foreshadow future modern warfare. Such battles provided the unstable mix of urbanization, a history of political, social and ethnic unrest, and population growth to set the stage for conflict.

An urban environment represents a problem for America's Armed Forces, who have a long tradition of battling in the jungles, deserts, fields, forests and on beaches. US forces may have some experience in urban combat, but only on a limited basis compared to the overall theater of operations in past wars. Experiences in Seoul, Hue City, Beirut, Panama, Haiti, Somalia, Bosnia, and Iraq have demonstrated a shift in US military operations from the open country to the tangled streets of small villages and large cities.[1] Table 1 summarizes the most significant urban conflicts of the last 100 years.

[1] Those wishing to further examine these and other historic urban conflicts are referred to a well written collection of urban conflict case studies in the book: *Soldiers In Cities: Military Operations On Urban Terrain* by Michael C. Desch (2001) (ISBN 1-58487-062-1).

ONE-HUNDRED YEARS OF CITIES CONTESTED IN CONFLICT								
	RIGA	1917	*	SEOUL	1950		ZAHLE	1981
	MADRID	1936		BUDAPEST	1956		TYRE	1982
	WARSAW	1939	*	BEIRUT	1958	*	BEIRUT	1983
	ROTTERDAM	1940	*	SANTO DOMINGO	1965	*	PANAMA CITY	1989-1990
	MOSCOW	1942		JERUSALEM	1967	*	COLON	1989-1990
	STALINGRAD	1942	*	SAIGON	1968	*	KUWAIT CITY	1991
	LENINGRAD	1942	*	KONTUM	1968		SARAJEVO	1991-1992
	WARSAW	1943	*	HUE	1968	*	MOGADISHU	1993
*	PALERMO	1944		BELFAST	1972	*	BOSNIA	1994
*	BREST	1944		MONTEVIDEO	1972		GROZNY	1994-1995
	WARSAW	1944		QUANGTRI CITY	1972	*	KOSOVO	1999
*	AACHEN	1944		AN LOC	1972		BELGRADE	1999
	ORTONA	1944		SUEZ CITY	1973	*	BAGHDAD	2003
*	CHERBOURG	1944		XUAN LOC	1975	*	MOSUL	2004
	BRESLAU	1945		SAIGON	1975	*	RAMADI	2004
*	WEISSENFELS	1945		TEL ZAATAR	1976	*	FALLUJAH	2004
	BERLIN	1945	*	BEIRUT	1975-1978	'*' indicates direct US troop involvement		
*	MANILA	1945		MANAGUA	1978			
*	SAN MANUEL	1945		KHORRAGHAR	1980			

Table 1. One-hundred Years of Urban Combat

Anthony Tether, Director of the Defense Advanced Research Projects Agency (DARPA), said,

> Urban operations are the most dangerous, costly and chaotic form of combat … America's enemies are moving from the open battlefield to the urban centers. More combat is likely to take place in cities and towns, rather than in open desert, fields, forests or jungles. (French, 2004)

Retired General Norman Schwarzkopf expresses the same message. In his autobiography, *It Doesn't Take a Hero*:

> I am quite confident that in the foreseeable future armed conflict will not take the form of huge land armies facing each other across extended battle lines on the field of battle. Conflict in the future will be similar to that which we have seen in the recent past. Both of the military operations in which we were involved with in the Middle East were the result of regional conflicts that grew to proportions that began to impact the rest of the world. Such dangerous regional conflicts will be with us for years to come. Any one of them could lead us to war. (Schwarzkopf, 1992)

The United Nations (UN) and the World Health Organization (WHO) emphasize the increased potential for the conditions leading to urban conflict. These organizations agree that the world's population is increasing and becoming more urbanized every day. The WHO projects the urban proportion of the world's six billion people will steadily increase (Global Water Supply and Sanitation Assessment, 2002.) The UN predicts the urban ratio to exceed the 50 percent mark by 2007, "thus marking the first time in history that the world will have more urban residents than rural residents." (UN Press Release, 2004) The WHO and UN agree that almost all the growth of the world's total population between 2000 and beyond will likely occur in developing nations in Africa, Asia, Latin America and the Caribbean. This will drive the proportion of the world's population of urban dwellers to 61 percent by 2030. It is no coincidence that countries in these regions top the advisory lists of our State Department and Energy Department. These two departments post the lists on their public service websites in order to provide traveler and business warnings. The link between urban growth and potential for conflict appears plausible.

Why would the enemy choose to skirmish in the streets? Many agencies and elements of the defense community have noted "the most obvious conclusion is that no nation today can directly challenge US conventional military strength, and it would be folly to try—a lesson our potential foes are certain to have learned." (Skelton, 2000) These foes will seek to defeat or repel the US, and to that end will attempt to capitalize on the principles of asymmetric warfare. The enemy will draw the fight into streets and terrain that he intimately knows, will use the US rules of engagement for his gain, and will involve the civilian population as either shields or as an empowering force. (Newton, 2004) In future conflict, the USMC will likely be fighting on enemy territory where the defenders have rehearsed and where a civilian population could hinder or help either side of the conflict.

A war in an urban environment could reduce or eliminate the US technology edge. Experience shows radios do not work well amid the concrete and steel structures of a city. Technology has not yet enabled troops to see inside or around buildings or to peer into a network of sewers and basements. Figure 1 details the complexity inherent in the urban environment.

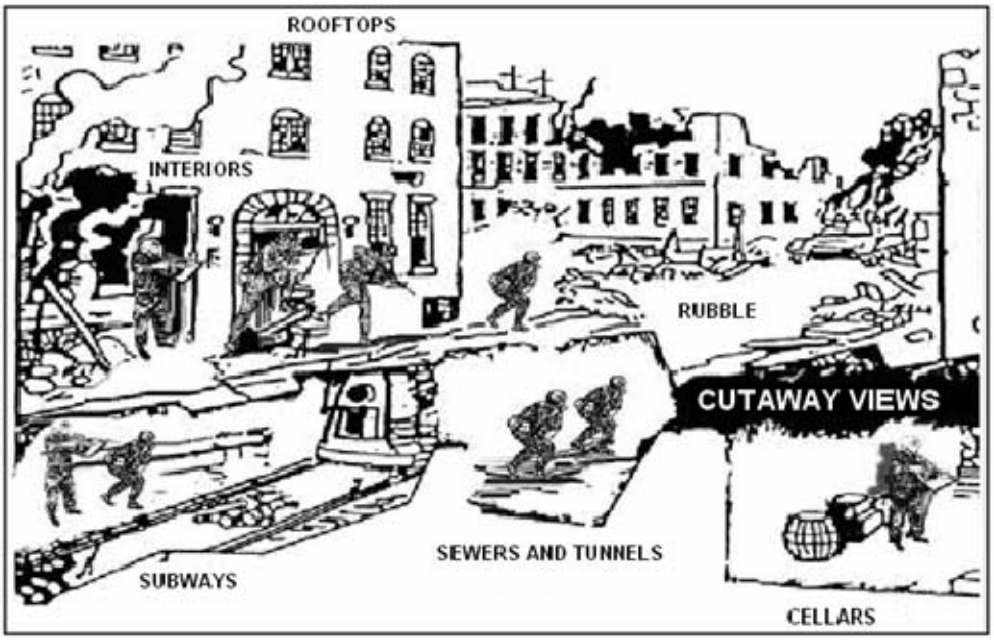


Figure 1. Complexity of Urban Environment
(After MCWP 3-25.3 p 1-4.)

The urban battlefield is a highly complex environment, generating many more concerns beyond just engaging the enemy. General Krulak noted,

> In one moment in time, our service members will be feeding and clothing displaced refugees—providing humanitarian assistance. In the next moment, they will be holding two warring tribes apart—conducting peacekeeping operations. Finally, they will be fighting a highly lethal mid-intensity battle. All in the same day, all within three city blocks. It will be called the three-block war.

Colonel John Toolan, USMC, observed in the Operation al-Fajr, that the three-block war scenario occurred immediately upon entry to the battlefield, and commonly in the span of a single block, not three.

The strategic and tactical motivations for the conduct of urban combat is beyond the scope of this thesis, but the following excerpt from GlobalSecrutriy.org places the subject in the proper context.

> Urban combat operations may be conducted in order to capitalize on the strategic or tactical advantages which possession or control of a particular urban area gives or to deny these advantages to the enemy. Major urban

> areas represent the power and wealth of a particular country in the form of industrial bases, transportation complexes, economic institutions, and political and cultural centers. The denial or capture of these centers may yield decisive psychological advantages that frequently determine the success or failure of the larger conflict.

B. DISTRIBUTED OPERATIONS: FORCE OF THE FUTURE

> I'm committed to building a future force that is defined less by size and more by mobility and swiftness, one that is easier to deploy and sustain, one that relies more heavily on stealth, precision weaponry and information technologies.
>
> —President George W. Bush

Transforming today's military force is a priority for the President, the Secretary of Defense, and the USMC Commandant. The evolution of a future force has been emphasized not only in service-specific vision statements, but also in the Department of Defense's (DoD) Transformation Planning Guidance.

Distributed Operations (DO) is transformational, but not a novel concept. It is a natural evolution of the DoD and USMC concept of warfare. DO seeks to further "develop the capability to deploy tactical units across the depth and breadth of a battle space in order to maximize opportunities to achieve favorable intelligence driven engagements." (Distributed Operations 2006, 2004) Technology has generated new capabilities, new possibilities, and new challenges. DO is the USMC's effort to incorporate the technological edge into its warrior ethos and to transform the concepts to doctrine.

A basic assumption of the continuing Sea Viking 2006 exercise program is that the Marine Corps of the future will continue to fight as a combined-arms, integrated force. DO units will have the ability to operate in a distributed and networked manner against both traditional and future emerging asymmetric threats. (Goulding, 2004) The DO skill set is a capability sorely needed in the USMC combat arsenal.

The 33rd USMC Commandant, General Hagee, has set the course to ensure the USMC remains a key component of the joint forces. The DO element is one part of the USMC's goals to transform the Corps by melding technological enhancements with decades of successful combat experience. General Hagee, who officially approved development of the DO concept in MARADMIN 303/05 July 23, 2005, envisions DO as an operational concept to allow small networked units to perform independently in the battle space of the future. (Navy League Almanac, 2005)

The DO Platoon will be composed of networked units that are dispersed over an extended battle space. The key characteristics entail operating in a decentralized manner, independently addressing multidimensional situations, and maintaining disruptive pressure on an adversary's entire system in a join environment. The DO concept is proposed for squad to battalion-sized MAGTF units for a full range of military operations. The DO units will be valuable because their non-linear, non-sequential manner of operation is much more difficult to predict than traditional forces. Their decentralized means of command and control brings decision-making down to the small unit leader level, the fire team, and squad leader. The decision-making at this level exploits human capital and agility and accelerates the operational speed and tempo of operations. (Shmiddle and Hoffman, 2004) Brigadier General Schmidle asserts that DO

> is an additional capability that will allow the Marine Corps to operate effectively on today's multi-dimensional battlefield. This is not really a change in mission. DO will complement our conventional capabilities and allow us to better accomplish our tasks.

C. THIRD BATTALION, 1ST MARINE DIVISION IN FALLUJAH

The Third Battalion, 1st Marine Division (3/1) was instrumental in the battle of al-Fajr. The efforts of those brave Marines liberated a city held hostage by lawless insurgents. The events of November 2004 and the efforts of the Thundering Third serve as the foundation of the scenarios.

In order to ground the analysis in reality, a portion of the events of Operation al-Fajr serves as the baseline model. The operation to regain control of Fallujah, named

Operation al-Fajr (Arabic for Dawn), began on 08 Nov 2004. From the initiation of the assault until the declared end of major operations six days later, US and Iraqi national forces fought insurgent forces in what is considered the "biggest urban assault by United States' forces since Vietnam." (Battle for Fallujah, 2004) The purpose of the assault was to destroy the insurgent forces occupying the city.

The assault forces were composed of 6,000 US troops in four Marine battalions (3/1, 1/3, 3/5, 1/8) and two US Army mechanized battalions, 2,000 Iraqi troops, as well as attack aircraft and several Marine and Army artillery battalions. (Keiler, 2005) The assault is depicted in Figure 2 and in Appendix D.

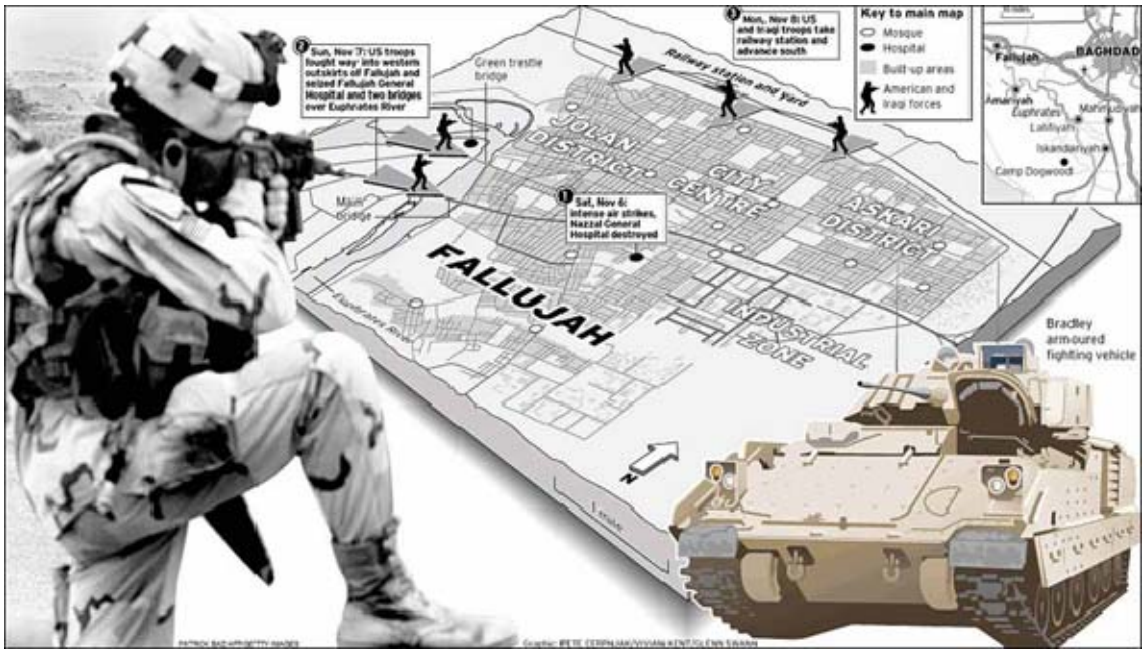


Figure 2. Events of Operation al-Fajr
(From Harnden, Nov 2004)

The 3/1 was the penetration force in the city and attacked the core of the enemy's defense. The Marines conducted house-to-house clearing of the area and the fighting was arduous against rocket-propelled-grenades, AK-47's, grenades, IEDs, and an enemy who had the area targeted with mortars. (Keiler, 2005) A six-hour portion of the battle conducted in the Jolan District, set a few hours after "A-Hour," serves as the baseline of the simulation. "In the northwestern area of the city, US troops advanced slowly after

dusk on the Jolan neighborhood, a warren of alleyways where Sunni militants had dug in." (Krane, 2004)

Although records and statistics for any single platoon in the operation do not exist in an unclassified form, news reports and web postings provide insight and figures by which one can gauge the accuracy of the model. Events occurring in the model are based upon doctrine instead of actual events.

Again, it is important to emphasize that the reported casualty statistics cannot tie directly to any particular platoon or platoons, so the casualty figures for Operation al-Fajr serve only as a benchmark. They allow one to compare the model's casualty numbers to the results of the first three days of fighting when 18 US troops were killed and 69 wounded. Total US casualties in Operation al-Fajr were 51 killed and 425 seriously wounded. As many as 1,200 insurgents were reported killed. (Kelly, 2004) The actual battle is akin to a single trial of an experiment, and as such, no determination as to whether the results are a maximum, minimum, mean, median or extreme outlier is possible. Another complicating factor is casualty reporting in times of war is often intentionally delayed in order to misinform the enemy and to erode the morale of an opposing force.

The baseline model is a hypothetical rendition of the events of six hours in the urban combat across a particular tract of terrain in the Jolan District, Fallujah, Iraq. The timeline has this particular area being assaulted during the night. The model is not intended to portray the exact events of the combat. What is reflected is hypothetical. From the basic model, extrapolations are possible.

D. MAGTFTC MOUT FACILITY

MAGTFTC has been refining the concept of Combined-Arms MOUT in order to provide a realistic environment to ensure Marines can be prepared for deployment and maneuver in an urban environment. MAGTFTC has begun construction of a $304

million training facility that encompasses live fire, joint fire, and large-scale urban evolutions in realistic urban conditions. Figure 3 shows the detailed planning and design of the facility.

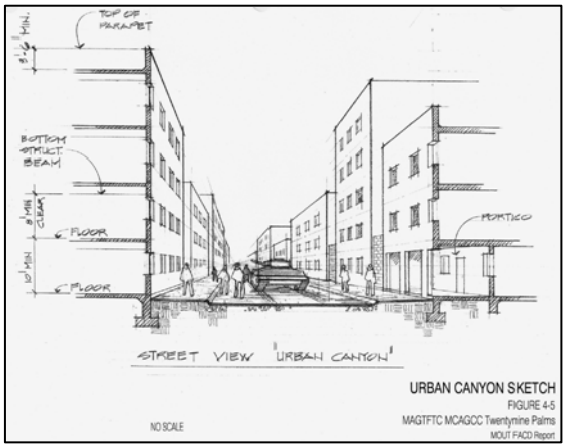


Figure 3. Illustration of Urban Canyon in MAGTFTC MOUT Facility (From FACD Final Report, May2005)

A portion of the facility will serve as a basis for the second terrain modeled. The complete facility will comprise five major functional components: Primary Town, Indirect Live-Fire Facility, Residential Village, Port/Industrial Complex, and Airfield Complex. The areas will have over 1,800 buildings and will be a combination of live-fire and non-live-fire locations. Range 200 is a recently completed portion of the non-live-fire training area and is designed to be representative of an urban desert community consisting of 100 structures, complete with underground tunnels and electrical lighting. Rage 200's layout (185 meters by 165 meters) serves as the MOUT terrain in the simulation. Figure 4 is a current photograph of Range 200 of the MOUT facility.

Figure 4. Range 200 Twentynine Palms, California (Photo Credit: Babilot)

THIS PAGE INTENTIONALLY LEFT BLANK

III. SCENARIOS

> We must take the battle to the enemy, disrupt his plans, and confront the worst threats before they emerge.
>
> —President George W. Bush

A. OVERVIEW

The previous chapters presented the motivation and background for the model development. The following section is a comprehensive overview of the four modeled scenarios. The terrain is the principal aspect of the scenarios, either Fallujah or MOUT, and is detailed in the first section. The scenarios are then subdivided according to the type of assault force, DO Platoon, or Traditional Platoon. Summaries of the force types are also provided. The result is four distinct scenarios, but all are based upon a common theme. The intent is to allow the reader to understand what is simulated. Principal elements shared by each of the scenarios are presented in Operation Order (OPORD) format in order to convey the concepts clearly. Additional guidance on the content of the OPORD can be found in Appendix E, which is based upon *FMFRP 0-6, Marine Troop Leader's Guide* and *Joint Publication 1-03.8*.

The OPORD is a core part of the training every USMC officer receives from The Basic School, Quantico, Virginia, directly after commissioning. The content of the OPORD, also known as "The Five Paragraph Order," is recalled using the acronym SMEAC (Situation, Mission, Execution, Administration and Logistics, Command and Signal). "SMEAC deals with every order that is given. It ensures that the orders that are given are able to be accomplished." (*Joint Publication 1-03.8*) Terrain and the force of the OPORD are provided in the preface to the OPORD. The remainder of the chapter explores the doctrinal convention and advances sequentially from Terrain, to Assault Forces, to the OPORD.

B. TERRAIN

1. Significance of the Terrain

> Terrain impacts our maneuver and influences our tactical dispositions. We must understand terrain and comprehend its effects, as it may limit our movement, reduce our visibility, or restrict our fires.
>
> *—MCDP 1-3: Tactics*

Encyclopedia Britannica notes that tactics are dependent and driven by the terrain on which a battle is fought and states:

> Land warfare … unfolds over concrete terrain, including roads, passages, elevated ground, cover, and obstacles of every kind. Victory goes to him who best understands and utilizes the terrain.

For this reason, the principal characteristics of each scenario are based upon the terrain. *Military Operations on Urbanized Terrain (MOUT)*, 1995, Vol. FM 3-06.11 recommends the assigned frontage for the attacks of an urban area be based upon the size and layout of buildings and the anticipated enemy resistance. This manual also recommends a typical company normally attack on a one-to-two block front. In the doctrinal context, a city block is considered to be approximately 175 meters wide, so a range of 175 to 350 meters is acceptable for a company-sized assault. Anticipating higher enemy resistance indicates that a frontage closer to 175 meters is more appropriate.

2. Jolan District, Fallujah, Iraq Terrain

The Jolan District of Fallujah was chosen as a terrain due to the data available from the 3rd Battalion, 1st Marine Divisions (3/1) assault there in November of 2004. Fallujah is unlike any city in which Marines have ever trained. The city is located forty miles west of Baghdad and measures three kilometers wide along an east-west axis and three and a half kilometers along a north-south axis. The city is home to an estimated 250,000 to 300,000 residents who live and work in an estimated 50,000 buildings. The

layout of the city is random, especially the Jolan district, which is the oldest section of the city and is criss-crossed with twisted, narrow streets and alleys. Zoning that distinguishes between residential, business, and industrial is non-existent. (Catagnus, Edison, Keeling, and Moon, 2005) For this research, the full city is too large to model in its entirety, at the current model resolution and within the available time. Figures 5 and 6 provide a glimpse of the complexity of the urban terrain in Fallujah.

Figure 5. Combat Photo Collage of the Complex Urban Environment of Iraq (Photo Credit: LtCol Norm Root, USMC)

Figure 6. Marines in Positions along a Narrow Street in Fallujah (Photo Credit: Luis Sinco─*Los Angeles Times*)

The Pentagon had a block-by-block schematic of the city prior to the assault. It also had daily intelligence reports of where insurgents were living and where they were building their operational plans. This knowledge and imagery allowed US forces to plan their actions on real-time and real-world information of where they would fight. (Scarborough and Gertz, 2004)

The Jolan District terrain modeled is 185 meters along the east-west axis and 165 meters along the north south axis. The area contains 91 buildings and is an appropriate frontage for the modeled Marine force due to the significant enemy resistance expected and their great resolve. Figure 7 provides a visual of the process employed to locate the modeled area of interest in the Jolan District of Fallujah, Iraq.

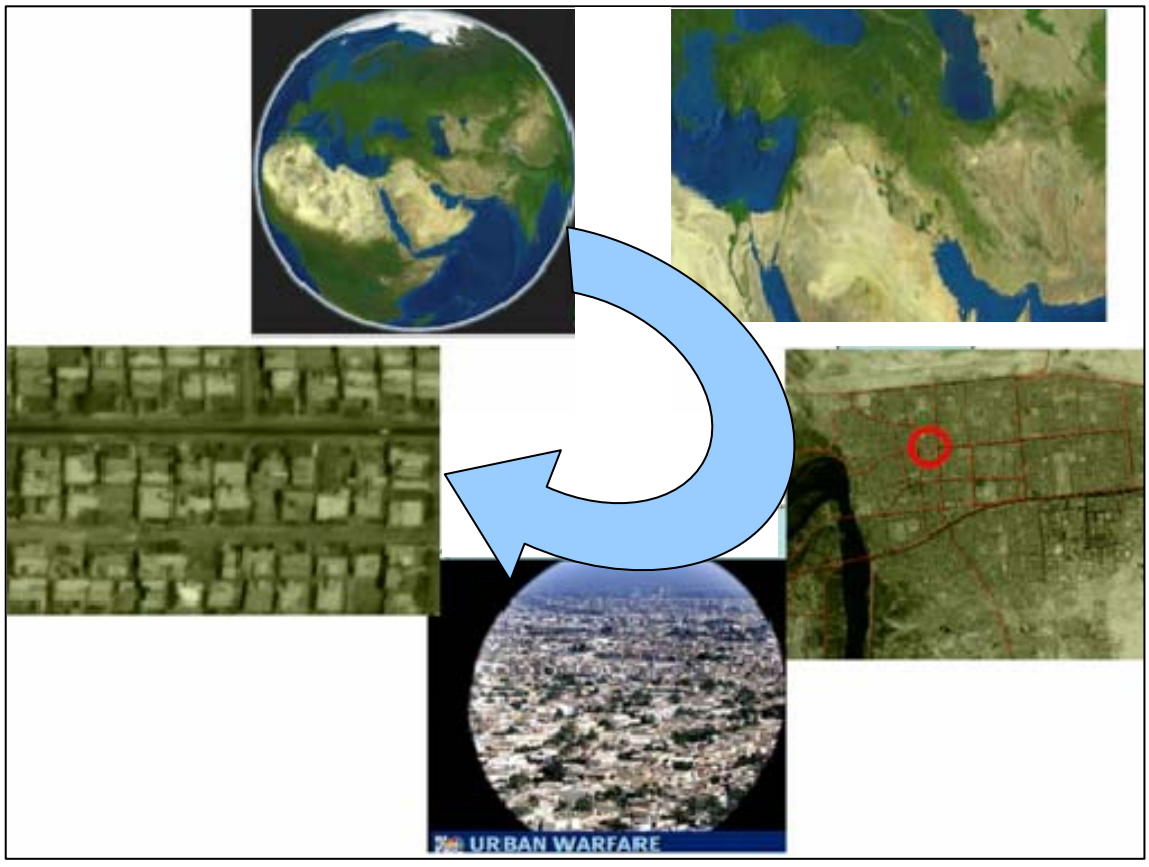


Figure 7. Satellite Imagery Transition to Modeled Section of Jolan District (Photo Credits: MSNBC; NGA)

General characteristics of the Jolan District terrain in the model are

- Observation and fields of fire are extremely limited due to the positioning of urban structures as well as the presence of palm trees, destroyed vehicles, rubble from damaged structures, crumbled outbuildings and fallen courtyard walls. (Krane, 2004) Figure 8 illustrates sight restrictions that exist in the urban Iraqi environment.

Figure 8. 1st Division Marines on the Move in Western Fallujah (Photo Credit: Associated Press)

- Cover protects combatants from weapon fire. Concealment protects combatants from observation. Cover and concealment are minimal or nonexistent in the streets. "The streets are narrow and are generally lined by walls. The walls canalize the squad and do not allow for standard immediate action drills when contact is made." The level of cover and concealment increases in the regions around structures. "Almost all houses have an enclosed courtyard" with many obstacles created by the preparatory bombing of the area. Cover and concealment are at a maximum within buildings where exterior windows are barred and covered with blinds or cardboard and the walls of the houses "are all

made of brick with a thick covering of mortar overtop." (Catagnus, Edison, Keeling, and Moon, 2005)

- There is no dominant key terrain in the zone modeled, but the enemy has built manmade obstacles to reinforce their defenses, to canalize and to impede the assault.
- Avenues of approach are significantly increased in an urban environment and can be considered possible in all directions, even vertically. All walls can be breached, but breaching movement, though often preferred, is considerable slower than using normal entrances. The slower speed of a breach entry yields increased safety for the assaulting Marines. The choice made at every structure is to breach a wall slowly or to attack through a potentially booby-trapped door or window. (Catagnus, Edison, Keeling, and Moon, 2005)
- Movement rates are quickest for dismounted troops in the streets, slower in the areas outside of structures, even slower within structures, and slowest when breaching walls.
- Visibility is reduced due to the events in the scenarios occurring during the night. The urban terrain is 185 meters wide by 165 meters deep and contains 96 buildings.
- Improvised explosive devices (IEDs) will likely be located in the streets, around and in buildings.

3. MOUT Training Facility Terrain

Marines gained experience in urban engagements prior to Fallujah through pre-deployment MOUT training. Many Marines noted the difference between the Marine Corps' relatively simple and limited MOUT training facilities and the actual urban environment encountered in Iraq. Colonel Philip J. Exner, USMC, cited the finding in the Summary Report of USMC Participation in Operation Iraqi Freedom and Operation

Enduring Freedom, Jan 2004. Conclusive evidence was also corroborated by a survey of the perceptions of 251 Marines who had recent urban combat experience in Iraq. As far back as February 25, 2000, the United States General Accounting Office (GAO) National Security and International Affairs Division published the report: "Military Capabilities—Focused Attention Needed to Prepare US Forces for Combat in Urban Areas," noting training MOUT facilities were not adequate to train for the type of urban battle Marines would actually experience. The same issues are restated in the report "GAO-05-534 Military Training," released in June 2005.

General characteristics of the MOUT terrain in the model are similar to the Fallujah terrain. Figures 9 and 10 give different views of the Range 200 facility.

Figure 9. Range 200 Twentynine Palms, Ca (Photo Credit: Babilot)

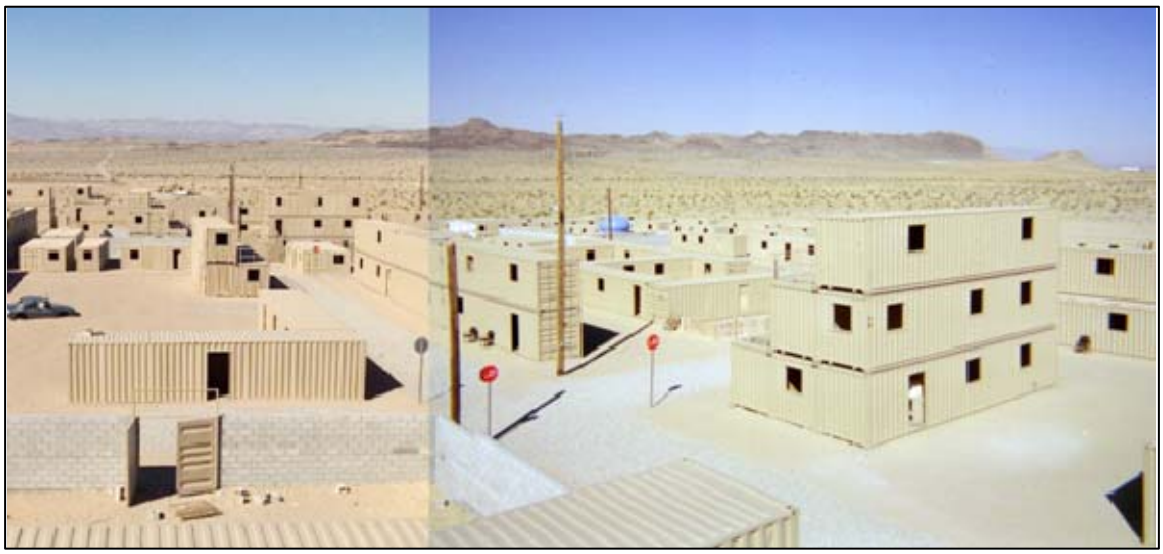


Figure 10. Range 200 Twentynine Palms, Ca (Photo Credit: Babilot)

In dimensions, the MOUT facility terrain is equivalent to the Fallujah Terrain (185 meters wide by 165 meters deep) and has approximately the same number of structures (100 buildings). Figure 11 shows how the MOUT facility was translated into the basis for the MOUT terrain in the model.

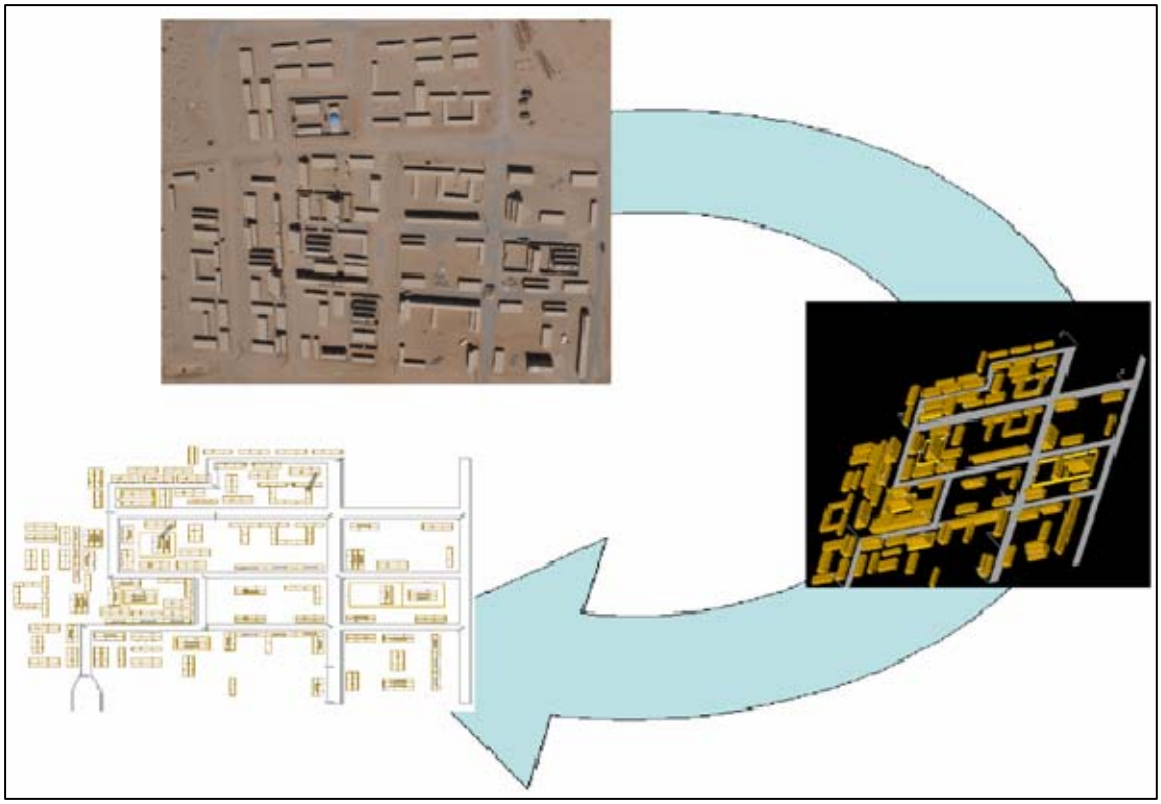


Figure 11. Layout of Range 200 MOUT Facility (MAGTFTC)

C. ASSAULT FORCES

1. Basic Elements of the Assault Force

A Traditional Platoon has the same number of members as a DO Platoon (44 total). The structure and equipment vary, and the DO Platoon has additional training. Tactics are driven by the urban terrain. Therefore, in the model, tactics employed by

each platoon are the same, but modified slightly to accommodate the two different terrains (the Fallujah and the Twentynine Palms MOUT site).

The basis of the tactics is that during house-to-house clearing attacks squads are to minimize their exposure in the streets. In the model, each fire team of a squad is assigned one of three missions: assault; support; or security. (Catagnus, Edison, Keeling, and Moon,2005) Figure 12 illustrates how a squad could be divided to satisfy the three missions.

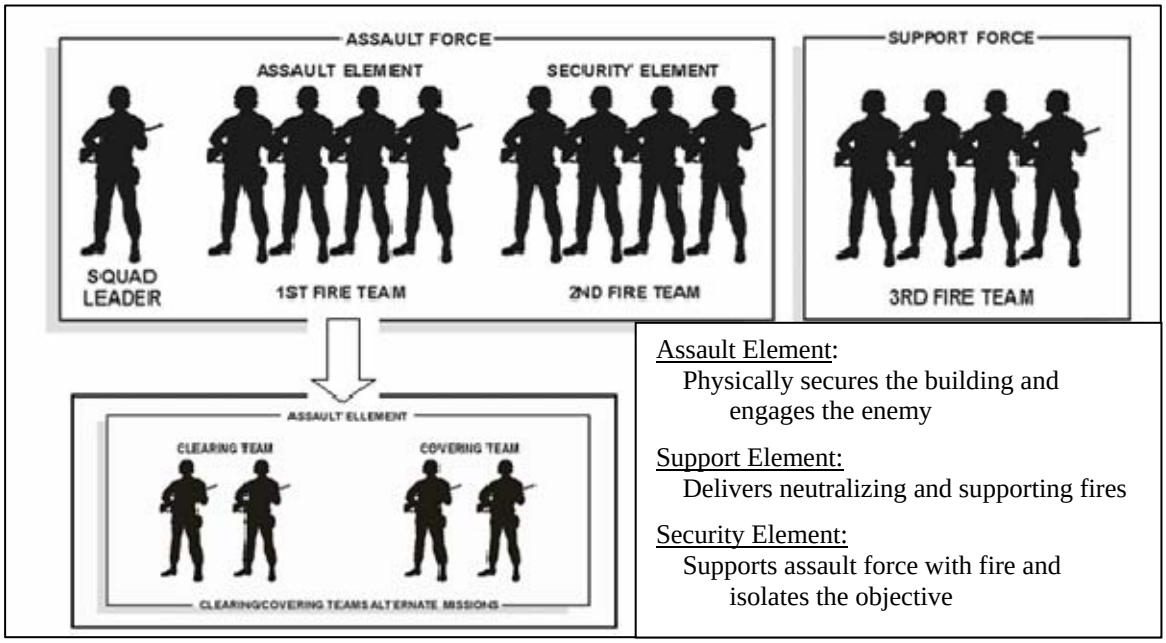


Figure 12. Breakdown of Responsibilities of Squad Teams
(After CALL Newsletter 99-10: Urban Combat Operation)

The amount of terrain for which units are responsible in the scenario is credible in that squads in Fallujah were tasked with clearing a lane that might have contained up to sixty houses. The model has each squad assaulting less than 60 structures.

a. Traditional Platoon

The structure and capabilities of the Traditional Platoon are based upon current Marine Corps doctrine. (FMFM 6-4 Marine Rifle Company/Platoon) Key details

of the modeled characteristics and capabilities are explained in the next chapter: "IV Model Development."

b. DO Platoon

The structure and capabilities of the DO Platoon are based upon the content of the draft report: "Distributed Operations 2006 Capabilities and Enhancements Report," from the Marine Corps Warfighting Laboratory, released 19 Jan 2005. A DO Platoon has a modified structure, an expanded communications package, enhanced optics, and increased training. The details of the modeled characteristics and capabilities are explained in the next chapter: "IV Model Development." The differences in the structure of the two platoons are readily apparent in Figure 13.

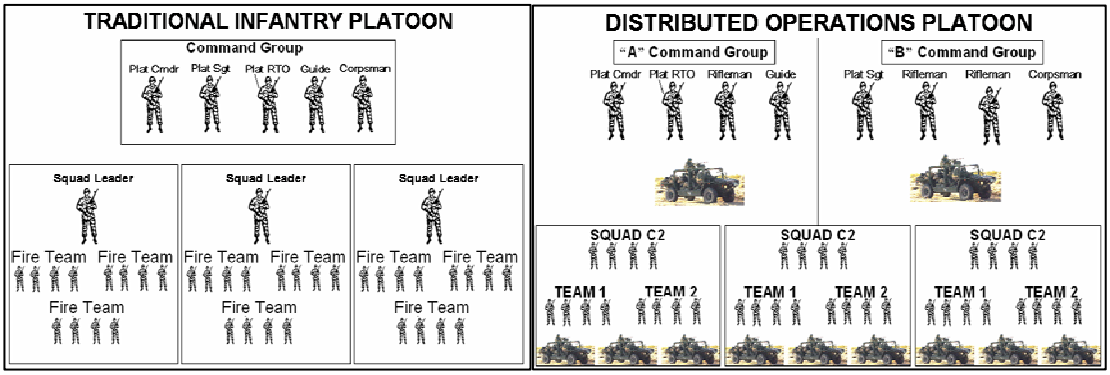


Figure 13. Comparison of Traditional Platoon Organization to a DO Platoon (After DO Capabilities, 2004)

D. OPERATION ORDER

The scenario is based on the actions of a platoon with attachments in urban combat. The OPORD is given from the perspective of 1st Platoon, A Company, 3/1, which acts as A Company's main effort. The remainder of the company plays roles in support of the 1st Platoon. What follows is not the actual OPORD of Operation al-Fajr, but rather a version the author would write if acting as the Commanding Officer.

1. Situation

Insurgent forces, who oppose free elections for the formulation of a legitimate and independent Iraqi government, have control of Fallujah. Their methods are terror and violence. The insurgent forces use Fallujah as a safe haven where the lawless can operate bomb factories, torture and behead hostages, rearm, refresh and regroup between actions, and to plan operations to disrupt activity throughout the whole of Iraq. Four contractors were publicly killed in Fallujah and the forces in control of the city, who consider themselves above the rule of law, support the perpetrators. The insurgents are aware of the pending US assault, but do not know the details of when or how. Ongoing US military operations in the area have served to deceive and confuse the enemy in regards to the true military intentions. The civilian population has heeded notification of the forthcoming attack and has mostly evacuated the city. The assault has the support of the new Iraqi government. Iraqi Prime Minister Ayad Allawi has authorized the assault, declared a round-the-clock curfew in Fallujah, and said, "The people of Fallujah have been taken hostage ... and you need to free them from their grip." (Krane, 2004)

a. Enemy Forces

The insurgents are both brutal and fanatic. Defense Secretary Rumsfeld has said insurgents would likely provide staunch opposition. He is quoted as saying

> Listen, these folks are determined. These are killers. They chop people's heads off. They're getting money from around the world. They're getting recruits. (Krane, 2004)

There is an estimated 2,000 to 3,000 insurgents in the city. (Johnston, 2005) The area of assigned terrain may contain up to a platoon-sized force of insurgents.

The opposing forces are believed to consist of poorly trained Iraqi nationals, foreign fighters, and members of Saddam Hussein's demobilized army. The enemy has shown a propensity to learn and to adapt to tactics. Their adaptability is exemplified in the way the insurgents negated the US's preference to fight in the dark

using night-vision equipment by focusing their attacks in the dim light of dawn and dusk. (Ware, 2004) The opposition can be classified into two types of forces: Guerrillas and the Martyrs. Guerrillas will only engage on terrain of their choosing, in possession of the tactical advantage, will seek to kill many Marines quickly, and will then seek to evade along a preplanned obscured route in order to fight another day. The Martyrs will likely be in fortified fighting positions in houses and will lie in wait and attempt to kill as many Marines as possible in a fight to their deaths. (Catagnus, Edison, Keeling, Moon, 2005)

The insurgents probably have an "outer-crust defense", which consists of a sparsely manned interior zone with the propensity of their forces creating a defense-in-depth from the perimeter to the edge of the interior zone (e.g., all insurgents will be spread in the depth of the battlefield, not lined up on the fringe, as is common with a perimeter defense). The enemy is prepared to defend in any direction and has been observed hardening its defenses. On contact, the enemy will either attrite Marine forces and then withdraw (to regroup for counter attack or to set-up an ambush) or will fight to their death. (Scarborough and Gertz, 2004 and Harnden, 2004) The enemy will operate in three- to six-person teams. (Spinner, Vick and Fekeiki, 2004)

The insurgents' weapons are small arms, like the AK-47, grenades, rocket propelled grenades (RPG's), heavy machine guns, and anti-air machine guns. Over 300 weapons caches are estimated to be in the city, so the enemy is consider well armed. The enemy's obscured evasion routes are suspected to link weapons caches and to be well rehearsed. The enemy has a history of using improvised explosive devices to disrupt assault momentum, to initiate ambushes, and to cover their escape.

b. Friendly Forces

Higher Headquarters: US Forces will penetrate the city from the north and sweep south in order to destroy the insurgent presence to regain control of the city in preparation for national elections scheduled for Jan 2005. The 3rd Battalion, 1st Marine Division (3/1), has been assigned the western sector of Fallujah (specifically the Jolan District), as an avenue of assault in Operation al-Fajr, with the intent of eradicating the

insurgent's presence in the zone. The 2nd Battalion, 7th Cavalry (2/7) will be conducting a parallel north-to-south assault on the eastern flank of 3/1 through the center of the city.

Adjacent commands: B Company, 3/1, will be conducting a parallel north-to-south assault along the territory near the west flank of the grid. C Company (2/7) will be conducting a parallel north-to-south assault along the territory near the east flank of the grid.

Supporting units: The 2nd Platoon, A Company, 3/1, will have the zone condoned off in order to isolate the enemy forces and to destroy retreating forces. Weapons Platoon will provide attachments to support the 1st Platoon, 2nd Platoons and 3rd Platoon's efforts. The 3rd Platoon will remain deployed in the assembly area and serve as the reserve force, enemy prisoner of war (EPW) processor, and recovery force for Marine casualties.

2. Mission

At H-hour, the 1st Platoon will perform a dismounted tactical assault to clear the assigned urban zone of insurgent forces in order to reinstate law and order and to ensure a safe environment for the return of the civilian population.

3. Execution

a. Commander's Intent

The assaulting force will perform a house-to-house clearing of the zone in order to seek out and to destroy enemy bunkers and weapons catches. The assaulting force will fully comply with the Laws of War. The forces are directed to minimize non-combatant casualties to the greatest extent possible without jeopardizing the safety of Marines. The 24-hour curfew and the voluntary evacuation of civilians from the city deem hostile actions of any type as justification for an armed response. Carrying or seeking to retrieve fallen weapons is a hostile action. "Rules of engagement: Real simple

—if someone points a weapon at you —kill 'em, if you see anyone with an RPG …—kill 'em." (Harp, 2004) We intend to destroy the insurgent forces in order to liberate Fallujah while upholding the Law of War. Even in war, the safety of Marines is paramount. Small unit leaders are empowered to decide the proper level of response when under fire from structures within their zone of responsibility, to include mosques used in violation of the rules of armed conflict.

b. Concept of Operations

The 1st Platoon will assault from assigned urban zone from phase line NORTH to phase line SOUTH. Every structure will be cleared of insurgents, weapons, weapons catches, and fortified bunkers. Squads will have assigned lanes. Forces will move at the fastest rate possible to clear the zone with a minimum of US casualties. The assault will occur at H-hour at the crossing of phase line NORTH. The execution will occur during darkness. The assault phase will be complete with consolidation of forces at phase line SOUTH at approximately H+6 hours. Battalion indirect fire missions will be supported according to battalion standard operating procedures (SOP).

c. Tasks

The 1st Squad will be the main effort. Their assigned region is the central north-to-south band of the region. The east and west flank structures are to be coordinated with the 2nd and 3rd Squads.

The 2nd Squad will support the west flank of the 1st Squad. Their assigned region is the western north-to-south band of the region. The east flank structures are to be coordinated with the 1st Squad.

The 3rd Squad will support the east flank of the 1st Squad. Their assigned region is the eastern north-to-south band of the region. The west flank structures are to be coordinated with the 1st Squad.

Weapons Attachment (Machine Gun Team 1 and 2, Shoulder Launched Multipurpose Assault Weapon [SMAW] Team 1 and 2 and Sniper Team 1) will support the forward movement of the 1st, 2nd, and 3rd Squads.

Reconnaissance Team 1 will be inserted into the zone at H-1 hour and provide forward surveillance of enemy forces in the area to the 1st, 2nd, and 3rd Squad.

d. Reserve

The 3rd Platoon, Company A, 3/1, will remain deployed in the assembly area and serve as the reserve force and will evacuate wounded Marines and escort enemy prisoners of war in accordance with battalion SOP.

e. Coordinating Instructions

The scheduled time of execution is H-hour on D-day. This order is effective immediately for planning.

4. Administration and Logistics

Forces will deploy with a full complement of rations and ammunition. Resupply is planned following consolidation at phase line SOUTH. EPW's will be handled according to battalion SOP and transferred to the 3rd Platoon. Casualties are to be reported to the 3rd Platoon for immediate aid and evacuation to Battalion Aid Station 1. Civil population and refugees are to be advised of curfew and to stay indoors and to lie on the floors of their structures.

5. Command and Signal

Platoon Commander will follow behind the 1st Squad.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. MODEL DEVELOPMENT

> Often there is a gap between principles and actual events that cannot always be bridged by a succession of logical deductions.
>
> —Clausewitz

The previous sections have provided a foundation for the development of the models. The reader should have a firm grasp of not only the motivation but also the scope of the scenarios modeled. The following chapter briefly introduces the modeling environment and the approach taken to create the elements of the simulation (i.e., Terrain and Forces). The overview is a broad overview of the model creation. Additional detail along with explicit MANA settings is provided in Appendix H. An in-depth explanation and a hands-on tutorial can be found in the MANA Users Manual (Lauren and Stephen, 2002), which can be requested by email from D.Galligan@dta.mil.nz.

A. DATA SOURCES

A broad literature review has set the stage for the research contain herein. Specifics of force structures and capabilities are derived from USMC doctrine wherever possible. In the absence of doctrine, reliable public sources (e.g., books, websites, newsprint and unclassified reports) are referenced. In the absence of substantive public sources, expert opinions were sought from colleagues. Additionally, the author made decisions and drew conclusions based upon 10 years of USMC experience. Sources of information are cited in the text and a complete reference list is provided at the end of the document.

B. AGENT-BASED MODELING ENVIRONMENT: MAP AWARE NON-UNIFORM AUTOMATA (MANA)

1. Overview

Map-Aware Non-Uniform Automata (MANA) was designed by the Operational Analysis Section of the New Zealand Defence Technology Agency (DTA) and belongs to the ABM class of models. MANA has been created to model human nature and capture interactions among agents and their environment. The environment creates a discrete-step simulation with event-triggered agent states. (Lauren and Stephen, 2002)

MANA is intended as a self-describing name:

- Map Aware: The moving parts in the model (the agents) are aware of their local surroundings, the ground features, and the events that occur around them on the battlefield.
- Non-Uniform: The agents can be a range of different actors on the battle, from people to aircraft, with a different set of characteristics possible for each individual.
- Automata: Each of the agents has its own internal decision-making algorithms, often referred to as individual personalities or rule-sets, which independently guide their actions in response to the environmental stimulus without user influence.

MANA was chosen for construction of the urban combat scenario for a variety of reasons. (1) MANA has an easy to understand graphical user interface (GUI), which minimizes the learning curve and allows rapid model construction, an important consideration in light of the limited research time available. (2) Model runs can be replicated easily and modified quickly. (3) Output consists of data and a visual replay of the scenario that aid in comprehending the events within the run and exploring surprising results. (4) The MANA environment outcomes are driven by the behavior of the agents within the model, instead of a fixed script or interactive user inputs. (5) Chance refers to

an invisible player on the modern battlefield and is present in MANA, which results in a large number of varied outcomes. (Lauren and Stephen, 2000) (6) MANA runs easily on a laptop computer but is resident at super computing centers (specifically, the Maui High Performance Computing Center (MHPCC) and the MITRE Corporation in Woodbridge, Virginia). This significantly increases the ability to generate data for analysis. (7) The final reason is that the US Marine Corps Warfighting Laboratory's Project Albert supports the use of MANA to examine and understand the landscape of potential simulated outcomes, enhance intuition, find surprises and outliers, and identify potential options. (MCWL Website, 2005)

MANA parameters are of four basic types:

- Personality Weightings determine an agent's propensity to move toward, or away from, an influence on the battlefield (friends, enemies, waypoints and/or desirable terrain).
- Movement Constraints modify how an agent moves and are not used in the scenario.
- Capabilities consist of weapons, sensors, movement speed, targeting priorities and communications.
- Algorithm Modifiers include whether terrain affects speed, degree of randomness when moving, whether obstacles should be avoided, and the specific movement algorithm used in the model.

2. Assumptions

Simulating or modeling a scenario has a single intent: abstracting reality into those salient points necessary to promote understanding and insight. Lesser details are omitted to simplify the model and to allow exploration of elements significant to the one who creates the experiment. The model of the scenario contains the following assumptions:

- Terrain modeling to the resolution of one foot is significant.

- Second story (+) effects are not a significant element.
- Structures can be breeched, but cannot be destroyed.
- Modeling of one step-per-second is an appropriate level of resolution for the activities in the model.
- No ground vehicles are involved.
- No air vehicles are directly modeled (indirect fire is characterized as bombs dropped on target).
- Fatigue is not a factor for all simulated forces.
- Resupply is not modeled.
- A Marine Reconnaissance team is forward deployed prior to the start of the scenario.
- The key elements that differentiate DO from a traditional force are organizational structure, communication capabilities, optics, tactics and training. Tactics and training are not addressed in the model.
- The insurgent force does not conduct electronic warfare.
- The insurgent forced does not employ weapons of mass destruction.
- The insurgent force is composed of paramilitary, non-uniformed, non-state actors.

3. Decision Points: Detail, Time and Behaviors

Modeling of the scenario creates certain obstacles inherent to most modeling endeavors. Foremost is the decision regarding the level of detail required in the model. A balance somewhere between modeling too much detail and not enough must be achieved. The constraints help to shape the modeling efforts to fit the modeling environment and assist significantly in achieving the balance.

The first modeling decision point was the terrain. The entire city of Fallujah was initially considered to serve as the terrain in the model scenario. This was determined to be an unreasonable course of action when each individual structure is to be modeled as well as the inhabitants and combatants. The full city and the incorporated agents could not be modeled in a reasonable amount of time, in the detail desired, and create a model in keeping with the original intent. The intent of the model is to portray urban combat at the individual Marine level and explore the effect of the DO force. The MOUT facility terrain is used to establish a reasonable and meaningful size for the terrain. The dimensions of the MOUT facility determined the size of the Fallujah terrain (185 meters by 165 meters) used in the model. The terrain size, in turn, determines that the assault force would be platoon sized. The terrain, historical facts, and published intelligence determined the composition of the defending insurgent forces.

Time is another modeling decision point. Data for analysis results from each model run. Early editions took six hours to simulate the six hours of battle. Multiple runs are required to obtain sufficient data to allow meaningful analysis, but the initial long run times were undesirable because they translated into less data for analysis. An adjustment was made to the model to reduce the time required to simulate the six hours of combat. The adjustment was a reduction of the time spent by units inside a structure from 40 minutes to two and a half minutes. The justification is that the time spent in structures is highly variable. A realistic timeline for the attack of each structure was not possible due to the high variability and complexity of eliminating insurgents and thoroughly searching for weapons. Two and a half minutes is sufficient for an agent to "forget" enemy locations as modeled in MANA. This is similar to the real world where once a unit moves into a structure to clear it and emerges 40 or more minutes later, the array of enemy forces could have changed completely. The model currently takes twenty minutes to simulate a six-hour battle.

A third decision point is the desire to achieve a balance of realistic military tactics and free acting agents. The decision was made that the agents within the model are allowed to behave in a manner according to their perception and personalities. The agents loosely follow a script that is created by a predefined set of waypoints to which they must travel in a set sequence. The individual agent actions are not scripted, so

agents might be observed behaving in ways interpreted as an error or mistake, but the manner nonetheless conforms with their rule-set. Every effort was made to capture the important relationships, interactions and dependencies of all the scenario elements.

A note regarding some of characteristics inherent to MANA is appropriate since they impacted the decisions made in the creation of the model. The modeling environment assessed battle damage perfectly, could not vary time of day or weather effects, and shared only position reports between agents. These eroded the confusion and uncertainty elements, called the "fog of war" (Clausewitz, 1827) that are present in real combat.

The driving intent of the model was to gain insight and to explore the concepts. The battle of al-Fajr occurred only once and can be considered a single replication of an experiment. Only the most general comparison can be conducted between hundreds of simulation runs and a single event. Therefore, emphasis is placed on the insights gained from an exploration of the relationships of model output values compared to the information gained for Operation al-Fajr.

C. TERRAIN

1. General Characteristics

Table 2 summarizes the elements of the model terrain that existed in the model and their modeled characteristics. The information shows how the type of terrain affected the speed of and agent and the cover (protection from small arms fire) each provides. In the model environment, the default setting was that weapons could not fire through walls. Relative levels of concealment (protection from observation) were provided for each terrain type. The final column of "MANA Color" aided in recognition of terrain elements when viewing the graphics of Figure 14 and 15.

MANA Terrain Translation				
Type	**Speed**	**Cover**	**Concealment**	**MANA Color**
Roads	Fast	None	None	Yellow
Rubble	Fast(-)	Some	Some	Light Green
Interior	Slow(+)	More	More	Dark Green
Walls	Slow	None	Near Complete	Grey

Table 2. Terrain Effects on Agents in MANA Model

Doctrine does not provide specifics regarding the movement rates of dismounted infantry in an opposed environment across urban terrain. For the purpose of the model, dismounted infantry movement on opposed terrain at night is considered equivalent to dismounted infantry movement upon restricted terrain at night. The rate is shown in Table 3.

Unopposed Movement Rates	
Terrain Type	**Dismounted Infantry**
Unrestricted	4.0 kmph (day) 2.2 kmph (night)
Restricted	2.4 kmph (day) 1.6 kmph (night)
Severely Restricted	1.0 kmph (day) 0.1 to 0.5 kmph (night)

Table 3. Foundation for Dismounted Infantry in MANA Model (After FM90-31 - Ch4)

In the model, each grid is one foot by one foot. The base movement rate for a dismounted infantry agent in the model is two feet-per-second. The base rate of speed can be reduced by limiting effects of the battlefield terrain.

Clutter on the urban battlefield restricts the ability to detect and classify friend or foe. Uniformly distributed small, static visual obstacles (such as a telephone pole or a small tree) represent clutter on the battlefield. Clutter exists in structures and in the regions around structures, but not in roads. The difficulty lies in determining the proper level of clutter to affect how far agents can see in the model.

> Studies and historical analyses have shown that only 5 percent of all [engaged] targets are more than 100 meters away. About 90 percent of all targets are located 50 meters or less from the identifying soldier. Few personnel targets will be visible beyond 50 meters and usually occur at 35 meters or less.
>
> —FM 90-10-1

For the scenarios, a moderate level of clutter in tandem with the limiting visual restrictions of the terrain (buildings and concealment inherent in areas of the terrain) is modeled. The engagement range is then visually confirmed in model runs to be within the desired range and reflecting the desired behavior.

2. Jolan District, Fallujah, Iraq

Creating the terrain involved taking satellite imagery of a section of the Jolan District, Fallujah, Iraq, and colorizing it with Microsoft Paint to create a simulated urban environment. Figure 14 illustrates the process. The region contained roads, 91 structures, interior and exterior components of the terrain. Additional limitations to the line of sight (LOS) were added to closer replicate the effect of rubble and clutter.

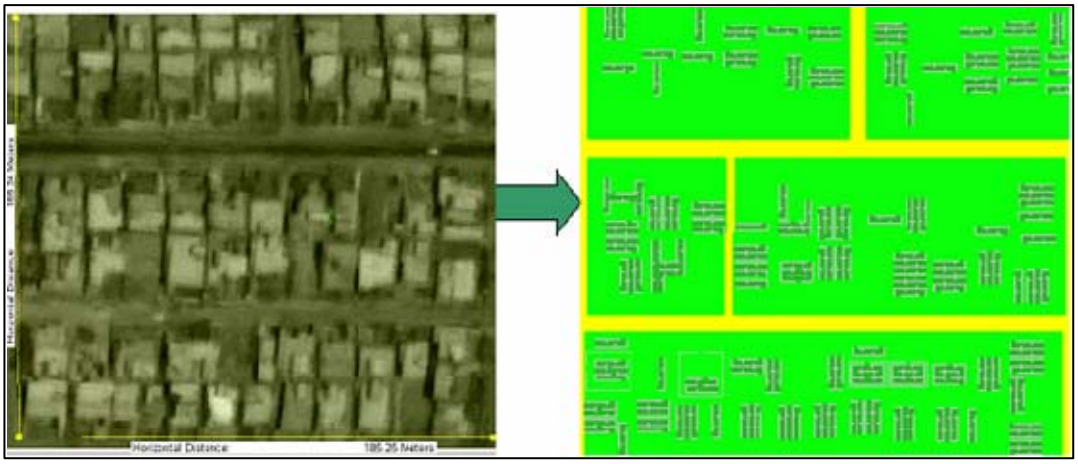


Figure 14. Satellite Imagery of Jolan District Converted to Model Terrain (Photo Credit: NGA)

3. MOUT Facility

Creating the MOUT facility terrain was similar to creating the Fallujah terrain. Engineering plans were colorized using Microsoft Paint to create a simulated urban environment. The region contains roads, 100 structures, interior and exterior components of the terrain. Additional clutter limitations to LOS were also added in the same density as the Fallujah terrain in order to compare similar terrains. Figure 15 illustrates the process.

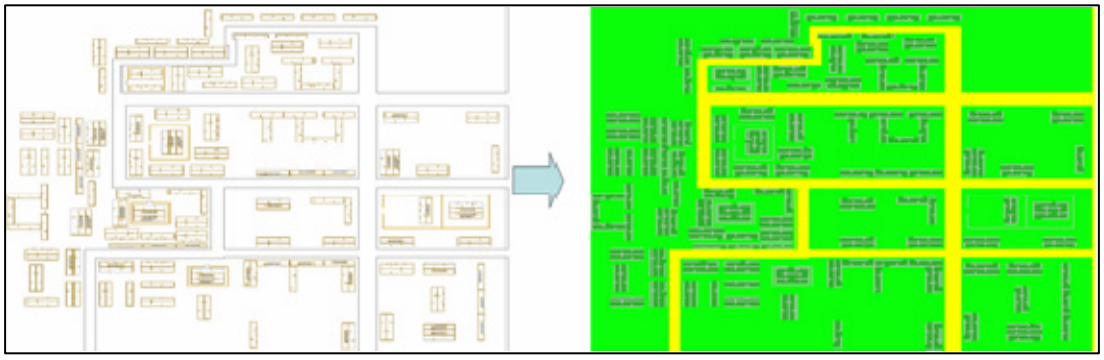


Figure 15. Range 200 Twentynine Palms, Ca, Converted to Model Terrain

D. FORCE CHARACTERISTICS AND BEHAVIORS

Agents in MANA have multiple states containing influencers, which a model builder can set to specific values to design agent personalities. Also many characteristics are essential in constructing an agent: unit composition and structure; agent states (e.g., in contact with enemy, not in contact with the enemy); movement rates; sensor capabilities; communication structure; lethality; survivability; situational awareness and tactics. The remainder of this chapter summarizes how these elements of the scenario were modeled.

The approach of modeling the agents was not to create each agent as an individual from the ground up. Instead, a logical approach was taken. Each agent of Blue or Red or Green (Media) or Yellow (Civilian) allegiance had the same general inherent personality characteristics of the color group. Depending on the form and function of an individual agent, the characteristics (e.g., weapon type, communication links, and sensor capability) were adjusted to capture elements that differentiate one agent from another.

1. Force Composition and Structure

a. Traditional Platoon

The traditional rifle platoon is manned with 44 members, organized in "a triangular structure composed of three rifle squads. Each squad is a balanced group of three fire teams; one rifleman, within each fire team will be assigned to carry the M16/M203 grenade launcher system." (FMFM 6-4 Marine Rifle Company/Platoon) Figure 16 illustrates the structure of the USMC Infantry Rifle platoon.

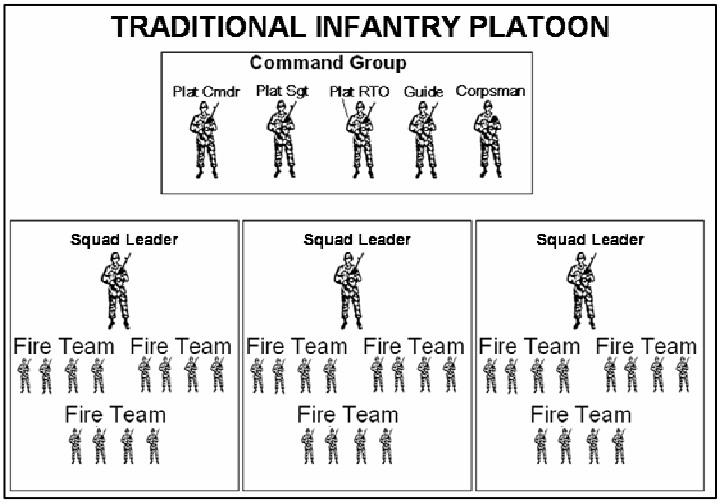


Figure 16. Doctrinal Organization of a USMC Infantry Platoon (After FMFM 6-4 Marine Rifle Company/Platoon)

In the model, agents are armed with only their primary weapon. Table 4 shows the ID numbers assigned to each agent in the model and their primary weapon.

ID RANGE	BLUE UNIT	COUNT	SIZE	WEAPON
28 — 36	Infantry Rifleman	9	2	M16A2
37 — 45	Infantry SAW	9	1	SAW
46 — 54	Infantry M203	9	1	M203
55 — 57	Infantry Squad Leader	3	1	M16A2
58	Infantry Platoon Command	1	5	M16A2

Table 4. Traditional Platoon Table of Agents, with ID Numbers, and Modeled Weapon

b. DO Platoon

> (A) revolution in military affairs is about more than building new high tech weapons … It's also about new ways of thinking, and new ways of fighting.
>
> —Donald H. Rumsfeld, Secretary of Defense

Whereas the structure and capabilities of the Traditional force are based upon current Marine Corps doctrine, the structure and capabilities of the DO force are based upon the content of the draft report *Distributed Operations 2006 Capabilities and Enhancements Report* from the Marine Corps Warfighting Laboratory, released in March 2005.

The manning (ranks, weapons, composition) of the DO Platoon will be the same as the Traditional Platoon. What will be considerably different is the structure. Figure 17 shows the new structure.

> The standard DO task organization changes the number of personnel in the rifle squad from 13 members to 12. One rifleman from each squad is put into either the Alpha or Bravo Command Group. This is done to provide the command groups with needed drivers, radio operators, and security; thus allowing the group to operate independently for short periods of time.
>
> —DO Capabilities, 2004

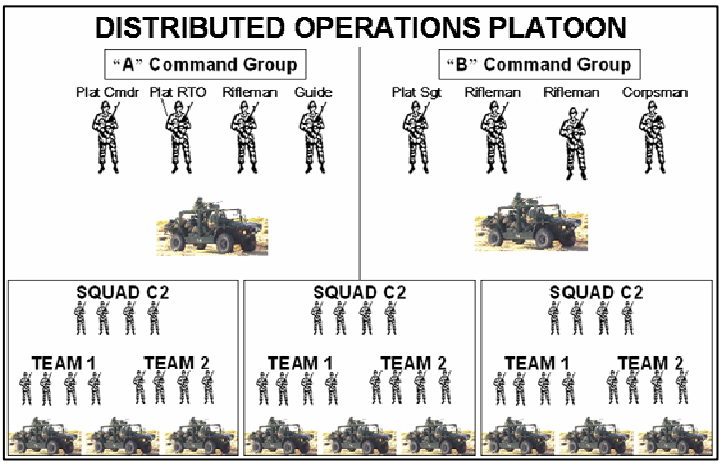


Figure 17. Task Organization of DO Platoon (From DO Capabilities, 2004)

Vehicles and the emulation of additional training for DO units are absent from the model. Vehicles serve as a transportation asset instead of as a combat vehicle and are therefore absent from the model. The additional training a DO Platoon receives

is unquantifiable at the current level of concept development. These are good areas to explore in future models and follow-on research.

Table 5 shows the ID numbers assigned to each Blue DO agent in the model and its primary weapon. The column called “moving parts” identifies that actual number of agents of that type that were present on the battlefield in the simulation.

ID RANGE	BLUE UNIT	COUNT	SIZE	WEAPON
59 — 64	DO Rifleman	6	2	M16A2
65 — 70	DO SAW	6	1	SAW
71 — 76	DO M203	6	1	M203
77 — 79	DO Team C2	3	4	M16A2
80 — 81	DO Command Group	2	4	M16A2

Table 5. DO Platoon Table of Agents, with ID Numbers, and Modeled Weapon

c. Attachments

The attachments in the model were drawn from the Weapons Platoon that directly supports the entire company and portions of the battalion mission. The agents shown in Table 6 were attached to the platoon to execute the assault. The indirect fire assets are representative of artillery and bombs from outside of the scenario and therefore cannot be engaged by the insurgent forces. Although tanks were involved in Operation al-Fajr, not every unit had them. Tanks are not a core component of DO and the decision was made to model the scenario without them.

ID RANGE	BLUE UNIT	COUNT	SIZE	WEAPON
21	Reconnaissance Team	1	6	M16A2
22	Sniper Team	1	1	M82A1A
23	Howitzer/Mortar Team	1	4	Indirect Fire
24 — 25	Machine Gun Team	2	1	Machine Gun
26 — 27	SMAW Team	2	1	MK153

Table 6. Attachments Table of Agents, with ID Numbers, and Modeled Weapon

d. Insurgent Forces

The red agents were modeled to fight to the death. Reports from Fallujah noted, when called upon to surrender, the enemy would yell back "It is better to die and go to heaven than to surrender to infidels." (Bellon, 2005) The actual size and composition of insurgent forces operating in the region of the scenario was impossible to determine exactly. "US officials estimated that 2,000 to 3,000 hardcore insurgents were entrenched in the city at the time the assault began." The value of 2,700 was chosen as the possible number of insurgents in the city. Next, the area of the model was divided by the area of the city to obtain a percentage of the city represented in the model: 0.003 or 0.3 percent. A uniformly distributed insurgent force would have eight insurgents in the area. The insurgent forces were not uniformly distributed. In expectation of the pending assault, the insurgents set up a 360-degree outer crust defense. Higher densities of forces in the outlying areas of a city than in the center of the city characterize an outer crust defense. The increased density was chosen to be a factor of four, which means there were 32 Red agents in the scenario region. The majority of the force was insurgents with AK-47's and insurgents with RPG's. There were a small number of riflemen from Saddam's disbanded military and a machine gun, a single mortar team, two scouts and an IED. The Red forces are summarized in Table 7.

ID RANGE	RED UNIT	COUNT	SIZE	WEAPON
1 — 3	Insurgent	3	5	AK47
4	Rifleman	1	4	AK47
5	Mortar	1	1	82mm
6	Machine Gun Team	1	1	.50 Cal
7 — 15	Rocketeer	9	1	RPG
16	Scout	1	1	AK47
17	IED Scout	1	1	Trigger
18	IED	1	1	IED

Table 7. Insurgent Table of Agents, with ID Numbers, and Modeled Weapon

e. Non-Combatants

The non-combatants modeled in the scenario were civilians and media agents. The population of Fallujah was estimated to be approximately 250,000 with 90% of them evacuated. A uniformly distributed population of civilians resulted in there being approximately 75 civilians in the model. The two media agents followed the Blue Forces. The non-combatant forces are summarized in Table 8.

ID RANGE	UNIT	COUNT	SIZE	WEAPON
19	Civilian (YELLOW)	1	75	None
20	Media (GREEN)	1	2	None

Table 8. Non-combatant Table of Agents, with ID Numbers

2. Agents States

Agents have different personalities depending on their personality or state. Events in the model triggered the transition from one state to another. The personality traits were weights that determined the level of attraction an agent had to other agents and terrain features. Table 9 shows the weightings that each agent had to nine elements of the environment and the model settings in the different model states. For a deeper explanation of the weightings and MANA states refer to the MANA Users Manual.

COMPARISON OF AGENT CHARACTERISTICS AS MODELED IN MANA						
Color	**Red**	**Red**	**Blue**	**Green**	**Yellow**	Key **State Names**
Type	Rifleman	Insurgent	Marine	Media	Civilian	
Enemy	EC/T/S 90/50/-75	EC/T/S 80/60/-45	SC/T/F 90/50/20	D -50	D -50	D - Default T- Taken Shot W- Reached Waypoint S – Shot Taken E – Enemy Contact C – Squad Enemy Contact F- Reached Final Waypoint N/A – Not Applicable
Friendly	S/EC/TD 80/60/50	C/SED/T 60/50/40	RF/all others 80/50	D 70	D 20	
Waypoint	N/A	N/A	ED/S/C/T 85/75/30/20	D 20	N/A	
Easy Going	30	20	D/all others 10/-20	N/A	N/A	
Cover	60	70	45	50	50	
Concealment	30	30	FD/all others 30/40	85	D 70	
Line Center	N/A	N/A	-10	N/A	N/A	
Squad Enemy	90	80	85	N/A	N/A	
Squad Friend	N/A	N/A	C 50/10	N/A	N/A	

Table 9. Comparison of Personality Characteristics of Agents in Model

Refer to the MANA Manual for details regarding the effects of the weights. The model used a small fraction of the states available in the MANA environment. Every attempt was made to keep the model as simple as possible while adequately exploring the concepts.

The trigger and the priority of the "to" state determined the state to which an agent transitions.

The "Default" state is anytime that the agent or his unit is not engaged with the enemy. The "Shot At" state shifts the agents' priorities to seeking cover and engaging the enemy. The "Reach Waypoint" and "Reach Final Waypoint" states serve to consolidate the assaulting force on the intermediate or final objective before continuing the assaults. "Enemy Contact" and "Squad Enemy Contact" are entered into when the agent is directly in contact with the enemy (the former) or a member of his fire team (the latter) is in contact with the enemy.

The "TYPE" column of Table 9 includes the influences upon an agent making a decision in the model. The closer a number (weight) is to 100, the greater an agent's desire to move toward a particular feature is. The closer a weight is to -100, the greater the desire of an agent to move away from a feature. A setting of zero indicates no influence on an agent's decision making.

a. Blue Forces

Blue Forces had the same set of states. The diagram in Figure 18 shows the possible transitions to and from any state. The "Shot Taken" state is the highest priority state and represents the time required by an agent to seek cover, rearm the weapon system, acquire a target and fire the weapon. For emphasis, the "Shot Taken" state is colored red in Figure 18. The time in state is determined by the sustained rate of fire for a weapon. For example, an agent armed with the M16A2, which can fire 12 well-aimed shots per minute (GlobalSecurity.org), would go into the "Shot Taken" state for five steps (five seconds) after every shot. See Appendix G for weapon specific information.

The "Enemy Contact" state is colored yellow because it was the state to which agents revert after any involvement with the enemy.

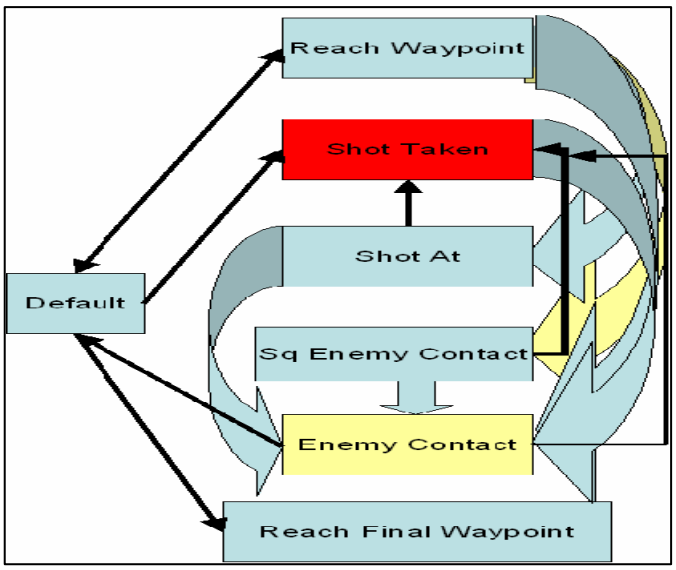


Figure 18. State Changes of All Blue Forces Modeled in MANA

b. Red Forces

Red agents had fewer states than Blue agents due to their relatively static defense, and they had no waypoints. The states are summarized in Figure 19. Colors red and yellow have the same meaning as in the previous explanation for the Blue forces.

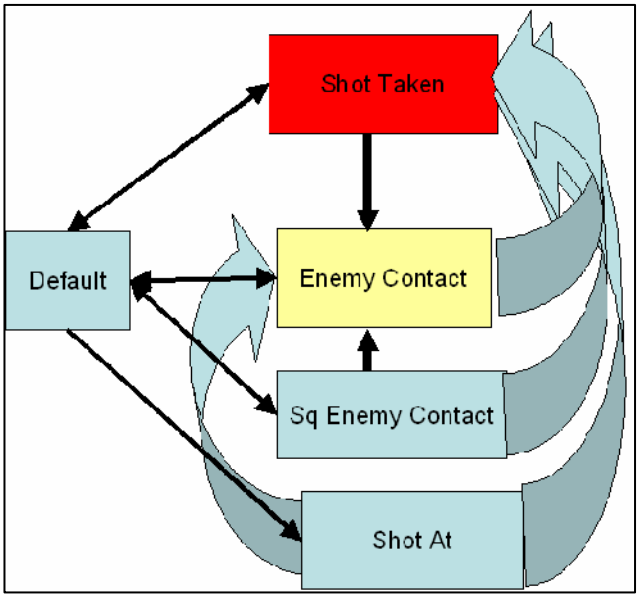


Figure 19. State Changes of All Red Forces Modeled in MANA

c. Non-Combatants

The non-combatants are constantly in a default state. Their behaviors do not change because the non-combatant's principal desire is to stay safe, and a single hit (shot) eliminates a non-combatant agent, meaning they die. The civilians are not intentionally targeted by either side, but can be killed as a result of collateral damage, typically the result of indirect fire.

3. Movement

The algorithms concerning the speed of an agent are based upon terrain, the maximum distance that can be moved during a time step, and the influences in the environment on the agent. The base rate of speed is between one and two feet per second. The base rate was calculated based upon the doctrinal rates published in FM90-31 and reflected in Table 3.

An assumption of the model is that night movement on restricted, unopposed terrain was similar to night movement on opposed, urban terrain. The rate of 1.6 km/h converted to feet per second as illustrated in Table 10.

1,600 meters per hour ÷ **60** minutes = **26** meters per minute
26 meters per minute ÷ **60 seconds = 0.444** meters per second
0.444 meters per second **X 3.28** feet per meter = **approximately 1.5** feet per second

Table 10. Calculation of Movement Rate in Model

In the model, a time step is one second, so the rate of 1.5 feet per second translates into agents who can move at least one foot for each turn of movement and 50% of the time they can move a distance of two feet. The movement rate is reduced in the areas around buildings, even slower within buildings, and slowest when breaching walls.

4. Sensing

The sensor levels are comprised of two ranges. The first is the range in which an agent can detect another agent. The second range is the distance that an agent can determine (or classify) whether another agent is a friend or foe. The terrain within a 54 foot (18 meters) range is also examined to determine its effect on movement action. Table 11 contains how far away an agent can detect another agent and the probability of classifying that agent as friend or foe each moment of model time in which they see another agent.

UNIT	DETECTION	CLASSIFY PROBABILITY
Red	150 meters	70%
Blue Traditional	150 meters	80%
Blue DO	300 meters	90%
Blue Attachments	300 meters	90%

Table 11. Detection Ranges and Probabilities to Classify per Time Step for Agents in Model (After DO Capabilities, 2004)

Another assumption is the Red Forces have optics slightly inferior to those of the Blue Forces. Table 11 indicates that for the model size (185 by 165 meters) all the agents have the capacity to see the entire terrain (barring line-of-sight restrictions like buildings and rubble). The values in Table 11 are ideal ranges and are further modified by the terrain an agent occupies (i.e., at the table value in a street but significantly lower in a building). The result is often a visual range of less the 50 meters in much of the model.

5. Communication

Communication in the model is considered the capability to talk to linked agents in the scenario. In the model, only position locations are transmitted between senior,

peer, and subordinate units. Communication links for each unit are illustrated in Appendix F.

a. Traditional Platoon

"The current rifle platoon has one VHF radio by T/E allowance." (DO Capabilities, 2004) The sole radio is an asset of the platoon leader. Therefore, the platoon leader is the only entity in the Traditional Platoon model that can call for indirect fire support and communicate with platoon attachments.

b. DO Platoon

"A key difference between a current rifle platoon and a DO capable platoon is the unit's communications capability." (DO Capabilities, 2004) The DO Platoon is highly networked. Indirect fire support can be called from the squad level and the squad leader is directly linked to every team in his squad. The squad leader can communicate directly with platoon attachments. Every internal team member is interlinked and Figure 20 graphically depicts the communication links. The graphic in Figure 20 is from the MCWL Sea Viking experiment and shows the planned communication links at the squad size and below force levels.

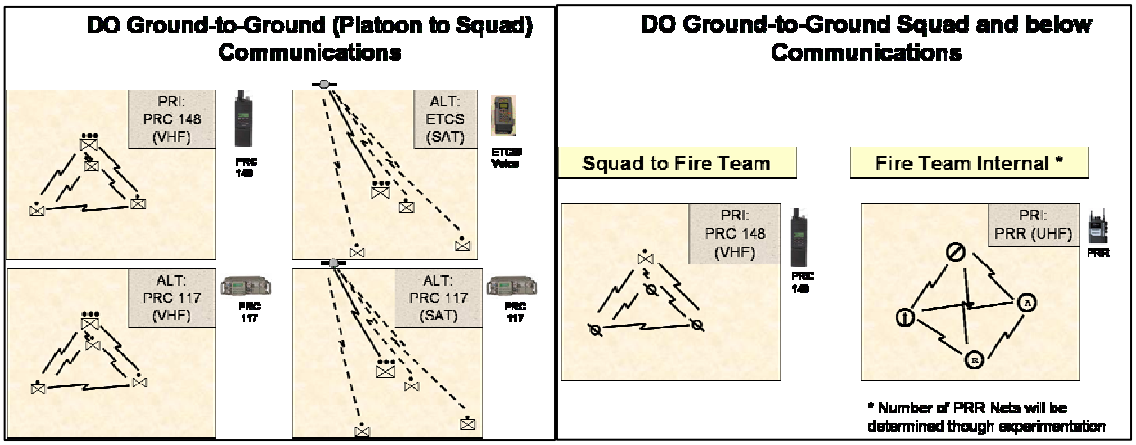


Figure 20. Communication Links within the DO Platoon (After DO Capabilities Report, 2004)

c. Red Forces

The Red forces are expected to have limited communication assets. The model assumes scouts can contact the machine gun team, mortar team, and the riflemen. The insurgents (armed with AK-47 and RPGs) do not have any communication links.

6. Weapon Lethality

The engagement rate, range and probability-to-hit a target serve to differentiate between the types of weapons employed. Supporting information was obtained from GlobalSecurity.org and can be found in Appendix G. Each agent has only one weapon to employ. The restriction allows the rate of fire and engagement of different weapon platforms to be modeled and eliminates a situation in which an agent could fire a well aimed shot from two different weapons at the same second. Engagement rates in the model are tied to doctrinal standards provided in FM90-10-1 and as obtained by weapon type from GlobalSecurity.org, see Appendix G.

The weapons are capable of engaging targets well beyond the range of the model; therefore, the probability to hit is high (above 80% anywhere on battlefield), with the probability increasing as the range to target decreases. Direct-fire weapons cannot fire through obstructing rubble or walls of buildings. Indirect-fire weapons can fire at targets on the other side of buildings or rubble.

7. Survivability

Survivability is the number of hits required to remove the agent from the fight. Injured agents on both sides continue to fight until the critical number of hits renders them dead. Survivability is difficult to quantify, and for this reason the relative hits to kill an opposing side creates a ratio from which to gain insights.

LtCol David G. Bellon reported a number of Marines have been wounded multiple times but refused to leave their fellow Marines. (Bellon, 2004) The ability of

injured Marines to stay in the fight shows they are tough, and the protective gear Marines wear significantly increases their survivability. Reports indicate about 45% of wounded US troops are returned to duty in Iraq. (Keiler, 2004) The value is also intended to capture the effect of the additional protection Marines gain from their body armor.

For these reasons, the number of times a Blue agent has to be hit to be killed (removed from the fight) is five compared to only two for the Red agents. Again, these values serve to represent relative survivability of the opposing forces.

8. Situational Awareness

> Situational awareness—Knowledge and understanding of the current situation which promotes timely, relevant, and accurate assessment of friendly, enemy, and other operations within the battlespace in order to facilitate decision making. An informational perspective and skill that fosters an ability to determine quickly the context and relevance of events that are unfolding
>
> —Marine Corps Reference Publication (MCRP) 5-12C

Situational awareness represents the sharing of a collective picture of what is known, and reported to be known, of the battlefield, between agents and the retention (or memory) of the information. In the simulation, the memory of agents is limited to 30 time steps (30 seconds). The reasoning is that if an agent disappears behind a building and is gone more than 30 seconds, the observing agent will not have any idea of the previously observed agent's new whereabouts. The situational awareness is directly affected by whomever an agent has a communication link, so the DO forces have the greatest situational awareness.

9. Tactics

> In tactics, the most important thing is not whether you go left or right, but why you go left or right.
>
> —General A. M. Gray, USMC(R)

The size of the unit dictates the relative urban coverage. A Marine company consists of three combat platoons and a weapons platoon. In support of the scenario, one off-model platoon of the company has established a perimeter and cordoned the area. A second off-model platoon is acting as the company reserve. The assault platoon modeled is the company's main effort and has attachments drawn from the Weapons platoon. The specifics of the application of these tactics are explained more exhaustively in the publication *Military Operations on Urbanized Terrain (MOUT)*. 1995. Vol. FM 3-06.11.

> The area should he divided into company zones of attack. This can result in heavy fighting as each zone is systematically searched and cleared—house by house, block by block. Each company must clear its zone completely, leaving no enemy in its rear.
>
> —*Military Operations on Urbanized Terrain (MOUT)*. 1995

The model is an attempt to balance freedom of choice with doctrinal actions of the agents in an assault formation.

a. Traditional Platoon

The exact tactics used on the terrain in Fallujah in Operation al-Fajr are not available in unclassified format. Militarily sound tactics were created with the help of a team of foreign officers, US officers, and military civilians at the Project Albert International Workshop in Sweden in May '05. The panel consisted of Mr. Kurt Grau, IABG—Analysis and Testing Division—German Ministry of Defence, Colonel Mats Olofsson, Swedish Air Force, LtCol Rick Holdren, US Army, LtCol Dave Hingston, New Zealand Army, Captain John Cheong, Singapore Army, Captain Mike Babilot, USMC, and Mr. Edmund Bitinas, Northrop Grumman.

The resulting tactics are house-to-house searches of the region with the terrain divided into three similar north-south zones. Each squad is assigned a zone. The squad assigns teams the responsibility of either clearing houses or providing over watch and security. The responsibility is depicted in the model by the location of the waypoints

selected as the assault route. The routes are modified to accommodate the terrain (MOUT or Fallujah) in order to maintain a house-to-house assault.

Model run performance was reviewed by a panel at the Naval Postgraduate School comprised of Col Ed Lesnowicz, USMC(R), Capt Matt Bain, USMC, Capt Todd Sanders, USMC, Professor Tom Lucas, NPS, Professor Susan Sanchez, NPS, and Professor Paul Sanchez, NPS, prior to executing the final data generating runs.

b. DO Platoon

Due to the newness of the DO force, the DO specific tactics have not yet been defined. There is also the desire to compare DO to traditional units in the same context. The same tactics are used for both the Traditional and DO forces to ensure the same context exists.

c. Attachments

A news report from Fallujah noted "US units appeared to be lined up at the edge of their neighborhoods with some scouts and perhaps special operators venturing inside." (Krane, 2004) This report led to the decision to forward deploy a reconnaissance team in the model. The remaining attachments are either directly attached to a specific team or placed in a position observing avenues of approach in order to provide cover fire for advancing agents. Attached agents have the same characteristics as the supported unit.

d. Red Force

The insurgents in Fallujah operated in the manner characterized by Mr. Ware who said

> (Insurgents acted in) … a classic guerrilla style, a rearguard detail to harass and interdict US forces. They are a tenacious enemy who fight as any guerrilla force might—never head on, always from behind or the sides

> at moments when it's least expected, initiating combat at weak points and then pulling back to strongholds, ducking and weaving all the while.

Red agents are set to attack Blue agents and to move away from Blue agents when shot at. Red will loiter in their assigned areas until contact with Blue.

e. Non-Combatants

> Iraqi health ministry's own figure for civilian casualties is 20 because it says most people are out of the town and those that are in have very sensibly—in fact they're compelled to—have stayed literally on the floor of their homes.
>
> —Paul Wood, from the BBC, Nov 2004

The civilian population in the model desires cover and concealment and to avoid enemies. The intent is to have civilian agents gravitate toward protected areas inside structures and avoid combat areas.

V. ANALYSIS METHODOLOGY

> The occurrences of war will not unfold like clockwork. Thus, we cannot hope to impose precise, positive control over events. The best we can hope for is to impose a general framework of order on the disorder, to prescribe the general flow of action rather than try to control each event.
>
> —Warfighting, FMFM-1

A. OVERVIEW

DO is in the concept development phase, and the insights from this research can assist in that development. The MOUT training environment is a continually evolving concept that can benefit from additional research. The main purpose of the simulations is to provide decision makers insight and allow rapid exploration of many facets of both concepts. This exploration requires testing the scenarios across many different parameter values. MANA is stochastic, which means multiple replications, with varying random number seeds and the same parameter values can produce a range of different results. These results are analyzed to provide insight into the models.

This section will highlight the process used to create the data for analysis from the scenarios introduced in the earlier chapters. The Measure of Effectiveness (MOE) of the analysis is presented. Next, the Design of Experiment is explored by examining the reasoning for each exploratory run.

B. MEASURES OF EFFECTIVENESS

> Measures of effectiveness—Measures designed to correspond to accomplishment of mission objectives and achievement of desired effects.
>
> *—CJCSI 3170.01E*

> Measure of effectiveness (MOE)—A measure of operational success that must be closely related to the objective of the mission or operation being evaluated. A meaningful MOE must be quantifiable and a measure to what degree the real objective is achieved.
>
> —*The Defense Acquisition University* (DAU) *10th edition Glossary*

These quotes guided the effort to determine the best MOE for this research. By definition, the MOE must support the hypothesis of the research. The primary hypothesis is that the DO Platoon is the same as the Traditional Platoon in urban combat. The secondary hypothesis is that there is no difference in effect on the outcomes of urban combat due to the differences in terrain between Fallujah and the MOUT facility.

Numerous combat MOEs were considered for the analysis. The Center for Naval Analysis suggest five types of measures. Of the five, Task-Performance MOEs and Mission-Level MOEs are most applicable to the urban combat scenarios.

Task-performance measures capture individual level-of-effort actions in the scenario (e.g., bullets fired per agent, enemy killed per agent, time in scenario until death, etc.). Mission-level measures encompass the actions of the force operating in the scenario (e.g., Red agents killed, Blue agents killed, time until Blue reaches goal, etc.). (CNA, 1996)

The application of the CNA guidance led to the following preliminary list of MOEs:

- Number of Blue agents killed (or percent Blue killed)
- Number of Red agents killed (or percent Red killed)
- Loss Exchange Ratio (Red Killed divided by Blue Killed)
- Blue Force Time to Complete Mission
- Number Blue-on-Blue kills (fratricide)
- Number of non-combatant kills (or percent non-combatants killed)
- Number of Red kills by Blue weapon systems.

The decision was made to focus the list to a single MOE in order to bound the research efforts. The MOE elimination process was accomplished by evaluating each of the preliminary MOEs and selecting the one deemed to provide the most meaningful information.

- "Number of Red kills by Blue weapon systems" and "Number Blue-on-Blue kills" were not included in the MANA data output and so were easily eliminated.
- "Number of Red agents killed" and "Blue Force Time to Complete Mission" were eliminated because there was little variability in these values. Nearly all the model runs took the maximum time allowed and involved the complete destruction of the Red force and therefore did not provide much insight.
- "Number of Non-combatant kills' could discriminate between the different scenarios, but was discarded because it was unrelated to the mission of eliminating the Red force.

The remaining potential MOEs were "Number of Blue force killed" and the "Loss Exchange Ratio" (or LER). The LER was selected as the MOE because it had the number of Blue kills as a component in its computation and retained the influence of the Red agents that were killed. The ratio is highest when the number of Blue agents killed is a low number and the number of Red agents killed is a high number. In the context of this research, a higher loss exchange ratio is preferred. The value in using LER is that it is a surrogate for the combat effectiveness of a force and is similar to attacker to defender force ratios. The LER MOE meets the criteria put forth by CNA in that it relates to the overarching mission, is responsive to actions in the model, and is meaningful. (CNA, 1996)

The loss exchange ratio is relevant in light of the forces employed or the terrain in the model. The validity of this MOE generates concern when there are no Blue agents killed in the simulation. This was not the case in any of the baseline experiments and was therefore not a concern for that portion of the analysis. Alternate LER MOEs were examined for use in the sensitivity analysis. The reason being that in 40 of the 12,400 simulation runs no Blue agents were killed. There were no instances in which there were

less than three Red agents killed. The alternative LER MOEs considered are identified in Table 12. The ones eliminated from consideration are designated with a red cross-out. The selected MOE for the comparative analysis of the hypothesis testing and the sensitivity analysis are circled in green.

LOSS EXCHANGE RATIOS EVALUTED FOR MOE OF ANALYSIS			
Red Killed / Blue Killed	Replace infinity values with 1000	Replace infinity values with 66	Replace infinity values with 36
Red Killed + 1 / Blue Killed +1	LER that serves a MOE for Baseline Comparison Analysis ⇐ LER that serves as MOE for Sensitivity Analysis		
% Red Killed / % Blue Killed	Replace infinity values with 1000	Replace infinity values with 66	Replace infinity values with 36
% Red Killed + 1 / % Blue Killed + 1	**Note:** there are 33 killable Red agents in the model. There are 55 killable Blue agents in the model.		
Blue Killed / Red Killed			
% Blue Killed / % Red Killed			

Table 12. Choices from Alternative LER MOEs Considered for Analysis

The analysis of the next chapter uses the LER, calculated by the number of Red killed divided by the number of Blue killed, as the MOE for the baseline population comparisons. The sensitivity analysis uses the LER with a "1" added to the numerator and denominator to allow evaluation of LERs that would otherwise result in a "0" or infinity value. The sensitivity analysis also explores categorical levels of the LER MOE.

C. DESIGN OF EXPERIMENTS

The basis of this research is a comparison of forces and a comparison of terrains. Figure 21 shows the four-way comparison that serves as the foundation for this thesis. Each of the green squares represents one of the four models that form a basis for this research. Examining the squares reveals that the top squares are of the same pattern (Fallujah) and the bottom squares are the same pattern (MOUT). The terms "TRAD," "DO" and "INSURG" represent the type of agents that characterize each model. In

addition to the model of the two forces on the two terrains, various excursions are performed to examine the sensitivity of the model to critical parameter changes. The arrows represent the comparisons that are then conducted using data obtained from baseline and sensitivity experiments on the models.

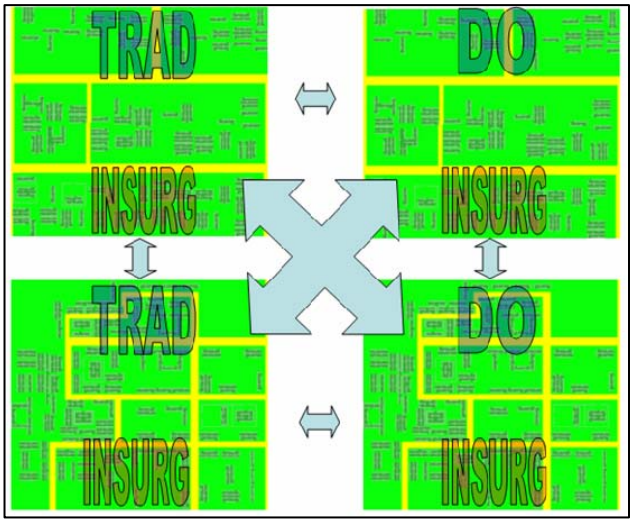


Figure 21. Four Models Compared in Analysis

A single run of the model takes 20 minute to simulate six hours of combat. Through use of the Maui High Performance Computing Center, 12,400 runs of the models representing over 3,720 computer hours were conducted. The MHPCC is the repository for the super computing power used to run the experiments. MHPCC is an Air Force Research Laboratory Center Managed by the University of Hawaii.

The evaluation of the baseline models is obtained by running them 100 times each. The importance of the sensitivity analysis is to determine how much the model outcomes are influenced by the same critical parameter settings.

A gridded design of experiments is applied to each of the runs. Gridded designs are useful for examining a limited number of factors at a few different levels. This method targeted and explored select areas of the parameter space that are explained in the next section of this chapter.

The key areas of the model chosen for sensitivity analysis are:

- the level of clutter on the battlefield
- the number of times an agent must be hit by a weapon to be killed
- the range at which an agent can classify another agent
- the personal concealment level of an individual agent.

The basis for choosing these factors to explore was gained from preliminary experimentation and by visually inspecting different settings on the factors to see the influence on the actions and outcomes of the model. A summary of the experiment design and computing time calculations is provided in Table 13. The 12,400 represent over 3,000 runs of each of the four models: DO on Fallujah, DO on MOUT, Traditional on Fallujah and Traditional on MOUT.

Experiment Number	Element Explored	Levels Explored	Number of Runs Each	Cumulative Runs
1 to 4	Baseline	Force: Traditional, DO Terrain: Fallujah, MOUT	100	400
5 to 204	Classification Range	Blue: 100, 150, 200, 250, 300, 350, 400 Red: 100, 150, 200, 250, 300, 350, 400	30	5,880
205 to 304	Personal Concealment	Blue: 20, 30,40, 50, 60 Red: 10, 20,30, 40, 50	30	3,000
305 to 364	Hits to Kill	Blue: 4, 5, 6, 7 Red: 2, 3, 4, 5	30	1,920
365 to 376	Terrain Clutter	None, Light, Dense	100	1,200
		Total number of Runs		**12,400**
		Run Time of each model (hours)		**0.33**
		Total Estimated CPU run time required (hours)		**4,092**

Table 13. Summary of Experimental Design and CPU Time Calculations

D. SPECIFICS OF EACH EXCURSION

1. Baseline Models

Four baseline models serve as the foundation for the analysis. They are Traditional Platoon with attachments on Fallujah terrain; DO Platoon with attachments

on Fallujah terrain; Traditional Platoon with attachments on MOUT facility terrain; and DO Platoon with attachments on MOUT facility terrain. Each of these four models is run for 100 excursions.

2. Clutter on the Battlefield

Preliminary experimentation showed that limitations to line of sight (LOS) in an urban environment are comprised of two elements: transitory and fixed. Transitory effects are elements like smoke, wind, dust and weather influences. MANA models these with a modifier that makes a probabilistic determination for each time-step of the model if an opposing agent in the field of view is observed. Structures, trees, fences, rubble and rubbish cause a fixed effect that restricts LOS. MANA only captures those elements modeled into the terrain. To model the level of clutter in the urban environment visual runs were conducted with varying densities of uniformly distributed pixels that affected line of sight, but not movement. This was accomplished by adding a pixel elevation map, with each white colored pixel acting as a sight limiter. The reader is encouraged to refer to the MANA Users Manual to obtain comprehensive information regarding the model elevation map.

The four levels of clutter modeled are none, light, medium and dense. Visual observation showed that the medium density reduced agent line of sight to the 50-meter range indicated by doctrine. Figure 22 shows a comparative difference between the levels of clutter and the medium level used in the baseline models is illustrated. Clutter adds realism to create micro-terrain effects and limited peripheral vision effects that are common in urban combat. As shown, the denser the concentration of clutter is on the battlefield, the more fractured the field of view of any particular agent is. The graphics use lines to trace the line of sight of a particular agent and the line continues until it is obstructed. This creates a 360-degree representation of what that agent can detect, or see, from its current position. The graphic provides the Blue Force LOS in Blue, the Red Force LOS in Red and the non-combatants LOS in white, and is best viewed in color.

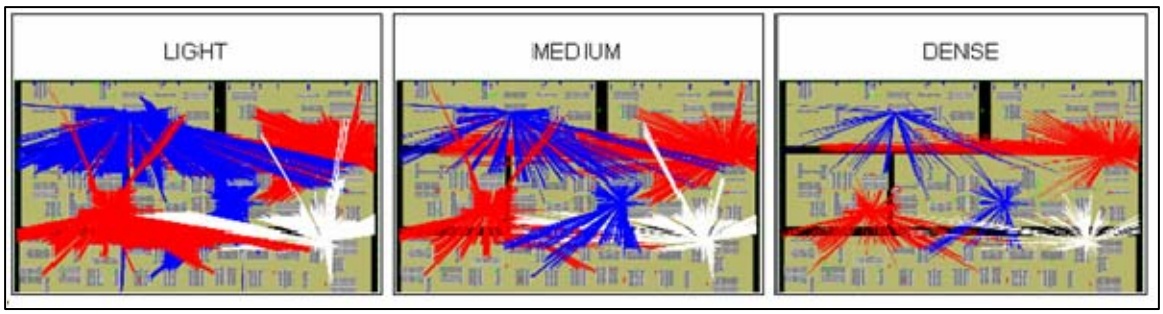


Figure 22. Effects on Line of Sight with Varying Levels of Clutter

Light, dense and no clutter levels were run for 100 iterations for each of the four models. The medium-clutter-level case is captured in the 100 baseline runs.

3. Hits to Kill an Agent

Relative survivability of an agent is difficult to quantify. It is common knowledge that body armor and training can increase an agent's resilience on the battlefield. Anecdotal information has been provided in earlier chapters relating to Marines' hardiness even after being hit. The baseline was set so that five hits are required to kill a blue agent and two hits are required to kill a red agent. These levels are set based upon visual review of different hit to kill levels and their impact on the outcome of the models.

The exploration of the levels of hit-to-kill can provide insight into the effects of relative survivability between Blue and Red forces and the impact of the ratio of hardening. The Blue force was gridded on the values of four, five, six and seven against the settings of two, three, four and five for the Red force. Each of the 16 combinations was run for 30 replications for each of the four models.

4. Classification Range

Classification range is the distance at which an agent can determine friend or foe. Although there are many limiting factors in the urban environment, there is some interest in exploring whether improving the agents' ability to see through the transitory effects of the battlefield would significantly impact the outcome of battles.

Classification was gridded on the values of 100, 150, 200, 250, 300, 350, 400 for both Blue and Red agents. This resulted in 49 combinations being run 30 times each. The levels correspond to a foot in measurement (e.g., 100 = 100 feet). The upper and lower bounds are based upon the visual capabilities of the unaided eye. Under night conditions, humans experience the worst visual acuity, estimated to be from 20/200 to 20/400, and possibly much worse according to FM 3-22.9. This means that if an individual could see 400 feet in daylight, then he would only see 20 feet in the worst night conditions. The size of the model, a maximum dimension of 607 feet, equates to a daytime sight distance of approximately 6,000 feet. This distance is beyond the ability of an unaided eye but is possible with optics.

5. Agent Concealment

Concealment, sometimes referred to as stealth, is the passive concealment that an agent has, like the digitalized camouflage of the USMC utility uniform and training (e.g., stay low and move fast.) The Red force represents an insurgent force that was not uniformed. These factors led to a modeling of the blue forces with a higher concealment level than the red forces. There was interest as to whether the proper relative concealment was applied in the model and how varying the relative concealment of the forces would affect the outcome.

A gridded design examines Blue force concealment at 20, 30, 40, 50 and 60 against Red force concealment of 10, 20, 30, 40, and 50. Each of the 25 combinations is run with 30 replications.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. DATA AND DATA ANALYSIS

A. OVERVIEW

In the preceding chapters the models have been described, the MOE defined, and the experimental designs determined. These have produced a volume of data to be analyzed, in light of the hypotheses, using Operations Research techniques. This section identifies the analysis tool, data, outputs and methods involved in the processing and analysis of the data to reach the conclusions presented in the next chapter.

B. ANALYSIS TOOL: JMP IN RELEASE: 5.1.2

> JMP® 5.1.2 statistical analysis software, for Windows, Macintosh, and now Linux, provides capabilities for all types of users to make quicker, data driven decisions that go straight to the bottom line. JMP provides companies with instantaneous insight and a common language for data analysis. The result is improved communication and quicker decision-making, which leads to discovery and innovation.
>
> —WWW.SAS.COM

JMP statistical discovery software is the analysis tool used to analyze the data obtained from the model runs. JMP was chosen in light of its ease of use and comprehensive graphical user interface, ability to deal with data sets larger that Microsoft Excel's capability, and its easily understood graphical and contextual output.

The JPM software package allows quick and easy data manipulation with built-in spreadsheet capabilities. The graphical output increases the likelihood of making a discovery in the data and facilitates understanding of the data. The interactive nature of the software also allows one to extrapolate more deeply and to further refine the data output. (Sall, Creighton and Lehman, 2005)

JMP allows a user to implement many analysis techniques to analyze data. This research focuses on three techniques available in the software package: graphical analysis, regression, non-parametric testing, and classification trees.

The graphical output of JMP lends itself to graphical analysis. This analytical method involves plotting aspects of the data and exploring different representations of the data. It requires no assumptions about the data and is useful for identifying insights hidden within the data. The principal method was examining histograms that show the characteristics and distribution of the samples.

Certain assumptions regarding a population are required to apply parametric statistics. Little is known about the true population parameters that are the basis for the data produced by the models. Nonparametric methods will be used to test the hypotheses. Nonparametric statistics are often referred to as distribution free, meaning that the analysis methods are valid without knowing the parametric distribution of the underlying population. (Conover, 1999) The issue of symmetry is addressed by analyzing the differences of the samples to examine the hypothesis.

Trees are a method by which the data are recursively partitioned. The partitioning of the successively smaller data sets occurs at the split that most significantly differentiates the data into two separate sub-sets of like responses.

C. MODEL DATA

The 376 experiments identified in Table 14 produced 12,400 sets of data, one for each simulated mission. The length of time required to run the model influenced the desire to keep the number of runs required in each experiment to as few as possible while maintaining a sufficient sample to analyze. The clutter experiments explore the density of clutter (fixed LOS obstructions) present on the battlefield and are uniformly spread at the density level everywhere but in the roadways. The clutter levels are classified relative to the level of clutter present in the baseline experiments.

376 SETS (94 OF EACH OF THE 4 MODELS)
196 Classification Experiments
100 Concealment Experiments
64 Hit-to Kill Experiments
12 Clutter Experiments (None, Lighter and Denser Clutter)
4 Baseline (2 Forces by 2 Terrains)

Table 14. Experimental Design Detail

The MANA experiments produced a large quantity of data that was then refined from their raw state. The raw output consisted of data regarding the end state count (dead or injured) for each of the 81 agents in the model, the simulation run seed, model duration, and other statistics that were not used in this analysis. The raw data were refined to indicate the information in Table 15. Of these values, LER serves as the MOE for the examination of the data.

Experiment	Time Steps	Terrain Type	Clutter	LER	Log(LER)	LER 2 lvl
Exp 10	1004	Fallujah	2	0.118	-2.14006	4:1 minus
Exp 11	1018	Fallujah	2	0.118	-2.14006	4:1 minus
Exp 58	2510	MOUT	2	0.139	-1.97048	4:1 minus

LER 5 lvl	Hits-to-Kill		Concealment		Classification	
	Blue	Red	Blue	Red	Blue	Red
0 to 1	5	2	Varied	Varied	100	350
0 to 1	5	2	Varied	Varied	100	400
0 to 1	5	2	Varied	Varied	100	300

Table 15. Sample of 12,400 Lines of Refined Data from Model Output

All experiments ran 30 times each, except the baseline and clutter experiments, which ran 100 times each. The average Red and Blue killed for each experiment is used to calculate a mean LER MOE for the 376 experiments and is saved in a separate file in order to serve as an additional data source to explore.

Two different categorical LER MOEs' are created based upon the LER produced from each of the 12,400 runs. These are explained in greater detail in the sensitivity analysis section of this chapter.

D. HYPOTHESIS TEST: POPULATION COMPARISONS

1. The Basic Comparisons

The intent of this research is to determine from the simulation whether the combat results of the DO Platoon are the same as the modeled Traditional Platoon. The secondary emphasis is determining how the modeled MOUT terrain compares to the Fallujah terrain. This is determined by identifying whether the results from the baseline experiments can be considered to be from the same or different populations. To do this six pair-wise comparisons are conducted:

- DO on the two terrains
- Traditional on the two terrains
- DO compared to Traditional on Fallujah terrain
- DO compared to Traditional on MOUT terrain
- DO on Fallujah Terrain compared to Traditional on MOUT terrain
- DO on MOUT Terrain compared to Traditional on Fallujah terrain.

For simplicity, the MOEs of the four separate experiments are referred to as LER 1 through 4, and they are: LER 1 = DO on Fallujah; LER 2 = DO on MOUT; LER 3 = Traditional on Fallujah; and LER 4 = Traditional on MOUT.

2. Testing Assumptions

The analysis presented in this research reflects only a sampling of the data examined and the extent of the data exploration performed. The analysis provided in this document is the heart of the research efforts and is intended to illustrate the analysis. In the interest of brevity and applicability, the parametric statistical analysis performed is not detailed since the normality assumption was proven to be violated. Only a representative analysis is presented to justify the conclusions drawn and the insights obtained and presented in the next chapter.

a. Independence

The first question to be answered: Are the groups unrelated and statistically independent or are they matched pairs of groups performing in different events? The experiments are considered matched pairs because each was run with the same set of random seeds and the same personality weightings. In essence, the experiments can be considered a "before and after" where DO enhancements have been added or the same agents run through a different environment.

Since the data produced by the different experiments may be slightly correlated, this must be considered during the analysis. (Sall et. al., 2005) If it is not considered, valuable information may be lost. This translates into a *p*-value that is lower than the one produced by the paired *t*-test (for a positive correlation) and could lead to the error of failing to reject a false null hypothesis.

b. Normality

The Shapiro—Wilk W test is performed upon each of the baseline experiments. The results of this test provide statistical evidence of non-normality in the LER data. The test produces a probability value, or *p*-value, which indicates the

statistical probability of obtaining the test results or more extreme ones, just by chance, if in fact the data are normal. The threshold value for the *p*-value is usually taken to be 0.05. (Conover, 1999) Therefore, values less than 0.05 are considered statistically significant.

Figure 24 was produced in JMP 5.1. It is a distribution of the LERs (as a histogram) computed from each of 100 baseline runs in each of the four baseline experiments. To the right of each histogram is a boxplot of the data illustrating the mean, quantile ranges and outliers. Figure 23 allows a quick visual assessment of the data and shows summary statistics regarding the sample and the results of the Shapiro-Wilk W test for each sample. Examining the data from the four experiments indicates a *p*-value (indicated by 'Prob<W' entry in Figure 23) of less than 0.0001, as indicated in Figure 23. This means that there is less than a hundredth of a percent chance that if the data actually are normal, we would observe these or more discordant results. The red line overlaid on the histogram depicts how a normal distribution of the data would look and provides a visual cue of further evidence of non-normality in the data.

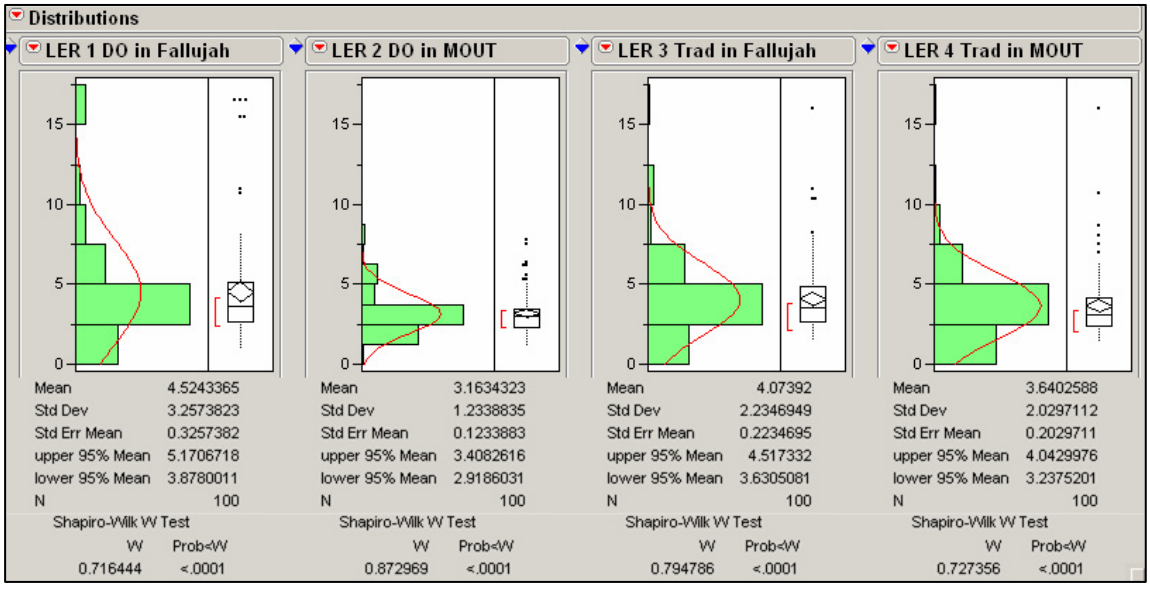


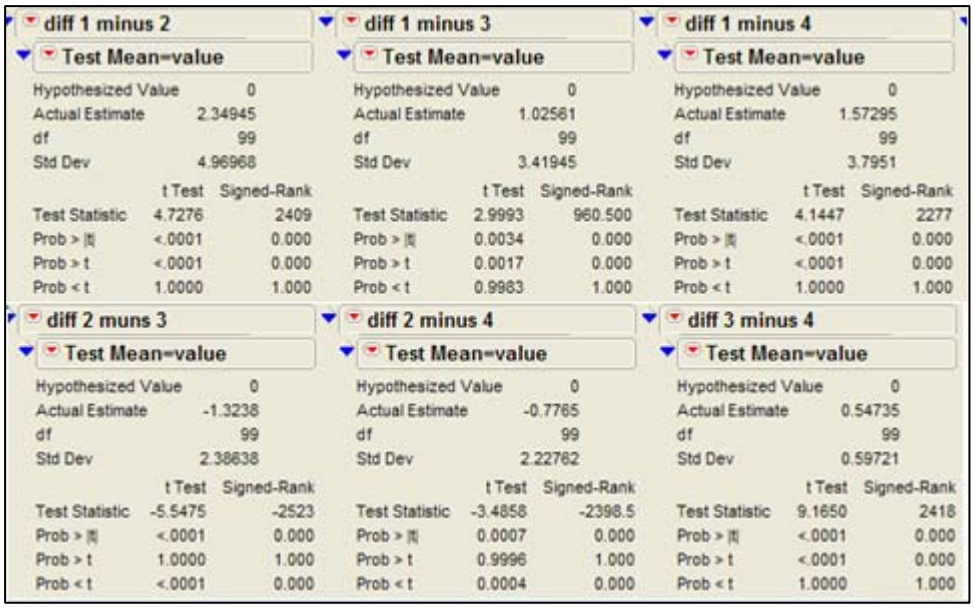
Figure 23. Results of Testing Four Baseline Experiments Data for Normality

The assumption of normal data is not valid for these data and indicates that non-parametric tests are the appropriate methods by which to examine the data.

3. Performing the Analysis

The absence of normality in the data led to the decision to use the non-parametric Wilcoxon signed-rank (rank-sum) test and the Kruskal-Wallis test to examine the hypotheses. The Kruskal-Wallis test is one of the most powerful non-parametric tests for comparing three or more samples and the signed rank test is similarly powerful in testing the null hypothesis that two populations have identical distribution functions. (Easton and McColl, 2005) The two tests do not require the differences between the two samples to be normally distributed. (Conover, 1999) The baseline runs are separated into the four individual experiments and compared. The runs are also combined along terrain relationships and evaluated. Finally, the runs are combined along force employed and tested.

The Wilcoxon signed-rank test is used to examine all six possible comparisons and the results, from JMP 5.1, are provided in Figure 24. This test can be used to determine if any two models are different. Here the *p*-value has the same meaning as before. The *p*-value is the 'Prob > |t|' entry in Figure 24 given the null hypothesis is true. Each comparison shows that if the models were actually the same (indicated by the hypothesized value of the difference is zero), there is no chance such results would be observed.



diff 1 minus 2 — Test Mean=value

Hypothesized Value	0	
Actual Estimate	2.34945	
df	99	
Std Dev	4.96968	
	t Test	Signed-Rank
Test Statistic	4.7276	2409
Prob > |t|	<.0001	0.000
Prob > t	<.0001	0.000
Prob < t	1.0000	1.000

diff 1 minus 3 — Test Mean=value

Hypothesized Value	0	
Actual Estimate	1.02561	
df	99	
Std Dev	3.41945	
	t Test	Signed-Rank
Test Statistic	2.9993	960.500
Prob > |t|	0.0034	0.000
Prob > t	0.0017	0.000
Prob < t	0.9983	1.000

diff 1 minus 4 — Test Mean=value

Hypothesized Value	0	
Actual Estimate	1.57295	
df	99	
Std Dev	3.7951	
	t Test	Signed-Rank
Test Statistic	4.1447	2277
Prob > |t|	<.0001	0.000
Prob > t	<.0001	0.000
Prob < t	1.0000	1.000

diff 2 muns 3 — Test Mean=value

Hypothesized Value	0	
Actual Estimate	-1.3238	
df	99	
Std Dev	2.38638	
	t Test	Signed-Rank
Test Statistic	-5.5475	-2523
Prob > |t|	<.0001	0.000
Prob > t	1.0000	1.000
Prob < t	<.0001	0.000

diff 2 minus 4 — Test Mean=value

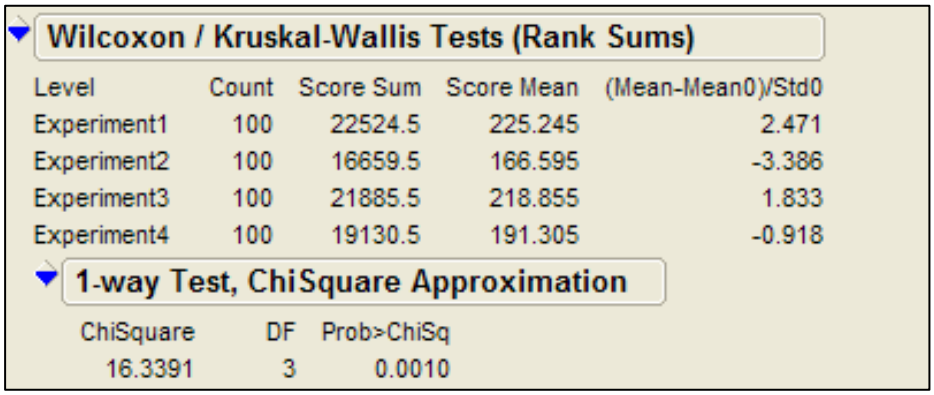
Hypothesized Value	0	
Actual Estimate	-0.7765	
df	99	
Std Dev	2.22762	
	t Test	Signed-Rank
Test Statistic	-3.4858	-2398.5
Prob > |t|	0.0007	0.000
Prob > t	0.9996	1.000
Prob < t	0.0004	0.000

diff 3 minus 4 — Test Mean=value

Hypothesized Value	0	
Actual Estimate	0.54735	
df	99	
Std Dev	0.59721	
	t Test	Signed-Rank
Test Statistic	9.1650	2418
Prob > |t|	<.0001	0.000
Prob > t	<.0001	0.000
Prob < t	1.0000	1.000

Figure 24. Results of Wilcoxon Signed-Rank Test

The Kruskal-Wallis test result from JMP 5.1 in Figure 26. This is a non-parametric test that tests the null hypothesis that all four baseline experiment group means are equal without regard to the nature of the overall population (e.g., normality). (Conover, 1999) In this test the *p*-value is the 'Prob>ChiSq' value, which indicates that if the models actually are the same, the likelihood of seeing results like this, or more extreme, are one-tenth of a percent, which is not very likely. Therefore, the null hypothesis is rejected.



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Experiment1	100	22524.5	225.245	2.471
Experiment2	100	16659.5	166.595	-3.386
Experiment3	100	21885.5	218.855	1.833
Experiment4	100	19130.5	191.305	-0.918

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
16.3391	3	0.0010

Figure 25. Results of the Kruskal-Wallis Test

The results of the two tests agree. There is statistical evidence that the four samples are each from a different population.

The baseline experiments are next divided according to whether the Blue forces are DO or Traditional. The Wilcoxon Signed-Rank test is again used to determine if there is a significant difference between the results obtained from using DO Forces compared to the use of the Traditional forces. The JMP 5.1 obtained results are presented in Figure 26. The *p*-value ('P{rob > |t|') is 0.002, which is significantly different from the threshold value of 0.05 and indicates there is a difference that results from the use of different force types in the two scenarios.

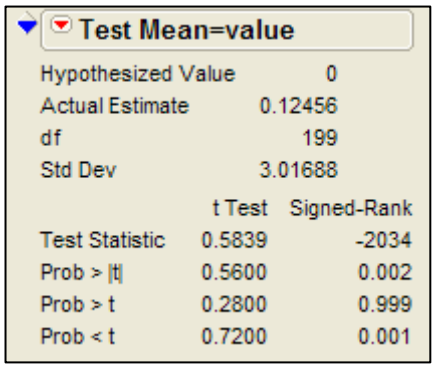


Figure 26. Different Means of DO and Traditional Sample

Next, the baseline experiments are divided according to the terrain, either Fallujah or MOUT. The Wilcoxon Signed-Rank test is used to see if there is a significant difference in the outcomes from Fallujah compared to MOUT. The results in Figure 27, from JMP 5.1, indicate that there is indeed a difference (0.000 is less than 0.05).

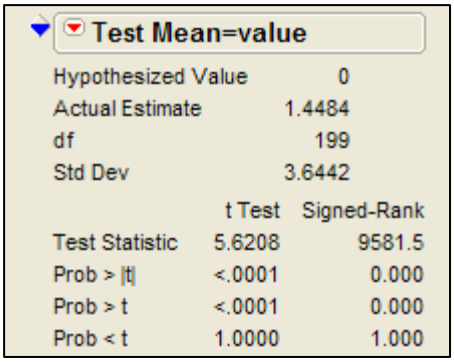


Figure 27. Different Means of Fallujah and MOUT Sample

The results of this section are interpreted in the next chapter.

E. SENSITIVITY ANALYSIS

1. Preparing the Data

Now that the baseline models have been explored to determine if the hypotheses should be rejected or not, there is interest in exploring the data to see other insights that may exist.

In order to better characterize the LER, this MOE has been converted into categorical levels. The intent is to capture an interpretation of the LER, not the precise value. Historical studies performed by the U. S. Army Human Engineering Laboratory have shown that the attacker-to-defender ratios in the 22 urban battles was approximately 4:1. (McLaurin, Jureidini, and McDonald, 1987) The size of an attacking force relative to the defender can be a critical determinant of the successful outcome of battle. The LER can serve as a surrogate to the force ratio identified from historical urban conflicts. A LER greater than or less than force ratio may exist, but the author considers the relationship sufficient to allow the reader to gauge the model results in light of the fixed number of forces on each side that exists in this scenario.

Two different versions of the categorical data are explored. Version 1 is split into an above and a below category and version 2 divides the two regions into a total of five

regions. These splits are shown in Figure 28 in the histogram format produced by JMP 5.1. To the right of each horizontal bar is a number that indicates the percentage of values that are contained in that bar and correspond to the tabulated values at the bottom of the figure.

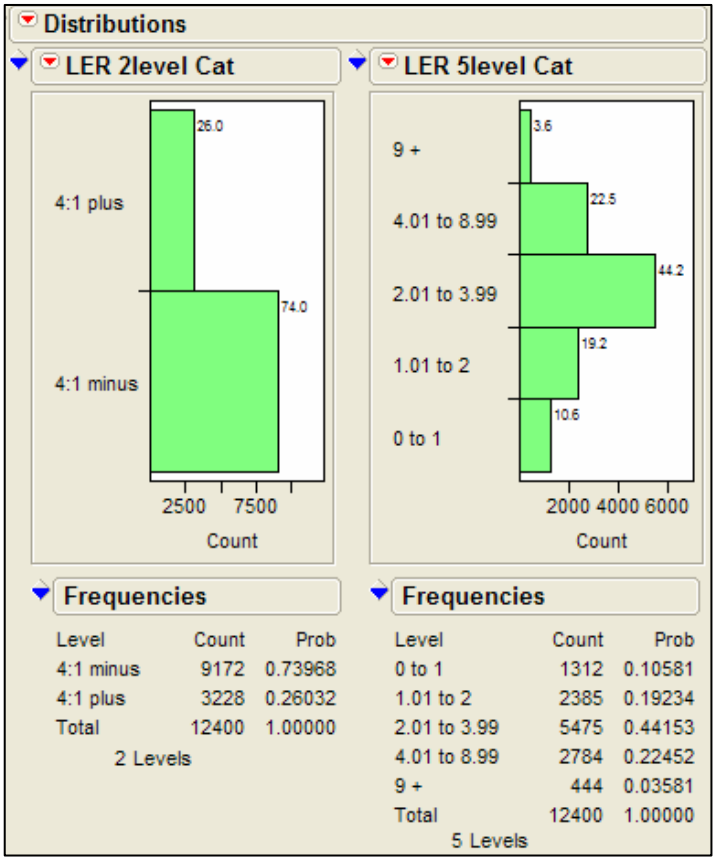


Figure 28. Categorical Results of 12,400 Model Runs

The historical 4:1 level serves as a point of departure for determining the categories for LER. The levels above and below 4:1 are of interest, so four served as the initial bin separator for the data.

The five categories were created by dividing the initial two levels. The region below 4:1 was subdivided into three areas of interest:

- values below 1:1 were outcomes that indicate the battle went badly for Blue;

- the partition from 1:1 to 2:1 captured all battles that end in Blue and Red at near parity for loses; and
- the remainder from 2.01:1 to 3.99:1 captured those outcomes in which Blue achieves a slight advantage over Red.

The above 4:1 bin was split into two parts, with a break at 9:1, to show those outcomes in which Blue attains a lopsided victory over Red.

Some may question the 4:1 force ratio and argue that attackers prefer a 5:1 or 6:1 or even a 100:1 ratio. The response to this is that the 4:1 ratio has been shown to hold as recent as the battle of Khorramshahr, in 1980 in the Iran-Iraq war. In this battle the defenders, irregular Iranian forces, outnumbered 4:1, held the city for 26 days. (MOUT Homepage and *MCRP 3-35.3A*) Although LER and force ratios can be significantly different due to technical and/or morale superiority, the model forces are fixed in numbers, have similar technical sophistication, and morale is not captured in this model. Therefore, it is argued that in this situation LER can serve as a surrogate to the force ratio.

2. Regression

A stepwise regression was performed to examine the relationship of the factors (e.g., troop hardening, classification ranges, personal concealment, terrain, force type and clutter) to the LER. Stepwise regression is a method of selecting factors with significant effects for a regression model. "It is used when there is little theory to guide the selection of terms for a model and the modeler, in desperation, wants to use whatever seems to provide a good fit." (Sall et. al., 2005) The intent of regression is to determine a mathematical equation that explains the behavior (data output) in the simulation. Parameter coefficients (weights) are determined in a manner that minimizes the error of explaining all the data. The stepwise regression procedure in JMP 5.1 produced the model illustrated in Figure 30. The mathematical equation shown provides an explanation of the response (LER) based on the significant factors that result in a minimal amount of error. Though many models were created, the one indicated in Figure 29

provides parameter estimates for the significant factors that result in the most preferred *R*-squared value, 71.9%, and an adjusted *R*-squared value of 70.3%. By definition, the *R*-squared value is the explained proportion of the variation in LER from fitting the model to the input values. (Conover, 1999) An *R*-squared value of 1.0 indicates that the model fits the data perfectly. The model provides a common sense validation of the behavior of the models. When Blue capabilities are improved, the LER improves. When Red capabilities are improved, the LER is reduced. The terrain and force type that affect model results are also identified.

The lower left portion of Figure 29 contains *t*-Ratio information. The *t*-Ratio is the ratio of the value estimated by the model formula to its standard error. A *t*-Ratio greater than 2 (in absolute value) corresponds to a significance of less 5%. (Sall et al., 2005) The absolute magnitude of the *t*-Ratio indicates the relative influence a factor has on the outcome of the LER. The "**23.12"** for "Blue_Classification" is the largest value in the table and thus has the most statistical significance in explaining the LER. The positive sign indicates that there exists a positively correlated relationship (i.e., as "Blue_Classification" increases the LER value produced in the simulation also increases). This is contrasted with the second highest magnitude value of "**-18.16**" for "Red_Classification." However, in the case of "Red_Classification, the relationship is negatively correlated (i.e., as "Red_Classification" increases the LER value decreases). Inspection of the remaining values yield an understanding of how the factors influence LER relative to one another and agree with real world expectations of model behavior.

The Analysis of Variance section of Figure 29 allows one to compare and predict the mean of the data compared to the equation of the model. This information combined with a visual examination of the Predicted Plot allow us to conclude that the model equation fits the data far better than predictions based upon the mean alone.

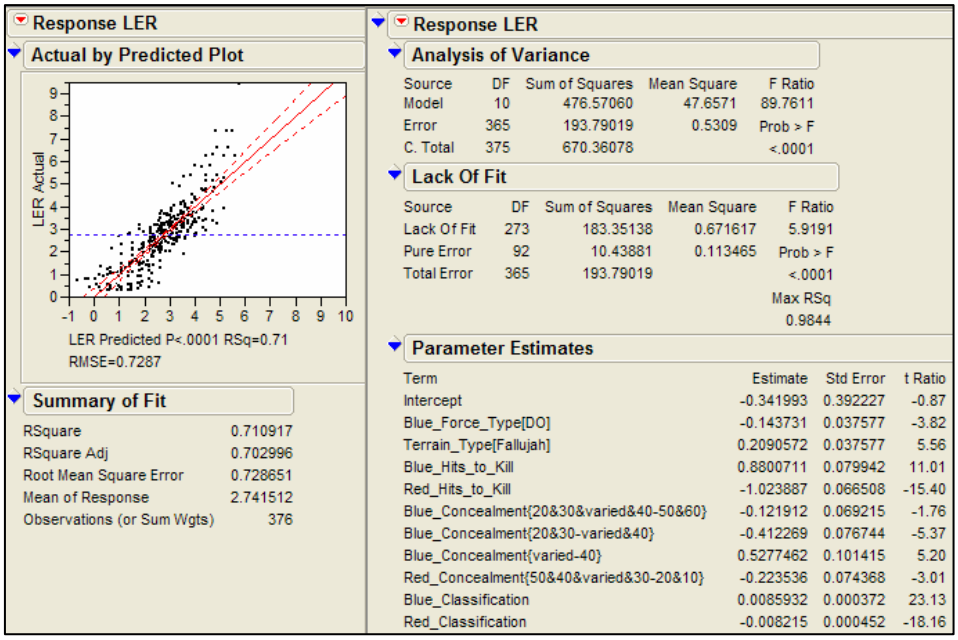


Figure 29. Regression Model of the Simulations

3. Classification Trees

The categorical LERs are used to examine the effects of different factors that influence the LER. They are an exploratory technique to examine the data structure captured from experiments. In the creation of classification trees, the data is partitioned, or separated, at the most significant factor at each split that partitions the variable space into regions that are increasingly similar (homogeneous.) (S-Plus 4 Guide to Statistics, 1997) The splitting point creates an upper and lower range of the factors that most significantly explains the MOE. Each level proceeds with a partition that differentiates the largest portion of the subset of data in question. The result is a set of prediction rules that allows the data to be screened and summarized quickly. Use of classification trees is a valuable method with this data since much of the data are categorical (terrain, clutter) that are not continuous. Figures 30 and 31 show two of the more telling pieces of trees produced by JMP 5.1. Each figure starts with a base node that contains all 12,400 LERs produced by the experiments.

Figure 30 examines all the variable factors that were examined in the experiments. Figure 30 shows that, above all other factors, the ability of the Blue Forces

to be able to classify other agents beyond 200 feet leads to higher (preferred) LERs, and this is where the first split in the data occurs. The diagram shows that the split that produced the most (internally) alike partitions occurs where Blue's Classification range crosses the 200 level. This means that Blue Classification, as modeled, is identified as the most important factor in determining the resulting LER from the simulation. The 1,680 results are most similar and the classification range in those runs is less than 200. The other 10,720 have a Classification range of 200 or greater. Additional splits occur at each level recursively to produce homogeneous branches and a limited number of these splits are included in the figure. Figure 30 shows that Red Classification is the second most important factor in the resulting LER.

Figure 31 also examines all 12,400 LERs, but only with respect to the factors of clutter, force type (DO or Traditional), and terrain (MOUT of Fallujah.) The effect of terrain is most pronounced. In this case, the first split is a result of the terrain that exists in the particular experiment: the split 6,200 of the MOUT experiments and 6,200 of the Fallujah experiments.

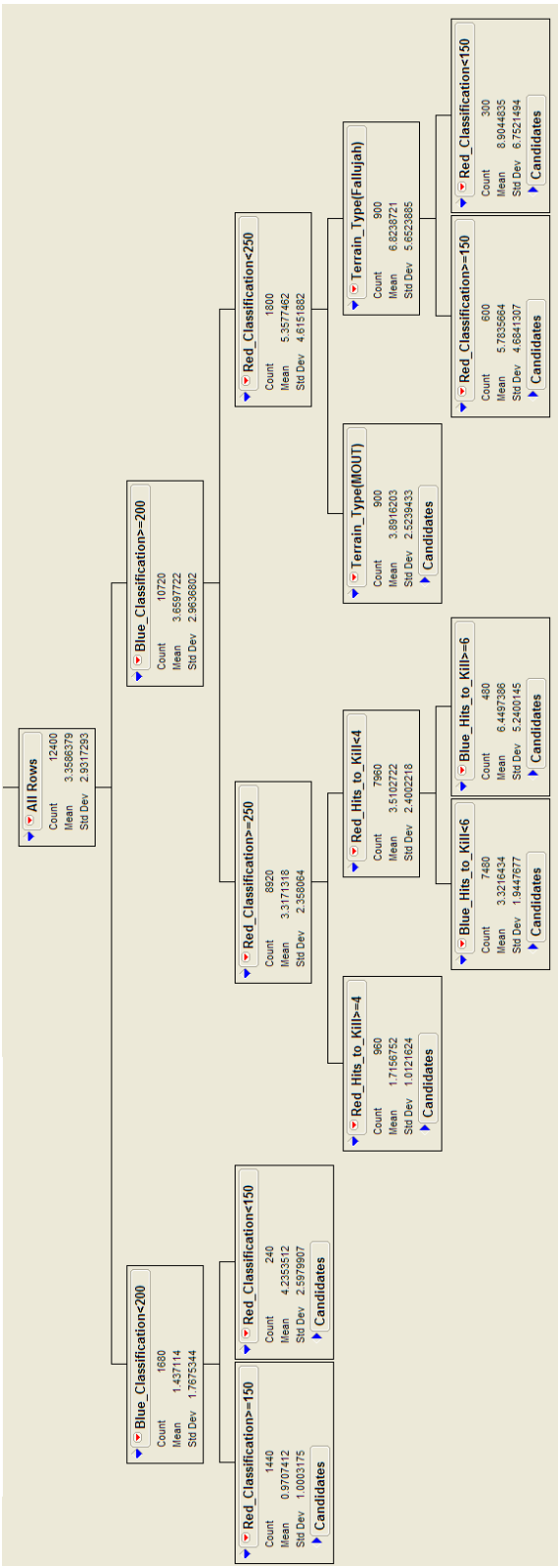


Figure 30. Classification Tree Shows Importance of Blue Classification Range

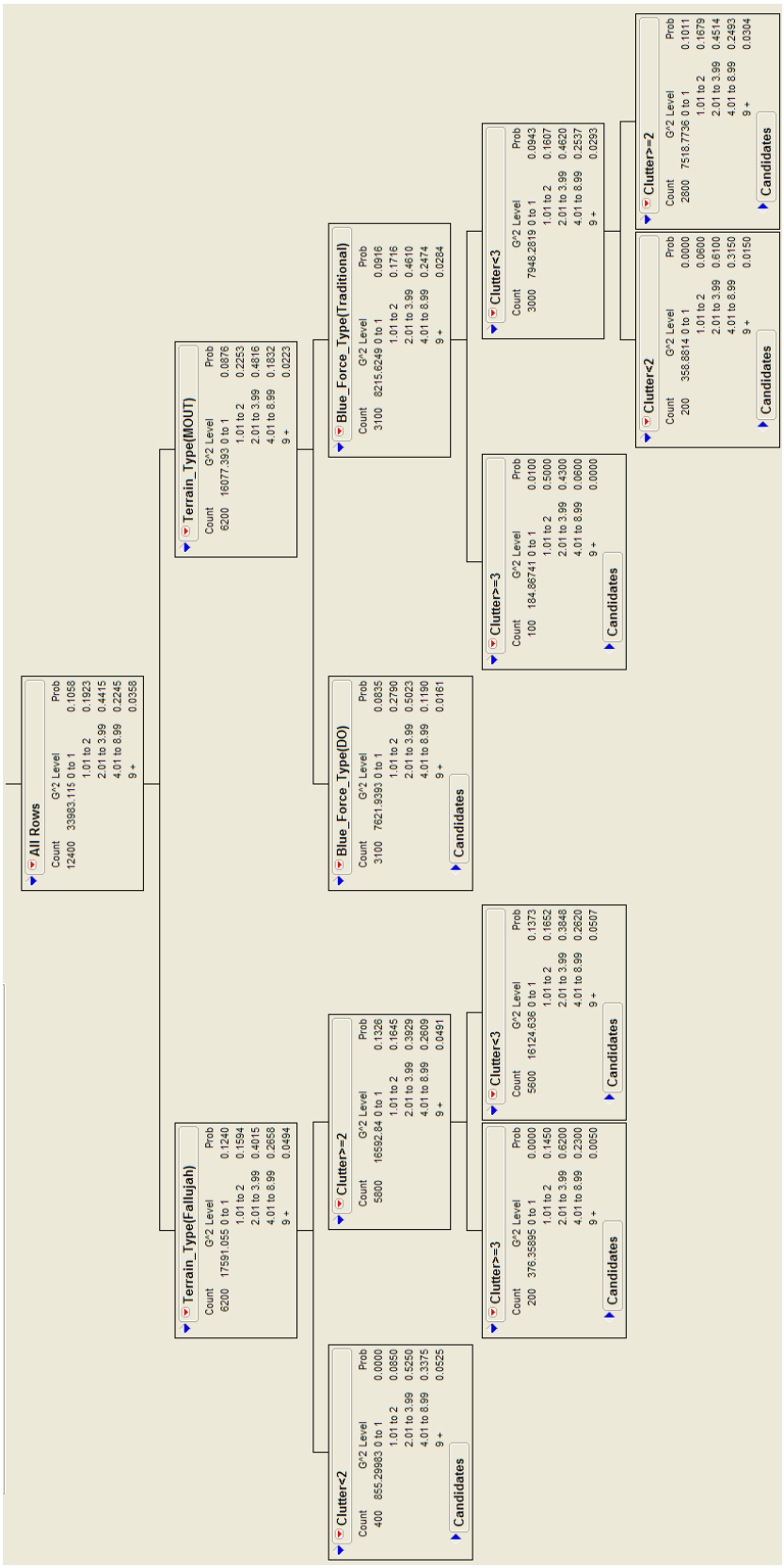


Figure 31. Classification Tree Shows Importance of Terrain over Force Type

4. Clutter Examined

The role of clutter is also explored. A washout effect is believed to exist in the full data set in regards to clutter since 90 percent of the data have the same level of clutter. In order to better examine the clutter effect a balanced sample of 1,600 observations are examined. From this examination, the effect of clutter when combined with the other factors is obvious.

Figure 32, produced in JMP 5.1, illustrates the relationship that is revealed through the regression of terrain and clutter against the response value LER. The relationship shows that lower levels of clutter lead to more favorable LERs for Blue. The explanation can be gleaned by observing the simulation as it runs. The agents act upon the targets they know and take the initiative to engage them intent on a quick kill. The agents pursue the known threats and appear to expose themselves to unknown threats. The higher level of clutter on the battlefield leads to a greater potential for unknown threats that could exist to actually exist.

The illustrated relationship also shows that the terrain effect, when combined with clutter, is different by an approximately constant value, as indicated by the parallel red and green lines. This too makes sense in that clutter is added to the terrain and intuitively one should agree that the ability to see and identify a target is not improved by adding additional obstructions to a set terrain and that the affect could be linearly related (or could equate) to a proportional reduction in LER.

The model created in which only clutter and terrain effects on LER are examined is not nearly as good as the one presented in Figure 29. This can be verified by comparing the adjusted *R*-squared value of 58.58% for Figure 33 to the 70.03% value obtained from the model in Figure 30.

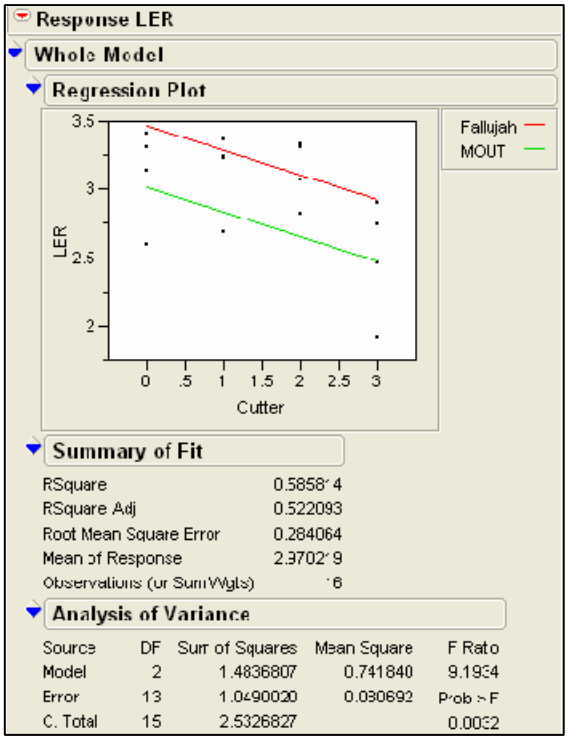


Figure 32. Effect of Clutter in Combination with Terrain Type on LER

Figure 33, also produced in JMP 5.1, illustrates the relationship that is revealed through the regression of Blue Force type (DO or Traditional) against clutter. It again shows that lower levels of clutter, lead to more favorable LERs for Blue. It also shows that the force effect, when combined with clutter is different by an approximately constant value, as indicated by the parallel red and green lines, but is not as significant as the terrain effect observed in Figure 33. The model created in this case in which only clutter and Blue Force type effects on LER are examined is also not nearly as good as the one presented in Figure 29. This can be verified by comparing the adjusted *R*-squared value of 28.05% for Figure 33 to the 70.03% value obtained from the model in Figure 30.

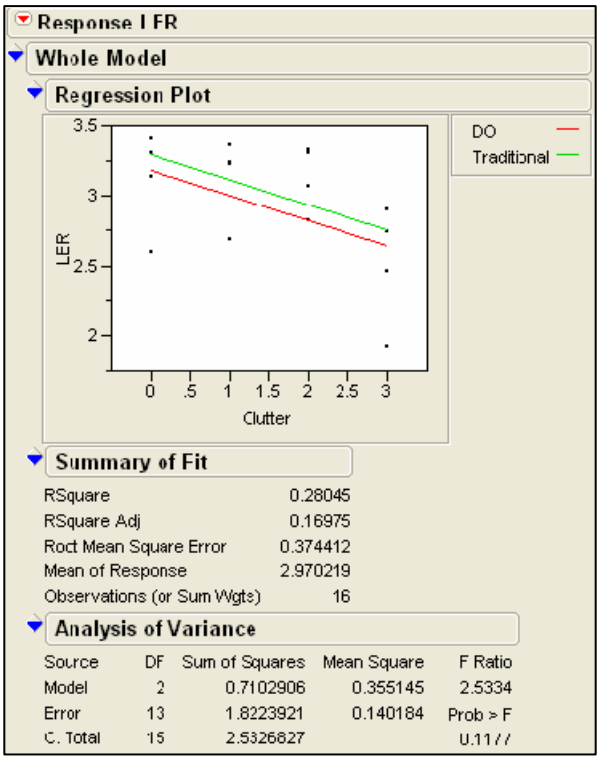


Figure 33. Effect of Clutter in Combination with Force Type on LER

F. SURVEY DATA ANALYSIS

1. Respondent Demographics

To gain insight and understanding of the impact of MOUT training to urban combat, 251 surveys were conducted. Figure 34 shows the histogram of the distribution of ranks and units information of those who completed surveys. Also provided in Figure 35 is clarification on the USMC military rank structure from highest rank (General) to lowest (Private) and the corresponding military grades (O-10 to E-1). Tags in the histogram correspond to abbreviated forms of the ranks (e.g., 1LT = First Lieutenant, MSGT = Master Sergeant). The prequalification criteria met by the respondents were that they were US Marines and were part of a unit that was involved in urban combat in Iraq. The figure shows that 68% of the respondents are Lance Corporals, E-3, and below. This compares favorably with the overall USMC population of 177,208 Active Duty Marines, of which 44 percent are Lance Corporals or below. (MCCS Demographics,

2005) Nearly one-third of the responses were received from the 1st Battalion, 7th Marines.

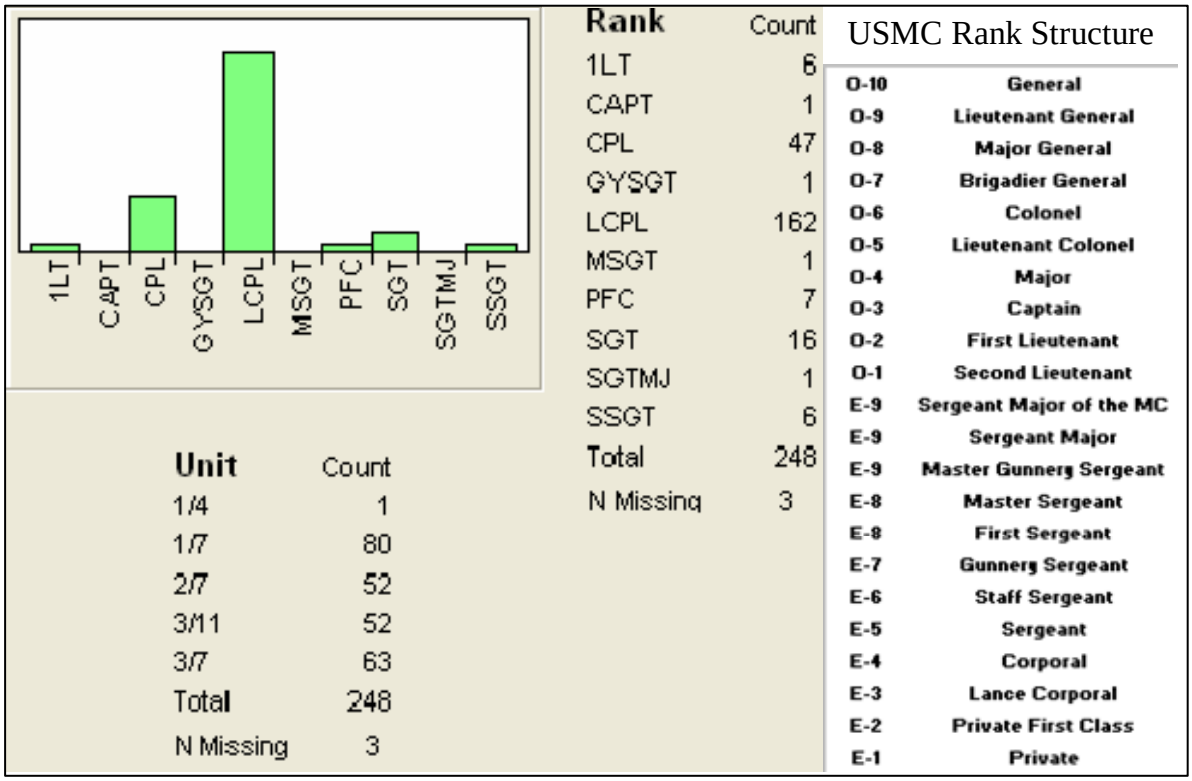


Figure 34. Demographics of Survey Respondents

Eighty-four percent of the respondents had three or fewer years of service and sixty-five percent had completed a single tour of duty Of the 251 respondents, 205 reported their level of combat experience to be, on average, in excess of 255 days. Of that, an average of more than 200 of those days were in urban combat. Approximately fifteen percent of the respondents reported that they did not receive MOUT training prior to their combat experience.

The survey itself was 134 questions in length and is provided in Appendix I. The survey questions are designed to gauge the perceptions that combat experienced Marines have of MOUT training.

2. Survey Data

The analysis of the full wealth of responses provided by the 135 questions is beyond the scope of this research. Trends apparent in the responses are focused upon here. Significant trends identified in the survey data are

- Ninety-five percent of the respondents reported that most casualties occurred outside of buildings.
- The highest proportion of the casualties occurred when troops were in clusters.
- An overwhelming majority of the Marines felt they were prepared for urban combat from MOUT facility training. Figure 36 from JMP 5.1 shows the histogram distribution of responses from the lowest level of "unprepared," to "prepared," then "proficient," and the highest level of "highly proficient."

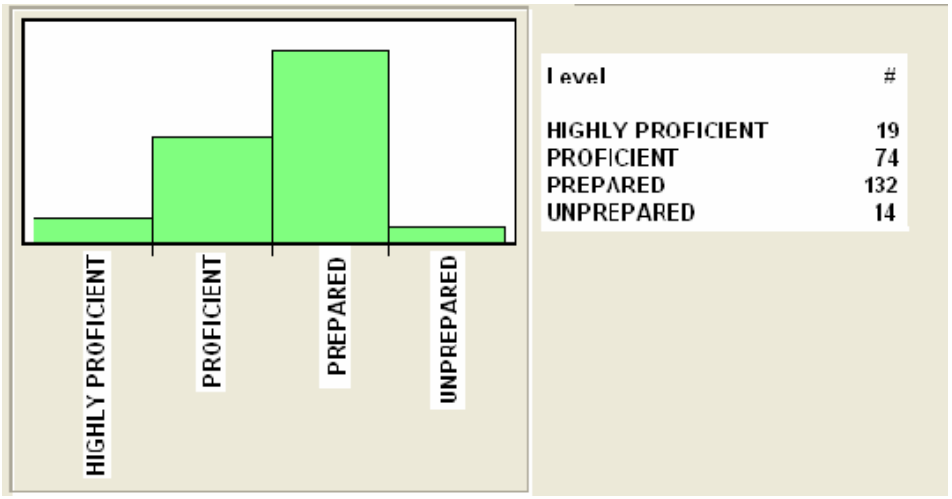


Figure 35. Level of Proficiency in Urban Combat Gained from MOUT Training

- In regards to the issue of MOUT facilities being large enough and realistic, the respondents tended to agree that the facilities were

sufficiently large and realistic. When asked if they felt the MOUT environment accurately depicted the urban environment where they fought, most said Iraq urban terrain was not accurately captured by the MOUT facilities. Figure 37, produced in JMP 5.1, shows the histogram distribution of the responses.

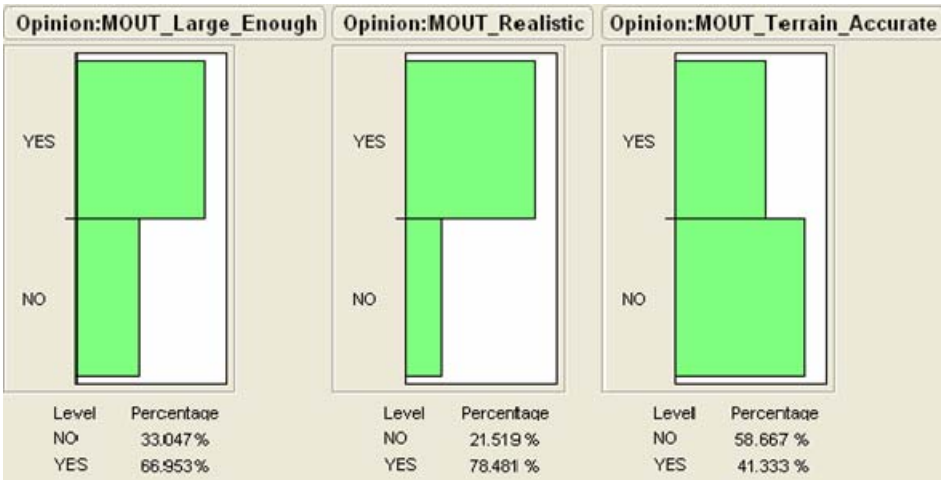
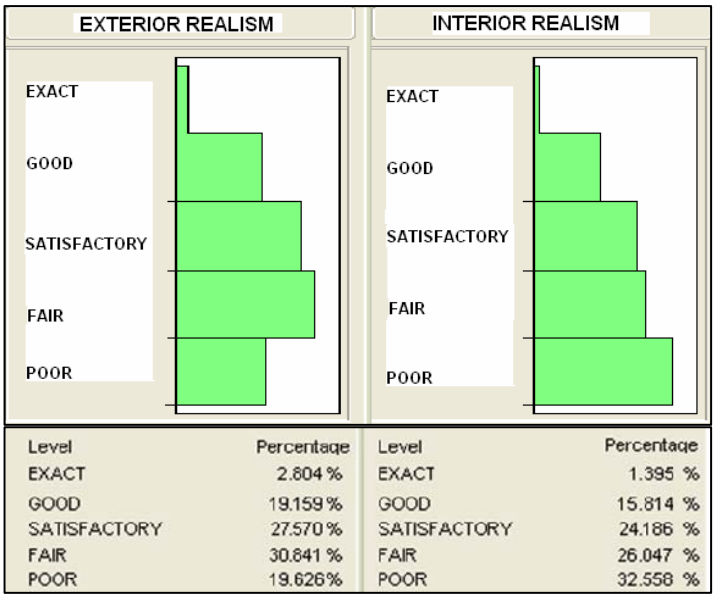


Figure 36. Survey Respondent Opinions regarding Size, Realism and Accuracy of MOUT Training Facilities

- When asked specifically regarding the exterior and interior of MOUT training facilities, a majority rated the realism in the poor to fair range. The distribution of the responses is captured in Figure 38 produced in JMP 5.1.



Level	Percentage
EXACT	2.804 %
GOOD	19.159 %
SATISFACTORY	27.570 %
FAIR	30.841 %
POOR	19.626 %

Level	Percentage
EXACT	1.395 %
GOOD	15.814 %
SATISFACTORY	24.186 %
FAIR	26.047 %
POOR	32.558 %

Figure 37. Survey Responses When Asked to Rate Interior and Exterior Realism of MOUT Facilities

VII. FINDINGS, INSIGHTS AND CONCLUSION

> War is the realm of uncertainty; three quarters of the factors on which action in war is based are wrapped in a fog of greater or lesser uncertainty….The commander must work in a medium which his eyes cannot see; which his best deductive powers cannot always fathom; and which, because of constant changes, he can rarely become familiar.
>
> —Clausewitz

A. OVERVIEW

This chapter translates the data analysis of the previous chapter into conclusions and findings. Significant and meaningful relationships are identified and justification for observed phenomena is provided. As is typical of research, in seeking to answer the research questions at hand, many new areas of potential research have been uncovered. The final chapter of this document summarizes the key areas that can benefit from additional research.

B. BASELINE MODEL CONCLUSIONS

The Wilcoxon signed-rank and the Kruskal-Wallis tests agreed that each of the four main samples are statistically significantly different from all the others (e.g., the results of DO is different from the results of Traditional Platoon results, and that the results obtained from operations on Fallujah are statistically significantly different than those from the MOUT terrain.)

The following graphic of Figure 38 prefaces the full explanation of the differences to aid in understanding the JMP output called the “means diamonds” plot. The dots represent each of the individual experimental runs. The spread of the values from high to low in each experiment is due only to the stochastic elements of the model. The diamonds create a 95% confidence interval for the estimated mean and overlays the data

points. This confidence interval can then be compared to other mean confidence levels and conclusions regarding significant differences can be drawn. The *y*-axis is the LER of the observation. The *x*-axis is the factor of concern. The vertical column of dots represents the individual observations. The upper and lower bars are called the "overlap bars" and are used to determine statistical significance when comparing the means of multiple samples.

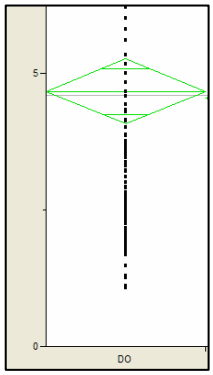


Figure 38. Example Diamond Plot

Although the previous chapter proved that the samples are drawn from statistically different populations, the meaning of this was deferred to this chapter. Figure 39, in conjunction with Table 16, allows an interpretation of the differences. The Fallujah terrain leads to a higher average LER regardless of force type. The DO force performs better in an environment where the structures are not as concentrated. This is reflected in the data that shows a lower LER for DO in MOUT (a terrain with denser structural clusters) than in Fallujah. The data show that the effect is apparent in the Traditional force as well, but not to as great a degree.

The possible reason, obtained from visual examination of model runs, is that the additional information available to the DO force may cause it to expose itself to unknown threats while pursuing one identified through its enhanced situational knowledge. A difficulty faced by any simulation is that the system operates on logic and responds to the known elements in their environment. Technology does not currently allow the simulation of many battlefield variables that a Marine in combat actually acts upon. An

additional conclusion is that a Traditional force is less affected by variations in terrain, but at the expense of not being able to attain as high an LER as the DO force.

EXPERIMENT	MEAN (LER)
DO Fallujah	5.835
DO MOUT	3.460
Traditional Fallujah	4.810
Traditional MOUT	4.262

Table 16. Sample Means

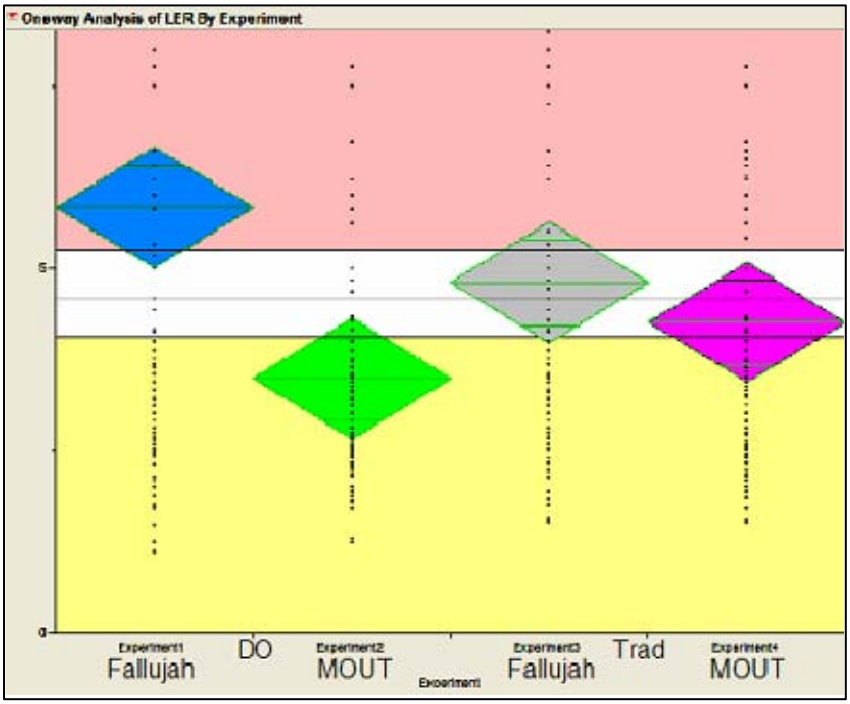


Figure 39. Comparative Diamond Plots

C. SENSITIVITY ANALYSIS INSIGHTS

1. Regression

The regression equation with an adjusted *R*-squared of 0.7 can be considered a relatively good model. The adjusted *R*-squared means that 70% of the total squared error is explained by the model. The remaining 30% is unexplained squared error.

The model itself conforms to the behavior expected. As Blue concealment, Blue hits to kill, and Blue classification range increase, the LER increases. The model also agrees with the conclusion that LER is higher on Fallujah terrain.

2. Classification Trees

The classification tree in Figure 34 shows that when considering the full set of data that Blue Classification range is the principal influence on the resulting LER. This is followed by the Red classification range. This makes sense since the ability to classify an agent corresponds with being able to engage the enemy, especially in close quarters and quickly evolving urban terrain. Improvements to engagements to either side should directly impact LER as the classification tree indicates.

The classification tree in Figure 35 examines only the effects of the factors of clutter, terrain and force type. It shows that the terrain effect is the dominant effect over the other two. This is followed by force type. This is not altogether surprising since 90% of the clutter values are the same, and this may dilute the effect of clutter.

3. Clutter Examined

The effect of clutter and terrain on LER was investigated by regression. The relation is illustrated in Figure 36 in the last chapter. The parallel lines indicate that the clutter effect has a negative correlation to LER, as clutter increases, LER decreases.

Also, when combined with a particular terrain, the difference caused by the clutter appears to be nearly constant.

D. SURVEY INFERENCES REGARDING POPULATION

The survey responses identified that Marines noted a lack of realism in MOUT training facilities and a large portion felt that the facilities did not accurately capture the features of the terrain encountered in Iraq.

Further research is recommended to determine the impact of MOUT realism to the quality and level of proficiency a Marine receives from MOUT facility training.

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. RECOMMENDATIONS FOR FUTURE STUDIES

The many facets of this research have provided a wealth of topics worthy of follow-on work. The topics fall into three general categories: Survey analysis, existing model work, and new model exploration. The topics can be explored from a Distributed Operations point-of-view, urban combat point-of-view, a MOUT Training Facility point-of-view, or any combination of the three.

A. SURVEY ANALYSIS

The 251 completed surveys contain a collection of open-ended questions that can be explored and translated into the modeling environment or contrasted to design points in MOUT training facilities. The categorical survey data can also be analyzed to identify trends and insights from the combat experience responses (specifically direct fire engagement ranges and casualty locations).

B. EXISTING MODEL WORK

The current model can be modified to explore field of view (how much of the surrounding area can actually be observed by an agent based upon the direction that agent is facing) and range of view (the distance away from an agent that can be observed by that agent) effects on unit movement rates in the urban environment. The effect of road width, alleys, and dispersion of troops on movement rates in different urban environments can be examined. Another modification could be done to identify the practical minimum or optimal proximity limit to the target for employing various types of indirect fires. Research can be performed with the current model to explore whether better sensors and communication affect the ratio of direct-fire engagements to indirect fire. Research can also be conducted with the model to find the relationship between troop dispersion and casualty rates. The current model can also be run through different urban combat scenarios from Iraq to see if additional insights can be gained. The current

model can also be used to explore various tactics that may be appropriate for DO forces or that may enhance Traditional force urban combat operations.

C. NEW MODEL EXPLORATION

The current model can be explored by being recreated in the Pythagoras, Combat XXI modeling, and other modeling environments. Each environment has different strengths that could more readily explore concepts like interactive influences between different types of agents (e.g., allegiance changes). A different modeling environment can also model how multi-level structures change the threat environment for mounted and dismounted troops.

A model could be created to explore casualties effects from urban combat weapons employment in daylight versus night combat operations, with and without optics. The concept of an embedded media effect could also be explored.

APPENDIX A: ORGANIZATION INVOLVED IN URBAN MODELING AND SIMULATION

Urban Operations Summit IV was held on 19-21 January 2005. The event included a keynote address from Dr. Russell Glenn, RAND, renowned urban operations expert and perspectives from senior leaders representing the Joint, Army and USMC communities. The following list contains organizations that attended this conference and articulated the emphasis and efforts being put into the modeling and simulation of urban environments. Much of the presentation material and lessons learned shared in side-bar discussions with modeling experts throughout the DoD assisted the author to comprehend the urban environment and the challenges faced in modeling it.

Organization Involved in Urban Modeling and Simulation	
RAND Corporation	US Army Engineer Research and Development Center (ERDC)
MITRE Corporation	
Natick Soldier Center (NSC)	Night Vision and Electronic Sensors Directorate (NVESD)
Center for Army Analysis (CAA)	
Sandia National Laboratories (SNL)	Deputy Under Secretary of the Army (Operations Research) (DUSA (OR)
Applied Research Laboratory (ARL)	
Air Force Research Laboratory (AFRL)	Joint Precision Strike Demonstration/Joint Virtual Battlespace (JPSD/JVB)
Joint Forces Command (JFCOM) J7 & J9	
National Ground Intelligence Center (NGIC)	US Army TRADOC Project Officer for One Semi-automated Forces (TPO OneSAF)
USMC Studies and Analysis (S&A) Division	
Marine Corps Warfighting Laboratory(MCWL)	US Army TRADOC Project Officer for One Semi-automated Forces (TPO OneSAF)
US Army Model and Simulation Office (AMSO)	
Defense Modeling and Simulation Office (DMSO)	Centre for Defence Analysis Defence Evaluation Research Agency (CDA DERA (UK))
US Army Special Operations Command (USASOC)	
Army Materiel Systems Analysis Activity (AMSAA)	US Army Program Executive Office for Simulation, Training, & Instumentation (PEO STRI)
Headquarters Department of the Army, G3 (HQDA G3)	
Intelligence Center, Space Based Laser (USAIC/SBL)	Enterprise Database Integrated Product Teams, Topographic Engineering Center (EDB IPT (TEC))
Marine Corps Concept Development Command (MCCDC)	
Defense Advanced Research Projects Agency (DARPA)	Research Development and Engineering Command & Simulation Technology Center (RDECOM-STC)
Logistics Focus Area Collaborative Team (LOG FACT)	
Air Force Agency for Modeling and Simulation (AFAMS)	Command and Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance Focus Area Collaborative Team (C4ISR FACT)
Training And Doctrine Command (TRADOC)	
Training And Doctrine Command (TRADOC) Futures	
TRADOC Analysis Center (TRAC), Monterey	American, British, Canadian, and Australian Armies' Program Special Working Party on Advanced Terrain Technology (ABCA SWP/ATT)
TRADOC Analysis Center (TRAC), White Sands Missile Range	
USMC Training, Exercises, and Military Operations (TEMO)	

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B: INCOMPLETE TABLE OF MOUT FACILITIES

This table contains some of the many MOUT facilities available to US Military Forces for training that were examined in the course of this research and basic statistics associated with each. This table is not comprehensive and cannot be considered completely accurate as facilities are being built and expanded each year. In fact the US Army intends to build up to 80 new MOUT sites by 2009.

Location—Name	**Size**
(1) Fort Polk—JRTC Shuttgart-Gordan MOUT	8km x 7km, 42 buildings
(2) Fort Campbell—Cassidy MOUT site	No specific information
(3) Fort Bragg—Fort McClellan MOUT	5 blocks, 32 buildings
(4) Fort Drum	33 buildings
(5) Fort Hood—St. Elijah MOUT	No specific information
(6) Fort Lewis—Leschi Town MOUT	85-acre, 50 buildings
(7) Schofield Barracks	20 buildings
(8) Fort Stewart—Em Karo Village	9 buildings
(9) Fort Benning—McKenna MOUT	16 buildings
(10) MCB Quantico—Combat Town	14 buildings
(11) Fort Irwin—National Training Center (NTC)	No specific information
(12) Camp Pendleton	Small village
(13) 29 Palms MC Air Ground Combat Center	140 buildings
(14) Fort Richardson	990-acre IPBC; 200-acre ISBC
(15) Fort Knox—Zussman Village	30-acre city, 21 buildings
(18) Fort Carson	16 buildings
(19) Camp Lejeune	30 buildings
(20) Camp Blanding	16 buildings
(22) Camp Hansen	No specific information
(24) NAS North Island	No specific information
(25) Fort Wainwright	17 buildings
(26) Camp Dawson	Airfield with terminal buildings
(27) Kuwait—Udairi training range	20 km by 27 km, mock buildings
(28) South Korea—Yongtari MOUT	small city block
(30) Southern California Logistics Airport (SCLA)—Victorville	200 acres
(31) Camp Bullis, Texas	26 acres, 19 buildings
(33) Fort Leavenworth	No specific information
(34) The Urban Target Complex (UTC)—Yodaville	178 Buildings
(35) Strategic Operations' Lot at San Diego Studios	4 acres

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C: CASUALTY FIGURES

This appendix contains the month-to-month casualty figures that resulted from combat operations in Iraq from March 2003 through January 2005. The month of November is the portion of the data concerned with this research. The other information is provided to give the reader perspective on the casualties experienced in the period leading up to and following Operation al-Fajr.

U.S. Casualties in Iraq

GlobalSecurity.org

Month	US Named Dead *	US Reported Dead **	US Wounded *** ****	US Army Evacuations from Iraq		
				Wounded In Action *****	Non-Battle Injury *****	Disease *****
March 2003	65	0	202			
April 2003	73	0	340			
TOTAL	138	0	542			
May	37	0	54			
June	30	0	147			
July	47	0	225			
August	35	0	181	930	3212	5846
September	30	0	247			
October	43	0	413			
November	82	0	337			
December	40	0	261			
January 2004	47	0	187			
February	19	0	146			
March	52	0	322	49	206	367
April	135	12	1205	203	355	262
May	80	8	753	106	348	146
June	42	2	573	141	138	389
July	54	7	551	71	157	337
August	66	5	883	139	74	379
September	81	3	699	122	84	391
October	63	5	637	100	94	457
November	137	3	1350	149	96	323
December	72	1	489			
January 2005	79	17	391			
Subtotal	1409	29	10372	1639	4490	7726
TOTAL	1,438			15,671		

* Includes both hostile killed and non-hostile killed
** Reported Killed but Unidentified Pending Notification of Next of Kin
*** Included both Wounded in Action and non-hostile prior to 01 Apr 04
**** Includes only Wounded in Action since 01 Apr 04
***** Excludes all non-Army troops, and all troops treated in theater

http://www.globalsecurity.org/military/ops/iraq_casualties.htm

additional details available at

http://www.globalsecurity.org/military/ops/iraq_casualties_notes.htm

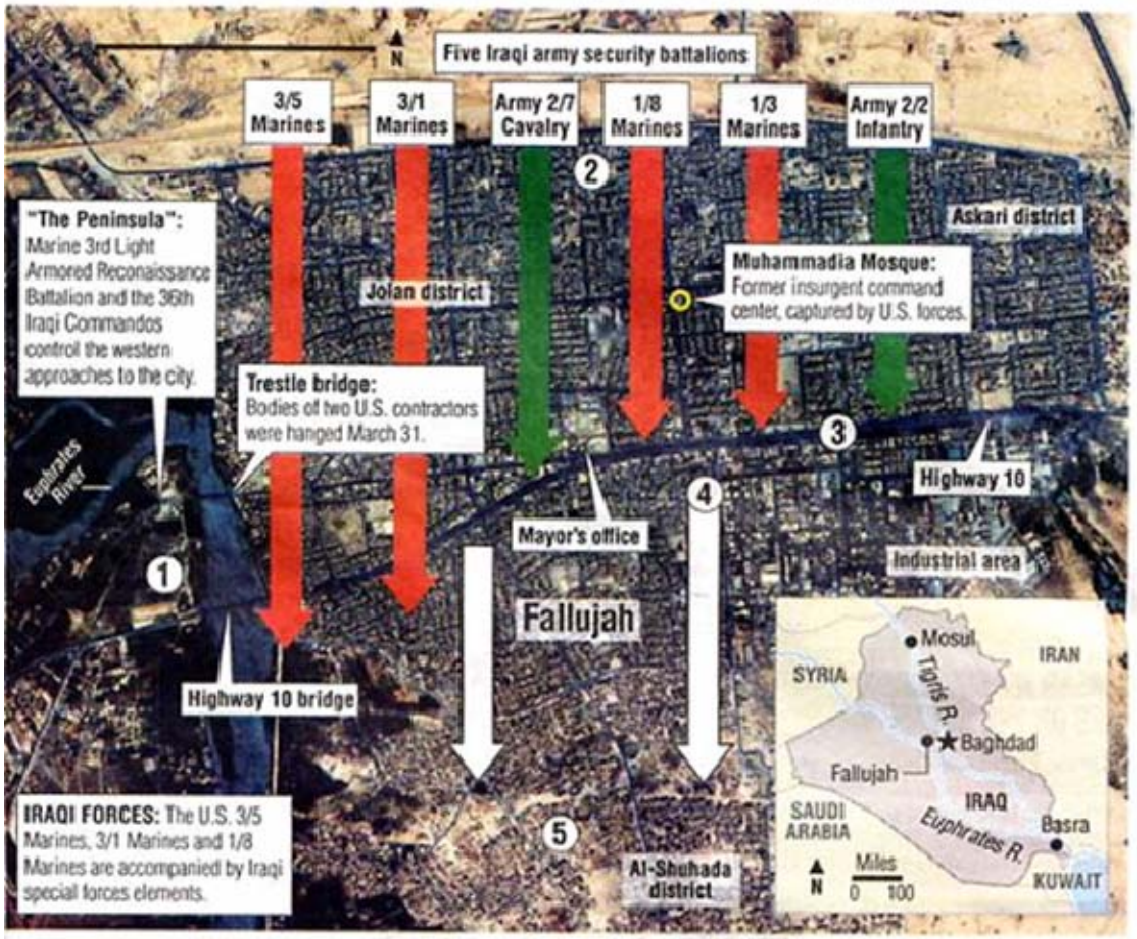
THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D: FOUR DAYS OF OPERATION DAWN

This appendix is an excerpt from the November 22, 2004 edition of the *Marine Corps Times* that provides an overview of the events of Operation al-Fajr.

FOUR DAYS OF OPERATION DAWN

After four days of fierce fighting that began Nov. 8, six Marine and Army battalion combat teams, reinforced by armor and engineer support, had pushed down from the northern edge of the insurgent stronghold of Fallujah to capture about 80 percent of the city, as of the evening of Nov. 11. Marines and Iraqi commandos control the western approaches, while an Army brigade combat team is arrayed to the south and southeast.



1. Late Nov. 7, U.S. and Iraqi forces secured two bridges and a hospital west of the city.
2. Six battalions began the attack Nov. 8, entering the city from the north. U.S. officers said they breached the outer defenses and fought their way into the city, initially encountering strong resistance. By Nov. 9, insurgents had broken into smaller cells and were roaming the city.
3. On Nov. 9, U.S. forces reached the main east-west highway that splits the city.
4. On Nov. 10, U.S. troops pushed south of the highway and consolidated their gains after capturing most of the city in three days. The mayor's office and several other key objectives were secured.
5. By Nov. 11, U.S.-led forces had pushed into Fallujah's southern districts and controlled about 80 percent of the city.

Sources: Globalsecurity.org; Space Imaging Middle East; and wire reports

SATELLITE IMAGE BY SPACE IMAGING MIDDLE EAST, GRAPHIC BY USA TODAY

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX E: OPERATION ORDER (OPORD) CONTENT

Adapted from FMFRP 0-6, Marine Troop Leader's Guide, PCN 140 000060 00 in order to acquaint the reader with the format. This appendix describes the general format for an Operation Order (OPORD) used in Crisis Action Planning (CAP). This order is prepared and issued in a clear and concise manner and is preceded by a thorough orientation of the area of operations.

SITUATION: Briefly state the general picture to apprise subordinate commanders of the current situation.

a. Enemy Forces: Summary of enemy information that may affect the accomplishment of the mission. This can include

- composition
- disposition
- location
- movements
- estimated strengths
- identification
- capabilities

Important factors to include in the summary:

- Time: Time of enemy intelligence
- Size: Size of enemy (i.e. squad, battalion, number of enemy)
- Unit: Unit they are serving (i.e. Republican Guard)
- Activity: What the enemy is doing (i.e. Preparing position)
- Location: Position
- Equipment: Weapons they have access to
- DRAW-D: what are the most likely/dangerous enemy courses of action upon contact (Defend, Reinforce, Attack, Withdraw, Delay)

b. Friendly Forces: Gives information on friendly HAS-S (higher, adjacent, supporting, and security) forces that may directly affect the action of subordinate commanders. These forces include those not attached or those organic to the command for the contemplated operation, but whose presence on a flank or other adjacent area is of interest.

MISSION: A clear and concise statement of the mission to be accomplished by the unit. Emphasize the purpose of the mission with the Five W's (Who, What, When, Where, Why).

EXECUTION: Summarizes the overall course of action intended, or concept of operations.

a. Commander's Intent: The commander's intent is a clear, concise statement that defines success for the force as a whole by establishing, in advance of events, the desired

result. The section contains: the purpose of the operation; the critical vulnerabilities and center of gravity for both enemy and friendly forces; a vision of how the operation will be conducted in a broad scope; a description of the result with respect to the relationship of the force, the enemy, and the terrain; and a description of how the result will facilitate future operations.

b. Concept of Operations: Briefly describes how the commander visualizes the execution of the operation from start to completion. Accurately conveys to subordinates the commander's intent (end state of the mission/battle, purpose of the mission) so that mission accomplishment is possible in the time available and in the absence of additional communications or further instructions. The concept should set forth the phases of the operation; schemes of maneuver for major subordinate task elements that describe precisely what the commander expects to be done; general plans for employment of supporting fires and weapons, including nuclear and chemical weapons; and the general plan for the landing force in amphibious operations. Specifically the enemy's critical vulnerability and how this critical vulnerability will be exploited.

c. Tasks: Assigns missions to each committed organic unit in numerical or alphabetical sequence followed by the attached unit(s). Specifically identifies the unit that is designated the main effort for this order.

d. Reserve: Designates and assigns a mission to the reserve unit.

e. Coordinating Instructions: The last paragraph in the execution section contains coordinating instructions pertaining to two or more elements of the task organization. This includes boundaries, objectives lines of departure, time and direction of attack, and other specifics needed to coordinate the activities of different task elements. Other information is also included (e.g., reporting instructions, anticipated time of execution (D-day and H-hour — day and hour action is initiated), when the order becomes effective for planning and/or execution (typically immediately)).

ADMINISTRATION AND LOGISTICS: Contains instructions regarding rations, ammunition, EPW handling and evacuation, aid station, resupply, control of civil population, refugees and administrative matters. Only necessary information is included.

COMMAND AND SIGNAL:

a. Communications/signal instructions and information.

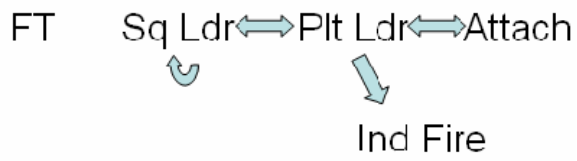
b. Location of the unit commander/leader and the next higher unit commander/leader.

APPENDIX F: FORCE COMMUNICATION NETWORKS

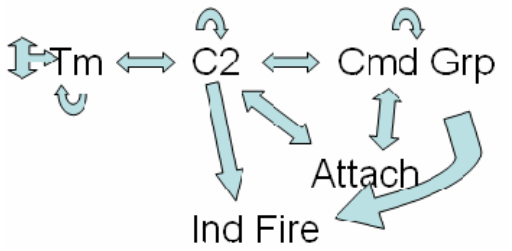
This appendix provides a graphical depiction of the communication links that exist in each particular type of unit as modeled in MANA.

Note: An absence of an arrow between different units indicates that there are no direct links between those units (i.e. in the first diagram, the FT has no communication links to any other unit.)

(1) Traditional Infantry Platoon Communication Links



(2) Distributed Operations Platoon Communication Links



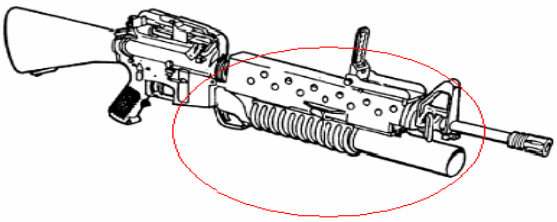
(3) Insurgent Forces Communication Links

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX G: WEAPONS CHARACTERISTICS

This appendix provides the manufacture specifications for the weapons modeled in the simulation. The data comes from GlobalSecurity.Org.

Weapon:	M16A2 Semiautomatic Rifle
Primary Functions	Infantry weapon
Manufacturer:	Colt Manufacturing and Fabrique Nationale Manufacturing Inc
Length (in cm):	100.66
Weight (in kg):	3.99
Bore Diameter (in mm):	5.56
Ranges (in meters)	
Minimum:	0
Max Effective Area Target:	800
Max Effective Point Target:	550
Maximum:	3,600
Muzzle Velocity (m/sec):	853
Rates of Fire (per minute)	
Cyclic:	900
Sustained:	12
Semiautomatic:	45
Burst:	90
Magazine Capacity:	30
Unit Replacement Cost ($):	588



Weapon:	M203 40mm Grenade Launcher
Primary Functions	Infantry Weapon
Manufacturer:	
Length (in cm):	30
Weight (in kg):	1.36
Bore Diameter (in mm):	40
Ranges (in meters)	
Minimum:	31
Maximum Area Target:	350
Maximum Point Target:	150
Maximum:	400
Muzzle Velocity:	76
Rates of Fire (per minute)	
Cyclic:	
Sustained:	5
Semiautomatic:	
Burst:	
Magazine Capacity:	36 (combat load)
Unit Replacement Cost ($):	601

Weapon:	M40A1 Sniper Rifle
Primary Functions	Infantry Weapon
Manufacturer:	special armorers at Quantico, Va
Length (in cm):	44
Weight (in kg):	6.58
Bore Diameter (in mm):	7.62
Ranges (in meters)	
Minimum:	0
Maximum Area Target:	
Maximum Point Target:	914
Maximum:	
Muzzle Velocity:	777
Rates of Fire (per minute)	
Cyclic:	
Sustained:	
Semiautomatic:	
Burst:	
Magazine Capacity:	5
Unit Replacement Cost ($):	2,105

Weapon:	M249 Squad Automatic Weapon
Primary Functions	Hand-held combat machine gun
Manufacturer:	Fabrique Nationale Manufacturing, Inc.
Length (in cm):	103.81
Weight (in kg):	6.88
Bore Diameter (in mm):	5.56
Ranges (in meters)	
Minimum:	0
Max Effective Area Target:	1,000
Max Effective Point Target:	800
Maximum:	3,600
Muzzle Velocity (m/sec):	
Rates of Fire (per minute)	
Cyclic:	650
Sustained:	85
Semiautomatic:	
Rapid:	200
Magazine Capacity:	200
Unit Replacement Cost ($):	4,087

Weapon:	MK19 40mm Machine Gun
Primary Functions	Infantry,Vehicle-mounted Weapon
Manufacturer:	Saco Defense Industries
Length (in cm):	109.47
Weight (in kg):	62.43 (gun/cradle/tripod)
Bore Diameter (in mm):	40
Ranges (in meters)	
Minimum:	
Maximum Area Target:	1600
Maximum Point Target:	
Maximum:	2200
Muzzle Velocity:	240.69
Rates of Fire (per minute)	
Cyclic:	325
Sustained:	40
Semiautomatic:	
Rapid:	60
Magazine Capacity:	
Unit Replacement Cost ($):	13,758

Weapon:	MK 153 Shoulder-Launched Multipurpose Assault Weapon (SMAW)
Primary Functions	Portable anti-armor rocket launcher
Manufacturer:	
Length (in cm):	137.16
Weight (in kg):	16.6
Bore Diameter (in mm):	83
Ranges (in meters)	
Minimum:	
Max Effective Area Target:	500
Max Effective Point Target:	250
Maximum:	
Unit Replacement Cost ($):	13,000

Weapon:	AKM (AK-47) Rifle
Primary Functions	Infantry Weapon
Manufacturer:	LZh
Length (in cm):	87
Weight (in kg):	3.8
Bore Diameter (in mm):	7.62
Ranges (in meters)	
Minimum:	
Max Effective Area Target:	300
Max Effective Point Target:	350
Maximum:	
Muzzle Velocity (m/sec):	710
Rates of Fire (per minute)	
Cyclic:	500
Sustained:	
Semiautomatic:	40
Rapid:	100
Magazine Capacity:	30
Unit Replacement Cost ($):	390

Weapon:	RPG-7 Rocket Propelled Grenade
Primary Functions	Shoulder-Fired Anti-tank Weapon
Manufacturer:	
Length (in cm):	950
Weight (in kg):	7.9
Bore Diameter (in mm):	85
Ranges (in meters)	
Minimum:	
Max Effective Area Target:	500
Max Effective Point Target:	300
Maximum:	920
Muzzle Velocity (m/sec):	140
Rates of Fire (per minute)	
Cyclic:	6
Sustained:	4

APPENDIX H: MANA WORKSHEETS

The many pages of this appendix allow the reader to recreate the models settings used in this research. The intent is to facilitate follow-on research. The MANA Model and this spreadsheet tool can be requested from TWLucas@NPS.edu

Terrain	going	cover	conceal
Walls	0.05	0	0.93
Interior	0.3	0.3	0.4
Exterior	0.75	0.26	0.3
Roads	1	0	0

CONFIGURE BATTLEFIELD SETTINGS

MAP SCALE

	X	Y	JUSTIFICATION
Number of Cells:	607	540	apprx 1 foot
Real World Range Min:	0	0	
Real World Range Max:	185	165	
Manage New Contact By:	Agent Location		Speedier - fog of war
When Agent is Shot Remove Corresponding Map Contacts By:	Underlying Contact ID		Speedier - fog of war
Contact Aggregation Radius:	6.56	2 meters	
LOS Mode	Simple		
Real World Elevation Range:	Min = 0	Max = 5	doesn't matter: no slope involved in model
Terrain Effect Range	33	10 meters	
Move Selection	Stephen Algorithm		

Best Move	**Precision**
Move Precision	**200**

Genral Movement Settings

	Multiple Agents in Cell
X	Diagonal Motion Correction
X	Navigate Obstacles
	Squad Moves Together
X	Going affects speed and Terrain affects LOS

Calculations

Hours In Scenario	Minutes In Scenario	Seconds In Scenario	Steps per Second	Steps in Scenario	Steps per min
7	420	25200	**1**	25,200	60

m on X axis of Terrain Map	m on Y axis of Terrain Map	Total m^2 in Map
185	165	30525

meters per grid squad	Grid Squares on X axis of Terrain Map	Grid Squares on Y axis of Terrain Map	Total Grid Squares in Map
0.304777595	607	540	327780

Start #		End #	UNIT	COUNT	# agents	moving parts	weapon 1	total entites	total agents
1	-	3	Red Insurgent	3	5	15	AK47		
		4	Red Riflemen	1	4	4	AK47		
		5	Red Mortars	1	1	1	82mm		
		6	Red MG Team	1	1	1	.50 Cal MG	18	33
7	-	15	Red Rocketeer	9	1	9	RPG		
		16	Red Scout	1	1	1	AK47		
		17	Red IED Scout	1	1	1	AK47		
		18	IED	1	1	1	IED		
		19	Yellow Civilian	1	75	75		1	75
		20	Green Media	1	2	2		1	2
		21	Blue Recon Tm	1	6	6	M16A2		
		22	Blue Sniper Tm	1	1	1	M82A1A		
		23	Blue Howitzer/Mortar Tm	1	4	4	Indirect Fire	7	15
24	-	25	Blue Machine Gun Tm	2	1	2	Machine Gun		
26	-	27	Blue SMAW Tm	2	1	2	MK153		
28	-	36	Blue Infantry Rifleman	9	2	18	M16A2		
37	-	45	Blue Infantry SAW	9	1	9	SAW		
46	-	54	Blue Infantry M203	9	1	9	M203	31	44
55	-	57	Blue Infantry Squad Ldr	3	1	3	M16A2		
		58	Blue Infantry Platoon Cmd	1	5	5	M16A2		
59	-	64	Blue DO Rifleman	6	2	12	M16A2		
65	-	70	Blue DO SAW	6	1	6	SAW		
71	-	76	Blue DO M203	6	1	6	M203	23	44
77	-	79	Blue DO Team C2	3	4	12	M16A2		
80	-	81	Blue DO Command Group	2	4	8	M16A2		
				81		213			

Summary	Traditional mix 1 agents	DO mix 2 agents
entities	58	50
total agents	169	169

U.S. officials estimated that 2,000-3,000 hardcore insurgents were entrenched in the city at the time the assault began.
American commanders said U.S. troops and Iraqi Security Forces secured the neighborhood of Jolan in the northwestern part of the city with less re
U.S forces also saw a lack of resistance by insurgents as they captured and crossed Fallujah's main east-west highway.
U.S. Military officials reported that as of 11 November 2004, at least 18 American service members and five Iraqi soldiers had been killed in the assa
164 American and Iraqi troops had been wounded and an estimated 600 insurgents killed.

Source: http://www.globalsecurity.org/military/world/iraq/fallujah.htm

Source: http://www.globalsecurity.org/military/ops/oif-phantom-fury-fallujah.htm

10%	270,000	civilians	27,000		Insurgent Zone			3000	x	3500	=	10500000	percentage
		red force	2,700		Area of Interest	185 m by 165 m		185	x	165	=	30525	0.29%
					so roughly 1/3% of city is my concern								
		civilians	78										
		red force	8		if uniformly distributed - not: outer crust defense... means higher desity in this zone than a uniform dist.								
				16	twice density								
				24	three times density								
				31	four times density								

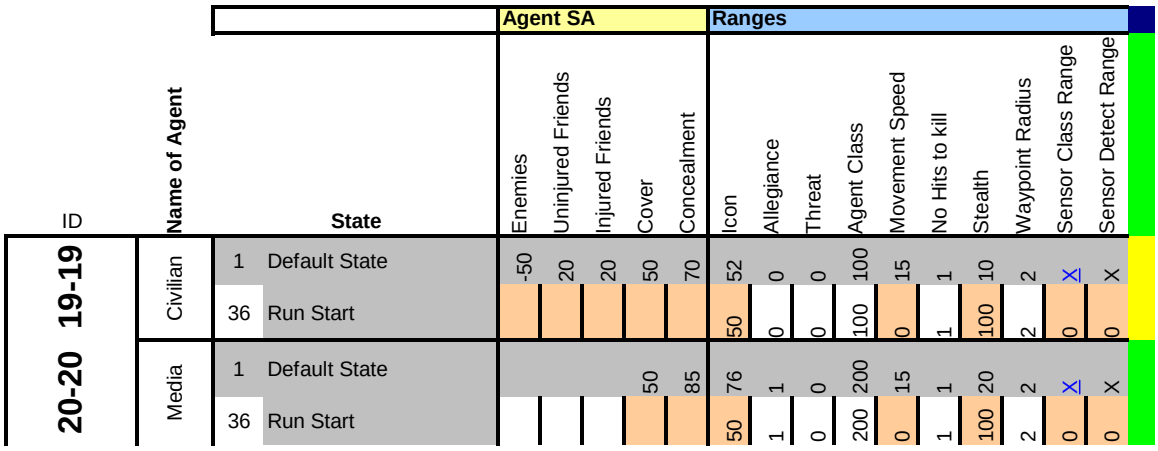
force composition	Uniform	Double	Triple	Quadruple		Units	Size	Agents
50.0%	4	8	12	16	Insurgents	3	5	15
28.0%	2	4	7	9	Rocketeers	9	1	9
10.0%	1	2	2	3	Red Infantry	1	4	4
3.0%	-	-	1	1	MG Team	1	1	1
3.0%	-	-	1	1	Mortar	1	1	1
4.0%	-	1	1	1	Scout	1	1	1
2.0%	-	-	-	1	IED	1	1	1
100.0%	7	15	24	32		- 17		32

ID	Name of Agent	State		Agent SA						Squad SA			Ranges										
				Enemies	Uninjured Friends	Injured Friends	Easy Going	Cover	Concealment	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Icon	Allegiance	Threat	Agent Class	Movement Speed	No Hits to kill	Stealth	Armour Thickness	Waypoint Radius	Sensor Class Range	Sensor Detect Range
1-3	Red Insurgent	1	Default State		50	50	30	60	30				101	2	3	0	15	2	20		2	X	X
		3	Taken Shot (Pri)	50	50	50	30	60	30				142	2	3		15	2	20		2	X	X
		5	Shot At (Pri)	-75	80	80	30	60	30				103	2	3		15	2	20		2	X	X
		7	Enemy Contact	90	60	60	30	60	30				141	2	3		15	2	20		2	X	X
		15	Squad En Contact	90	60	60	30	60	30	90	90	90	140	2	3		15	2	20		2	X	X
		36	Run Start										25	2	3		0	2	100		2	0	0
4-4	Red Rfilemen	1	Default State		50	50	20	70	30				149	2	3		11	3	30		2	X	X
		3	Taken Shot (Pri)	60	40	40	20	70	30				146	2	3		11	3	35		2	X	X
		5	Shot At (Pri)	-45	50	50	20	70	30				28	2	3		11	3	35		2	X	X
		7	Enemy Contact	80	50	50	20	70	30				145	2	3		11	3	35		2	X	X
		15	Squad En Contact	80	60	60	20	70	30	80	80	80	144	2	3		11	3	35		2	X	X
		36	Run Start										25	2	3		0	3	100		2	0	0
5-5	Red Mortars	1	Default State		50	50	30	60	30				39	2	3		11	2	20		2	X	X
		3	Taken Shot (Pri)	-50	50	50	30	60	30				148	2	3		11	2	10		2	X	X
		5	Shot At (Pri)	-90	80	80	30	60	30				64	2	3		11	2	20		2	X	X
		7	Enemy Contact	-90	60	60	30	60	30				89	2	3		11	2	20		2	X	X
		36	Run Start										25	2	3		0	2	100		2	0	0
6-6	Red MG Team	1	Default State										143	2	3		0	3	50		2	X	X
		3	Taken Shot (Pri)										37	2	3			3	10		2	X	X
		36	Run Start										25	2	3			3	10		2	X	X
7-15	Red Rocketeer	1	Default State		50	50	30	60	30				26	2	3	0	11	2	30		2	X	X
		3	Taken Shot (Pri)	50	50	50	30	60	30				146	2	3		11	2	30		2	X	X
		5	Shot At (Pri)	-75	80	80	30	60	30				28	2	3		11	2	30		2	X	X
		7	Enemy Contact	90	60	60	30	60	30				145	2	3		11	2	30		2	X	X
		15	Squad En Contact	90	60	60	30	60	30	90	90	90	144	2	3		11	2	30		2	X	X
		36	Run Start										25	2	3			2	100		2	0	0
16-16	Red Scout	1	Default State		50	50	30	60	30				28	2	3		15	2	10		2	X	X
		5	Shot At (Pri)	-75	80	80	30	60	30				53	2	3		15	2	10		2	X	X
		7	Enemy Contact	-50	60	60	30	60	30				145	2	3		15	2	10		2	X	X
		36	Run Start										25	2	3		0	2	100		2	0	0
17-17	Red IED Scout	1	Default State										28	2	3		5	2	70		2	X	X
		5	Shot At (Pri)	-75	80	80	30	60	30				53	2	3		5	2	70		2	X	X
		36	Run Start										25	2	3		0	2	100		2	0	0
18	IED	1	Default State										147	2	3		0	1	80		2	0	0

AK47	shot delay	6							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	0.95	0.95	0.93	0.80	0.00
MG	shot delay	N/A							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.00
RPG	shot delay	10							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96	0.00
Mortars	shot delay	8		indirect fire		use min engage > shot radius			
	0	131	164	246	328	410	492	656	0
	0.99	0.99	0.99	0.99	1.99	1.99	1.99	1.99	0.99
IED	shot delay	N/A							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALL WEAPONS									
	Interpolate within subranges			☑					
	Firing on Class Order								
	Non-Target Classes								

			Agent Memory	30	seconds												
Intra-Squad Comms Delay		2					min link Rank			low							
Squad Threat Persistence		30					Inorganic Threat Persistance			30							
Fuse Unknowns		No					Fuse Unknowns on Inorg map			No							
Fuse Time		-					Fuse Time			-							
Fuse Radius		-					Fuse Radius			-							
							Outbound Comm Link			X							

Type	From Squad	To Squad	Type	LINK (Y/N)	#	DEVICE	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery
Red Riflemen	4	5	Red Mortars	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red Riflemen	4	6	Red MG Team	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red MG Team	6	4	Red Riflemen	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red MG Team	6	5	Red Mortars	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red Scout	16	4	Red Riflemen	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red Scout	16	5	Red Mortars	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red Scout	16	6	Red MG Team	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red Scout	16	17	Red IED Scout	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red IED Scou	17	4	Red Riflemen	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red IED Scou	17	5	Red Mortars	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red IED Scou	17	6	Red MG Team	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red IED Scou	17	16	Red Scout	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F
Red IED Scou	17	18	IED	y	1	cellphone	6562	1	2	20	120	70	100	30	High	SETC	F-N-F



ID	Name of Agent	State	Agent SA					Ranges									
			Enemies	Uninjured Friends	Injured Friends	Cover	Concealment	Icon	Allegiance	Threat	Agent Class	Movement Speed	No Hits to kill	Stealth	Waypoint Radius	Sensor Class Range	Sensor Detect Range
19-19	Civilian	1 Default State	-50	20	20	50	70	52	0	0	100	15	1	10	2	X	X
		36 Run Start						50	0	0	100	0	1	100	2	0	0
20-20	Media	1 Default State				50	85	76	1	0	200	15	1	20	2	X	X
		36 Run Start						50	1	0	200	0	1	100	2	0	0

26-27									24-25									23-23								22-22								21-21								ID	
Blue TOW-SMAW Tm									Blue MG Tm									Blue Indirect Fire								Blue Sniper Tm								Blue Recon Tm								Name of Agent	
36 Run Start	35 Reach Final Waypoint	15 Squad En Contact	7 Enemy Contact	5 Shot At (Pri)	3 Taken Shot (Pri)	2 Reach Waypoint	1 Default State		36 Run Start	35 Reach Final Waypoint	15 Squad En Contact	7 Enemy Contact	5 Shot At (Pri)	3 Taken Shot (Pri)	2 Reach Waypoint	1 Default State		no selection	no selection	no selection	36 Run Start	3 Taken Shot (Pri)	1 Default State		no selection	no selection	no selection	no selection	36 Run Start	3 Taken Shot (Pri)	1 Default State		no selection	no selection	no selection	no selection	36 Run Start	5 Shot At (Pri)	3 Taken Shot (Pri)	2 Reach Waypoint	1 Default State	State	
	20	90	90	90	50					20	90	90	90	50																												Enemies	Agent SA
	80	50	50	50	50	80	50			80	50	50	50	50	80	50																										Uninjured Friends	
	80	50	50	50	50	80	50			80	50	50	50	50	80	50																										Injured Friends	
	0	30	40	75	20	0	85			0	30	40	75	20	0	85																										Next Waypoint	
	0	-20	-20	-20	-20	-20	10			0	-20	-20	-20	-20	-20	10																										Easy Going	
	45	45	45	45	45	45	45			45	45	45	45	45	45	45																										Cover	
	30	40	40	40	40	40	30			30	40	40	40	40	40	30																										Concealment	
	0	-10	-10	-10	-10	-10	-10			0	-10	-10	-10	-10	-10	-10																										Line Center	
		85									85																														Enemy Threat 1	Squad SA
		85									85																														EnemyThreat 2	
		85									85																														EnemyThreat 3	
		50									50																														Squad Friends	
		10									10																														Other Friends	
0	3	131	132	78	133	3	1		0	3	134	135	53	136	3	1				0	38	0					0	136	1					0	150	129	3	1				Icon	Ranges
1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1				1	1	1					1	1	1					1	1	1	1	1				Allegiance	
3	3	3	3	3	3	3	3		3	3	3	3	3	3	3	3				3	3	3					3	3	3					3	3	3	3	3				Threat	
0	4	11	11	11	11	4	11			2	11	11	11	11	4	11						0	0												0	15	15	4	15				Movement Speed	
5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5				1000	1000	1000					5	5	5					5	5	5	5	5				No Hits to kill	
100	30	30	30	30	30	50	30		100	30	30	30	30	50	30	30				100	100	100					100	60	60					100	80	80	90	80				Stealth	
4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4				4	4	4					4	4	4					4	4	4	4	4				Waypoint Radius	
X	X	X	X	X	X	X	X		0	X	X	X	X	X	X	X				0	0	0					X	X	X					0	X	X	X	X				Sensor Class Range	
X	X	X	X	X	X	X	X		0	X	X	X	X	X	X	X				0	0	0					X	X	X					0	X	X	X	X				Sensor Detect Range	

ID	Name of Agent		State	Agent SA								Squad SA					Ranges								
				Enemies	Uninjured Friends	Injured Friends	Next Waypoint	Easy Going	Cover	Concealment	Line Center	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Squad Friends	Other Friends	Icon	Allegiance	Threat	Movement Speed	No Hits to kill	Stealth	Waypoint Radius	Sensor Class Range	Sensor Detect Range
28-36	Blue Inf Rifleman	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
37-45	Blue Inf SAW	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						
46-54	Blue Inf M203	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						
			no selection																						
55-57	Blue Inf Sqd Ldr	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						
58-58	Blue Inf Plt Cmd	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						

ID	Name of Agent		State	Agent SA								Squad SA					Ranges								
				Enemies	Uninjured Friends	Injured Friends	Next Waypoint	Easy Going	Cover	Concealment	Line Center	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Squad Friends	Other Friends	Icon	Allegiance	Threat	Movement Speed	No Hits to kill	Stealth	Waypoint Radius	Sensor Class Range	Sensor Detect Range
59-76	Blue DO Tm/SAW/203	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						
77-79	Blue DO Tm C2	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10						127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X
			no selection																						
80-81	Blue DO Cmd Grp	1	Default State		50	50	85	10	45	30	-10						1	1	3	11	5	30	4	X	X
		2	Reach Waypoint		80	80	0	-20	45	40	-10						3	1	3	4	5	50	4	X	X
		3	Taken Shot (Pri)	50	50	50	20	-20	45	40	-10						129	1	3	11	5	30	4	X	X
		5	Shot At (Pri)	90	50	50	75	-20	45	40	-10						78	1	3	11	5	30	4	X	X
		7	Enemy Contact	90	50	50	40	-20	45	40	-10						128	1	3	11	5	30	4	X	X
		15	Squad En Contact	90	50	50	30	-20	45	40	-10	85	85	85	50	10	127	1	3	11	5	30	4	X	X
		35	Reach Final Waypoint	20	80	80	0	0	45	30	0						3	1	3	4	5	30	3	X	X
		36	Run Start														0	1	3	0	5	100	2	X	X

M16A2	shot delay	5							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	0.95	0.95	0.93	0.81	0.00
SAW	shot delay	N/A							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.95	0.00
M203	shot delay	9							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	0.95	0.95	0.80	0.80	0.65	0.30	0.00
M82A1A	shot delay	30							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
MG	shot delay	N/A							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.00
Tank	shot delay	15							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
SMAW	shot delay	120							
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	0.90	0.90	0.80	0.60	0.00
indirect fire	shot delay	30		indirect fire					
	0	131	164	246	328	410	492	656	0
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
ALL WEAPONS									
	Interpolate within subranges			☑					
	Firing on Class Order								
	Non-Target Classes								
	100	200							
	civilian	media							

Agent Memory: 30 seconds

Intra-Squad	-	min link Rank	low
Squad Thre	30	Inorganic Threat Persistance	30
Fuse Unkno	No	Fuse Unknowns on Inorg map	No
Fuse Time	-	Fuse Time	-
Fuse Radius	-	Fuse Radius	-
		Outbound Comm Link	X

From Squad	To Squad	Type	LINK (Y/N)	#	DEVICE	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery
21	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	24	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	25	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	26	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	27	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	57	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	58	Blue Infantry Platoon Cmd	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
21	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	57	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	58	Blue Infantry Platoon Cmd	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
24	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	57	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	58	Blue Infantry Platoon Cmd	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
25	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	57	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	58	Blue Infantry Platoon Cmd	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
26	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	57	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	58	Blue Infantry Platoon Cmd	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
27	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
55	56	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
55	57	Blue Infantry Squad Ldr	y	7	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
55	58	Blue Infantry Platoon Cmd	y	8	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
56	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
56	57	Blue Infantry Squad Ldr	y	7	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
56	58	Blue Infantry Platoon Cmd	y	8	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
57	55	Blue Infantry Squad Ldr	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
57	56	Blue Infantry Squad Ldr	y	7	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
57	58	Blue Infantry Platoon Cmd	y	8	PRC 150	164054	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	24	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	25	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	26	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
58	27	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
59	65	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
59	71	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
59	77	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
60	66	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
60	72	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
60	77	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
61	67	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
61	73	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
61	78	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
62	68	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
62	74	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
62	78	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
63	69	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
63	75	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
63	79	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
64	70	Blue DO SAW	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
64	76	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
64	79	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
65	59	Blue DO Rifleman	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
65	71	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
65	77	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
66	60	Blue DO Rifleman	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
66	72	Blue DO M203	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
66	77	Blue DO Team C2	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
67	61	Blue DO Rifleman	y	3	I Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F

Agent Memory: 30 seconds

Intra-Squad	-	min link Rank	low
Squad Thre	30	Inorganic Threat Persistance	30
Fuse Unkno	No	Fuse Unknowns on Inorg map	No
Fuse Time	-	Fuse Time	-
Fuse Radius	-	Fuse Radius	-
		Outbound Comm Link	X

From Squad	To Squad	Type	LINK (Y/N)	#	DEVICE	Range	Capacity	Buffer	Latency	Self	Reliab.	Acc.	MxAge	Rank Filter	Include	Delivery
67	73	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
67	78	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
68	62	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
68	74	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
68	78	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
69	63	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
69	75	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
69	79	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
70	64	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
70	76	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
70	79	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
71	59	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
71	65	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
71	77	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
72	60	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
72	66	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
72	77	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
73	61	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
73	67	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
73	78	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
74	62	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
74	68	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
74	78	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
75	63	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
75	69	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
75	79	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
76	64	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
76	70	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
76	79	Blue DO Team C2	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	59	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	60	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	65	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	66	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	71	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	72	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	21	Blue Recon Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	24	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	26	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
77	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	61	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	62	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	67	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	68	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	73	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	74	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	21	Blue Recon Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	24	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	26	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
78	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	63	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	64	Blue DO Rifleman	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	69	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	70	Blue DO SAW	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	75	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	76	Blue DO M203	y	3	l Role Radi	1641	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	21	Blue Recon Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	25	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	27	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
79	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	21	Blue Recon Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	24	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	26	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	77	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	78	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
80	81	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	21	Blue Recon Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	22	Blue Sniper Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	23	Blue Howitzer/Mortar Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	25	Blue Machine Gun Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	27	Blue SMAW Tm	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	79	Blue DO Team C2	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F
81	80	Blue DO Command Group	y	6	PRC 117	37732	1	10	10	120	93	100	30	High	SNETC	F-N-F

MOVEMENT CALCULATOR

Base Movement Rate (kmph)	1.6

Relative movement to walking speed

Walk	Jog	Run	Sprint
100%	200%	400%	600%

Dismounted Infantry Movement Rates: Ideal Terrain (meters per min)

	Adjustment Factor	Walk	Jog	Run	Sprint
Unencumbered	1.00	27	53	107	160
Light Combat Load	0.75	20	40	80	120
Full Combat Load	0.60	16	32	64	96
Heavy Load	0.25	7	13	27	40

Dismounted Infantry Movement Rates: Ideal Terrain (feet per min)

	Adjustment Factor	Walk	Jog	Run	Sprint
Unencumbered		87	175	350	525
Light Combat Load		66	131	262	394
Full Combat Load		52	105	210	315
Heavy Load		22	44	87	131

Dismounted Infantry Movement Rates: Ideal Terrain (meters per sec)

		Walk	Jog	Run	Sprint
Unencumbered		0.4	0.9	1.8	2.7
Light Combat Load		0.3	0.7	1.3	2.0
Full Combat Load		0.3	0.5	1.1	1.6
Heavy Load		0.1	0.2	0.4	0.7

Dismounted Infantry Movement Rates: Ideal Terrain (feet per sec)

		Walk	Jog	Run	Sprint
Unencumbered		1.5	2.9	5.8	8.7
Light Combat Load		1.1	2.2	4.4	6.6
Full Combat Load		0.9	1.7	3.5	5.2
Heavy Load		0.4	0.7	1.5	2.2

Model Dismounted Infantry Movement Rates: Ideal Terrain (grids per step)

		Walk	Jog	Run	Sprint
Unencumbered		1.5	2.9	5.8	8.7
Light Combat Load		1.1	2.2	4.4	6.6
Full Combat Load		0.9	1.7	3.5	5.2
Heavy Load		0.4	0.7	1.5	2.2

Terrain Effects		Rough % in path
Road (Ideal Terrain)	1.00	0%
Rubble	0.65	20%
Interior	0.20	70%
Wall	0.05	10%
		100%

Dismounted Infantry — Adapted From FM90-31 - Ch4

Table IV-5. Unopposed Movement Rates

TYPE TERRAIN	DISMOUNTED INFANTRY	ARMORED/MECHANIZED
Unrestricted	4 kmph (Day) 3.2 kmph (Night)	24 kmph (Day) 24 kmph (Night with lights/passive)
Restricted	2.4 kmph (Day) 1.4 kmph (Night)	16 kmph (Day) 16 kmph (Night, blacked out)
Severely Restricted	1.0 kmph (Day) 0.1 to 0.5 kmph (Night)	1.0 kmph (Day) 0.1 to 0.5 kmph (Night)

Target Zone (average rate)	1.48

3.28 feet = 1 meter

Logic: movement unopposed over restricted terrain = movement opposed over restricted terrain

Scenario: occurs at night in combat

			MANA Speed
Default movement Rate	100%	1.48	150
Reach Waypoint (also Final)	10%	0.15	10
Taken Shot	60%	0.89	90
Shot At	50%	0.74	70
Enemy Contact	70%	1.03	100
Sq Enemy Contact	70%	1.03	100

Max Terrain Dimension	185	Meters		0.305	Meters per grid
# CELLs in maximum dimension	607	# GRIDS		0.333	Yds per grid
Steps per Minute	60	Steps		1.000	Feet per grid
Steps per Second	1	Steps			

Weapon Specs

Weapon	Max Effective Range (m)	Shot Radius (m)	Max Targets/ min	Carried Rounds
M82A1A .50 Caliber	1800	1	2	1000
M16A2 5.56mm Rifles	550	1	12	1000
M203 Grenade Launcher	350	5	7	60
M249 Saw	1000	1	85	1000
81 mm Mortars	5700	35	33	1000
.50 Cal MG	1830	1	40	1000
M240G MG	1800	1	100	1000
MK 19 Mod 3 MG	1500	15	40	1000
SMAW (83mm MK153)	400	1	0.5	1000
TOW M220E4	3750	1	0.5	1000
155mm M198 Howitzer	14700	50	3	1000
M242 25mm chain gun (LAV)	2000	1	100	1000
TOW M220E4 (LAV)	3750	1	0.5	1000
M240 7.62mm Mach. Gun (LAV)	1800	1	100	1000
M256 120mm main gun (munitions: kinetic and chemical) (M1A1 TANK)	2200	5	4	40
M2 .50 cal machine gun (M1A1 TANK)	1830	1	40	1000
M240G 7.62mm machine gun (M1A1 TANK)	1800	1	100	1000
Hand grenade	40	15	6	20
T-62	800	5	0.5	30
82 mm Mortars	8000	35	8	1000
AK47	400	1	10	1000
2S3 152mm Self-Propelled Gun-Howitzer	15400	50	7	1000
RPG-7	500	1	6	1000
IEDs	40	10		1

Maximum effective range is the maximum range within which a weapon is effective against its intended target. interpret to be 50% kill rate

Weapon	Effects in Grid Range	Pkill at Max Grid Range	Grid Shot Radius	engagmnt/step	Targets / 100	time in shot taken state
M82A1A .50 Caliber	607	1	3	0.03	100	30
M16A2 5.56mm Rifles	607	0.86	3	0.20	100	5
M203 Grenade Launcher	607	0.4	16	0.12	100	9
M249 Saw	607	0.96	3	1.42	142	N/A
81 mm Mortars	607	1	115	0.55	100	2
.50 Cal MG	607	0.985	3	0.67	100	2
M240G MG	607	0.98	3	1.67	167	N/A
MK 19 Mod 3 MG	607	0.971	49	0.67	100	2
SMAW (83mm MK153)	607	0.65	3	0.01	100	120
TOW M220E4	607	0.999	3	0.01	100	120
155mm M198 Howitzer	607	1	164	0.03	100	30
M242 25mm chain gun (LAV)	607	0.99	3	1.67	167	N/A
TOW M220E4 (LAV)	607	0.999	3	0.01	100	120
M240 7.62mm Mach. Gun (LAV)	607	0.98	3	1.67	167	N/A
M256 120mm main gun (munitions: kinetic and chemical) (M1A1 TANK)	607	1	16	0.07	100	15
M2 .50 cal machine gun (M1A1 TANK)	607	0.985	3	0.67	100	2
M240G 7.62mm machine gun (M1A1 TANK)	607	0.98	3	1.67	167	N/A
Hand grenade	131	1	49	0.10	100	10
T-62	607	0.97	16	0.01	100	120
82 mm Mortars	607	1	115	0.13	100	8
AK47	607	0.85	3	0.17	100	6
2S3 152mm Self-Propelled Gun-Howitzer	607	1	164	0.12	100	9
RPG-7	607	0.97	3	0.10	100	10
IEDs	131	1	33	0.00	100	N/A

RANGE PROFILE FOR MAP		max req:	185	*Note: simply highlight last column and expand to right to cover additional distance or change Real world values to desired values*				
Weapon								
Real World	0	40	50	75	100	125	150	200
GRID	0	131	164	246	328	410	492	656
M82A1A .50 Caliber	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M16A2 5.56mm Rifles	1.00	1.00	1.00	1.00	0.95	0.95	0.93	0.81
M203 Grenade Launcher	1.00	1.00	0.95	0.95	0.80	0.80	0.65	0.30
M249 Saw	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.95
81 mm Mortars	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
.50 Cal MG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98
M240G MG	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
MK19 Mod 3 MG	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.96
SMAW (83mm MK153)	1.00	1.00	1.00	1.00	0.90	0.90	0.80	0.60
TOW M220E4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
155mm M198 Howitzer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M242 25mm chain gun (LAV)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
TOW M220E4 (LAV)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M240 7.62mm Mach. Gun (LAV)	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
M256 120mm main gun (munitions: kinetic and chemical) (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M2 .50 cal machine gun (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96
M240G 7.62mm machine gun (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
Hand grenade	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
T-62	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96
82 mm Mortars	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
AK47	1.00	1.00	1.00	1.00	0.95	0.95	0.93	0.80
2S3 152mm Self-Propelled Gun-Howitzer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RPG-7	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96
IEDs	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
TOW M220E4 (LAV)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M240 7.62mm Mach. Gun (LAV)	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
M256 120mm main gun (munitions: kinetic and chemical) (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M2 .50 cal machine gun (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98
M240G 7.62mm machine gun (M1A1 TANK)	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
Hand grenade	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
T-62	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96
82 mm Mortars	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
AK47	1.00	1.00	1.00	1.00	0.95	0.95	0.93	0.80
2S3 152mm Self-Propelled Gun-Howitzer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RPG-7	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96
IEDs	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

	Detect (meters)	Detect (grids)		Classify (meters)	(meters)	(meters)		Classify (grids)	(grids)	(grids)
BLUE										
Traditional	150	492		50	75	150		164	246	492
				0.95	0.9	0.8		0.95	0.9	0.8
DO	300	984		100	150	300		328	492	984
				0.95	0.9	0.8		0.95	0.9	0.8
Attach	300	984		100	150	300		328	492	984
				1	0.95	0.9		1	0.95	0.9
RED										
All	150	492		50	75	150		164	246	492
				0.95	0.8	0.7	270	0.95	0.8	0.7
Non-Combatants										
	100	328		100				328		
				0.7				0.7		

APPENDIX I: SURVEY

This survey was developed to assess MOUT training perceptions and gauge the realism of MOUT Training Facility experiences. This survey was conducted with 251 Marines who were pre-qualified to have combat experience from Iraq. The insights from this survey are intended to be incorporated into future urban combat models.

URBAN TRAINING AND COMBAT SURVEY

JUNE 2005 Tracking Number _____

This goal of this survey is to create a better training facility and training environment for you, the Marine. Your input is needed to make sure that training facilities can be their best to train for war.

1. This survey is confidential. **DO NOT PUT YOR NAME ON ANY PAGES**

2. Be Honest!
If you cannot answer a question,
indicate a "No Response" with an **X over the number**

ie ~~33~~

3. Carefully read each question before answering. Approximate answers are OK.

4. Survey time is expected to take between 30 and 50 minutes.

5. This is an unclassified survey, **DO NOT USE CLASSIFIED INFORMATION**.

6. (CIRCLE) appropriate response or fill in the blanks where applicable.

7. Thank you for your participation in this survey.

MOUT – Military Operations on Urban Terrain

Unit _____

Rank _____

MOS _____ PMOS_____SMOS_____

URBAN TRAINING AND COMBAT SURVEY

JUNE 2005 Tracking Number _____

SECTION ONE PERSONAL BACKGROUND

#

1. Years of Service _____

2. OFFICER ENLISTED CIVILIAN

3. List Billet's Held while in Urban of Combat

_____

_____

_____

4. Total # of Days Spent in Any Combat _____

5. Total # of Days Spent in Urban Combat _____

6. From Your Experience: How Often Did Urban Combat Engagements Occur While You Were in Country

DAILY WEEKLY MONTHLY

7. Number of Combat Tours _____

8. How Well Do You Feel MOUT Training Prepared You for Urban Combat

UNPREPARED PREPARED PROFICIENT HIGHLY PROFICIENT

SECTION TWO MOUT FACILITY TRAINING

#			
9.	Have You Received Training at an Urban Training Facility	YES	NO
10.	Did You Receive MOUT Training Before Combat	YES	NO
11.	Approx Number of Different MOUT Locations Trained at	_____	

List TEN *(if you trained at less than 10 then # trained at)* different MOUT facilities, **Put Facilities you are most familiar with** (been to the most times) **first.** Include base where located, the approximate number of buildings, approximate number of times you trained at that facility and approximate size of facility– use below classifications for size [from small to large] (basketball court, baseball diamond, football field, rifle range, town, city)

12.	Name of Base	Approx # of Buildings	Times Trained At	Approximate Size
example	*Quantico*	*8*	*4*	*Baseball Diamond*
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				

13.	Length (in Days) of **Shortest** MOUT Training Evolution	_____	
14.	Length (in Days) of **Longest** MOUT Training Evolution	_____	
15.	Most of the MOUT Evolutions were approx this many Days	_____	
16.	Overall are MOUT Facilities Large Enough for Proper Training	YES	NO
17.	Overall Do MOUT Facilities Provide Realistic Training	YES	NO
18.	Overall are MOUT Facilities Accurate to actual Urban Combat Terrain You have Experienced	YES	NO

SECTION THREE URBAN COMBAT SPECIFIC

19. List Cities where You Participated in Urban Combat: _____

_____

_____

20. Briefly Describe the Buildings in Areas where Urban Combat Occurred

_____

_____

21. Briefly Explain what Effect did Roads have on Combat _____

_____

22. Briefly Explain what Effect did Multiple Stories have on Combat

_____

23. Number of Urban Battles _____ Ave Duration _____

24. # of Daytime Urban Battles _____ Ave Duration _____

25. # of Nighttime Urban Battles _____ Ave Duration _____

26. # of 24hr+ Urban Battles _____ Ave Duration _____

27. Squad Area of Operation Number of Buildings _____ _____ Meters by _____ Meters

28. Civilians Observed During Combat YES NO

29. Civilian Reactions Before Combat FRIENDLY NEUTRAL FEARFUL HOSTILE

30. Civilian Reaction On-Contact FRIENDLY NEUTRAL FEARFUL HOSTILE

31. Civilian Reactions After Combat FRIENDLY NEUTRAL FEARFUL HOSTILE

32. Were MOUT Tactics from Training Effective in Combat YES NO

33. How were Tactics Learned in MOUT Training Applied in Combat

UNUSABLE SLIGHTLY MODIFIED EXACTLY AS INSTRUCTED

34. Area Around Buildings Lots of Trash and Rubble Some Rubble Some plant Nothing at all

35. Interior of Buildings Furniture and Clutter Some Furniture Nothing at all

36. Typical Time Required to Clear a Small Single Story Bld ____ Minutes

37. Typical Time Required to Clear a Large Single Story Bld ____ Minutes

38 Typical Time Required for Each Additional Story of Bld ____ Minutes

39. On Average: How Far Could You See _____ Meters

40. Typically How Far Out were Targets Engaged (rifle) ___ Meters

41. Typically How Close were Targets Engaged (rifle) ___ Meters

42. Typically How Far Out were Targets Engaged (supporting fire) ___ Meters

43. Typically How Close were Targets Engaged (supporting fire) ___ Meters

44.. Most Casualties Observed were cause by RIFLE MORTAR OTHER

45. Location where Most Casualties Occurred INDOORS OUTDOORS

46. Casualties were Most Likely to occur to Troops In a cluster Separated from the unit On the flanks On Point or in the lead

SECTION FOUR **FACILITY A** (from section two)

#							
	Facility Name: _____ Base: _____ State: _____						
47.	Approx Number of Times Visited for Daylight Training	_____					
48.	Approx Number of Times Visited for Nighttime Training	_____					
49.	Approx Number of Times Visited for 24hr+ Training	_____					
50.	This Facility Big Enough to Properly Train for Urban Combat	YES	NO				
51.	Exterior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
52.	Interior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
53.	Training Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
54.	Did You Use the Tactics Trained Here in Combat	YES	NO				
55.	Between Buildings	Lots of Trash and Rubble	Some Rubble	Some plant	Nothing at all		
56.	Interior of Buildings	Furniture and Clutter	Some Furniture	Nothing at all			
57.	Could the EDGE (or boundary) of the Facility be Seen Easily during Training in the Facility	YES	NO				
58.	Typically How Many Edges Could be seen at any time during Training	0	1	2	3	4	
59.	On Average: How Far Out Could You See _____	meters					
60.	Typically How Far Out were Targets Engaged (rifle) _____	meters					
61.	Typically How Close were Targets Engaged (rifle) _____	meters					
62.	Typically How Far Out were Targets Engaged (supporting fire) __	meters					
63.	Typically How Close were Targets Engaged (supporting fire) __	meters					
64.	How Long Did it Take to Clear a Typical Structure _____	minutes					
65.	How Significant were Multiple Stories to Training	LOW	MED	HIGH			
66.	Simulated Unit Casualties were Approx	< 1%	1 to 10%	10 to 25%	26%+		
67.	Simulated Casualties Caused by Enemy Mortar Fire	YES	NO				
68.	Simulated Casualties Caused by Enemy Rifle Fire	YES	NO				
69.	Simulated Casualties Caused by Enemy Grenades	YES	NO				
70.	Simulated Casualties Caused by Friendly Units	YES	NO				
71.	Simulated Casualties Caused by Improvised Explosive Device	YES	NO				
72.	Location where MOST Casualties Occurred	INDOORS	OUTDOORS				
73.	Casualties were <u>Most Likely</u> to occur to Troops	In a cluster	Separated from the unit	On the flank	On Point or in the lead		
74.	Civilian Actors Present in Facility while Training	YES	NO				

SECTION FOUR FACILITY B (from section two)

#	Facility Name: _____ Base: _____ State: _____						
75.	Approx Number of Times Visited for Daylight Training	_____					
76.	Approx Number of Times Visited for Nighttime Training	_____					
77.	Approx Number of Times Visited for 24hr+ Training	_____					
78.	This Facility Big Enough to Properly Train for Urban Combat	YES	NO				
79.	Exterior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
80.	Interior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
81.	Training Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT	
82.	Did You Use the Tactics Trained Here in Combat	YES	NO				
83.	Between Buildings	Lots of Trash and Rubble	Some Rubble	Some plant	Nothing at all		
84.	Interior of Buildings	Furniture and Clutter	Some Furniture	Nothing at all			
85.	Could the EDGE (or boundary) of the Facility be Seen Easily during Training in the Facility	YES	NO				
86.	Typically How Many Edges Could be seen at any time during Training	0	1	2	3	4	
87.	On Average: How Far out Could You See _____	meters					
88.	Typically How Far Out were Targets Engaged (rifle) _____	meters					
89.	Typically How Close were Targets Engaged (rifle) _____	meters					
90.	Typically How Far Out were Targets Engaged (supt fire) _____	meters					
91.	Typically How Close were Targets Engaged (supt fire) _____	meters					
92.	How Long Did it Take to Clear a Typical Structure _____	minutes					
93.	How Significant were Multiple Stories to Training	LOW	MED	HIGH			
94.	Simulated Unit Casualties were Approx	< 1%	1 to 10%	10 to 25%	26%+		
95.	Simulated Casualties Caused by Enemy Mortar Fire	YES	NO				
96.	Simulated Casualties Caused by Enemy Rifle Fire	YES	NO				
97.	Simulated Casualties Caused by Enemy Grenades	YES	NO				
98.	Simulated Casualties Caused by Friendly Units	YES	NO				
99.	Simulated Casualties Caused by Improvised Explosive Device	YES	NO				
100.	Location where MOST Casualties Occurred	INDOORS	OUTDOORS				
101.	Casualties were Most Likely to occur to Troops	In a cluster	Separated from the unit	On the flank	On Point or in the lead		
102.	Civilian Actors Present in Facility while Training	YES	NO				

SECTION FOUR **FACILITY C** (from section two)

#	Facility Name: _____ Base: _____ State: _____					
103.	Approx Number of Times Visited for Daylight Training	_____				
104.	Approx Number of Times Visited for Nighttime Training	_____				
105.	Approx Number of Times Visited for 24hr+ Training	_____				
106.	This Facility Big Enough to Properly Train for Urban Combat	YES	NO			
107.	Exterior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT
108.	Interior Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT
109.	Training Realism	POOR	FAIR	SATISFACTORY	GOOD	EXACT
110.	Did You Use the Tactics Trained Here in Combat	YES	NO			
111.	Between Buildings	Lots of Trash and Rubble	Some Rubble	Some plant	Nothing at all	
112.	Interior of Buildings	Furniture and Clutter	Some Furniture	Nothing at all		
113.	Could the EDGE (or boundary) of the Facility be Seen Easily during Training in the Facility	YES	NO			
114.	Typically How Many Edges Could be seen at any time during Training	0	1	2	3	4
115.	On Average: How Far Out Could You See	_____ meters				
116.	Typically How Far Out were Targets Engaged (rifle)	_____ meters				
117.	Typically How Close were Targets Engaged (rifle)	_____ meters				
118.	Typically How Far Out were Targets Engaged (supt fire)	_____ meters				
119.	Typically How Close were Targets Engaged (supt fire)	_____ meters				
120.	How Long Did it Take to Clear a Typical Structure	_____ minutes				
121.	How Significant were Multiple Stories to Training	LOW	MED	HIGH		
122.	Simulated Unit Casualties were Approx	< 1%	1 to 10%	10 to 25%	26%+	
123.	Simulated Casualties Caused by Enemy Mortar Fire	YES	NO			
124.	Simulated Casualties Caused by Enemy Rifle Fire	YES	NO			
125.	Simulated Casualties Caused by Enemy Grenades	YES	NO			
126.	Simulated Casualties Caused by Friendly Units	YES	NO			
127.	Simulated Casualties Caused by Improvised Explosive Device	YES	NO			
128.	Location where MOST Casualties Occurred	INDOORS	OUTDOORS			
129.	Casualties were Most Likely to occur to Troops	In a cluster	Separated from the unit	On the flank	On Point or in the lead	
130.	Civilian Actors Present in Facility while Training	YES	NO			

#	SECTION FIVE OPEN DISCUSSION
131.	What one piece of gear (that you don't have) would you want to have in Urban Combat (body armor for…, optics that…, something that can look over or around walls… a radio… etc)?
132.	Is more or less Body Armour needed in Urban Combat?
133.	Did your unit have Unmanned Aerial Vehicles for Urban Combat? Were they or would they have been helpful?
134.	Which information is most important in a Urban fire fight: Location of Friends, Location of Enemies or Comm?
135.	Is Comm an asset or distraction in an Urban fire fight?

APPENDIX J: BRIEF

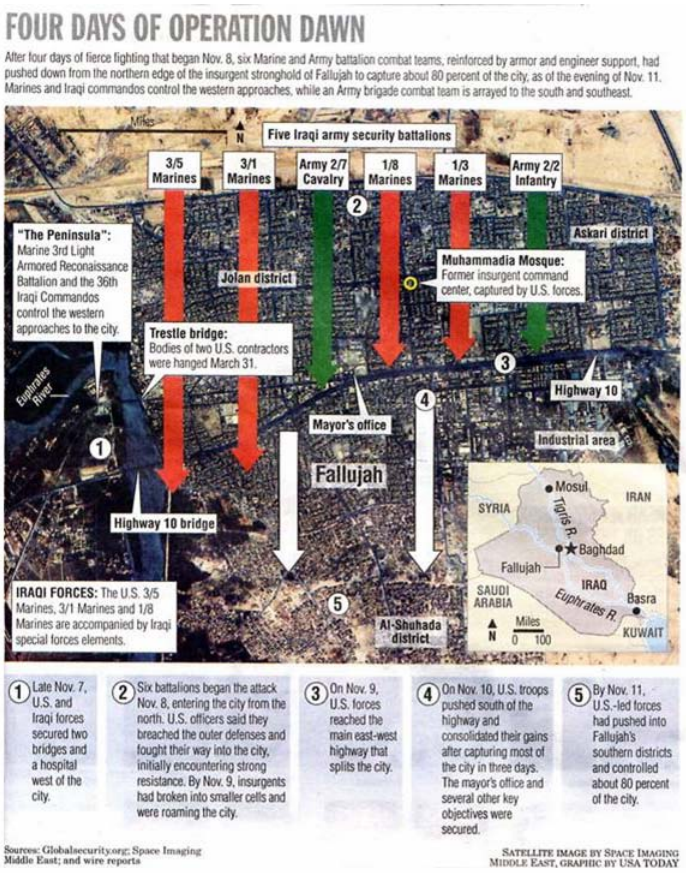
The brief on the following pages was presented to the Operations Analysis Directorate (OAD), MCCDC on the September 8th 2005, TECOM on September 9th 2005, and MCAGTFTC on September 16th 2005, prior to final edits on this thesis.

Comparison of a Distributed Operations Force to a Traditional Force in Urban Combat

Mike Babilot, Capt USMC
Operations Research, NPS

Purpose

Explore the effectiveness of the DO in urban combat and explore the influences of terrain on the outcome of combat



Time-line of Events

- **7 – 13 Nov 04** **PAIW, New Zealand**
  International Workshop addressing agent-based modeling
- **9 – 17 Dec 04** **S&A, MCCDC; TECOM, MCCDC; MCWL**
  Explore potential thesis topics of USMC nature
- **21 Dec 04** **MCAGTFTC**
  MOUT Training Facility development
- **19 – 21 Jan 05** **Urban Operations Summit IV**
  Current DoD M&S efforts to address the urban environment
- **17 – 22 Feb 05** **Maui High Performance Computing Center**
  Inside track on usage and capabilities of Maui assets
- **5 May 05** **MCAGTFTC**
  Interim research report briefed to BGen Zilmer, CG, MCAGTFTC
- **13 – 21 May 05** **PAIW, Sweden**
  International Workshop addressing agent-based modeling
- **6 – 8 Jun 05** **MCAGTFTC**
  Survey and MOUT Site familiarization tour
- **8 – 9 Sep 05** **S&A, MCCDC; TECOM, MCCDC**
  Research Out-brief
- **16 Sep 05** **MCAGTFTC**
  Research Out-brief to BGen Zilmer, CG, MCAGTFTC

UNCLASSIFIED

Agenda

- Sources of Information
- Urban Environment
- Distributed Operations
- Analytical Approach
- Findings
- Follow-on Research Topics

UNCLASSIFIED

Sources of Information

- MCCDC
  - Expeditionary Force Development Center, under BGen. Schmidle
  - The Marine Corps Center for Lessons Learned (MCCLL)
- MCWL
  - SeaViking 06
  - Project Metropolis X-files
- DoD agencies involved in urban M&S
  - Urban Operations Summit IV
- DoD, Joint Publications and USMC Doctrine
- GlobalSecurity.ORG
- Federation of American Scientists FAS.ORG
- Research of documents from GAO, RAND, DARPA, UN, WHO, DoD/USMC Vision Statements and unclassified briefs, Congressional Hearings, published books, news reports and web postings
- Peer Marines, Military professionals, experience

Urban Environment

Almost all population growth expected for the world in the next thirty years will be concentrated in the urban areas. Population growth will be particularly rapid in the urban areas of less developed regions.

–United Nations Department of Economic and Social Affairs/Population Division
World Urbanization Prospects: The 2003 Revision

- **Urbanization is a global trend**
  - Urban population growing from 2.9 billion in 2000 to a projected 5 billion in 2030
  - Percentage of world's population in urban areas has grown from 47% (2000) to 60% (2030)
- **Growth attributed to the littoral regions**
  - 60% of the world's 100 largest cities are located within 100 miles of the ocean
- **USMC currently fighting on urban terrain**

Distributed Operations

Implementation of Distributed Operations as an extension of Maneuver Warfare will require a focus on enhanced small units: more autonomous, more lethal, and better able to operate across the full spectrum of operations. It is a logical extension of our philosophy of war – maneuver warfare.

Commandant of the Marine Corps, General Mike Hagee

- **DO doctrine on the fast track**
- **Urban terrain can neutralize many current technological advantages**
- **Is DO applicable to urban combat?**
- **DO and urban combat are important to USMC**
  - **Combined studies of both deferred to future**

UNCLASSIFIED

Analytical Approach

- Modeling and Simulation
  - Scenarios
    - MOUT
    - Fallujah
- Experimental Design
- Survey
- Statistical and Visual Analysis

UNCLASSIFIED

Modeling and Simulation

The occurrences of war will not unfold like clockwork. Thus, we cannot hope to impose precise, positive control over events. The best we can hope for is to impose a general framework of order on the disorder, to prescribe the general flow of action rather than try to control each event.

–Warfighting, FMFM-1

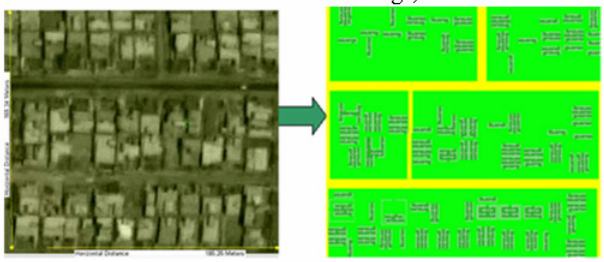
- Create a Simulation to examine
  - DO
  - MOUT Training Facilities
- Use of Agent-Base Modeling
  - Model individual agent (Marine, insurgent, civilian) and their actions on the battlefield
  - Explore:
    - Capabilities
    - Structure
    - Communications
    - Terrain

UNCLASSIFIED

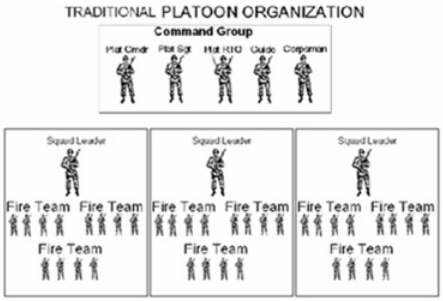
Modeling and Simulation

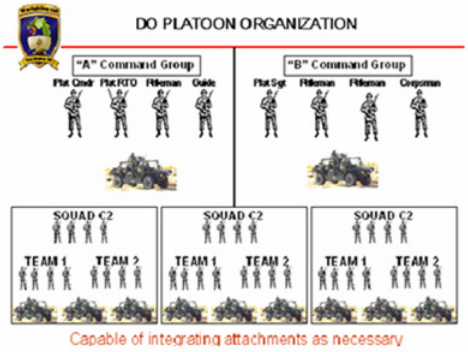
The purpose of [scientific] computing is insight, not numbers

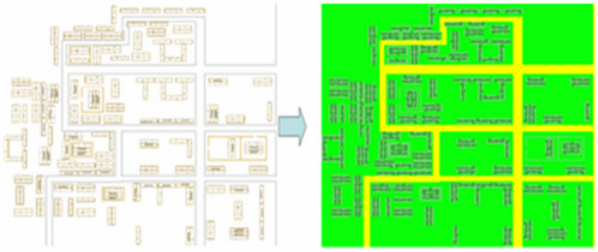
- Richard Hammings, Numerical methods for scientists and engineers, 1962



Section of Jolan District Modeled in MANA







Range 200 Modeled in MANA

UNCLASSIFIED

UNCLASSIFIED

Experimental Design

In the best tradition of scientific discovery, simulation experiments can … have a role in supporting the development of insights or theories...

-Kleijen, Sanchez, Lucas and Cioppa A User's Guide to the Brave New World of Designing Simulation Experiments

- Data Farming
- 376 Separate Experiments Conducted
- Total of 12,400 model runs completed
- Required over 4,000 cpu hours to produce data for statistical analysis
- Areas Explored
  - ➢ Terrain
  - ➢ Force Type
  - ➢ Optics
  - ➢ Troop Hardening
  - ➢ Terrain Clutter
  - ➢ Agent Concealment

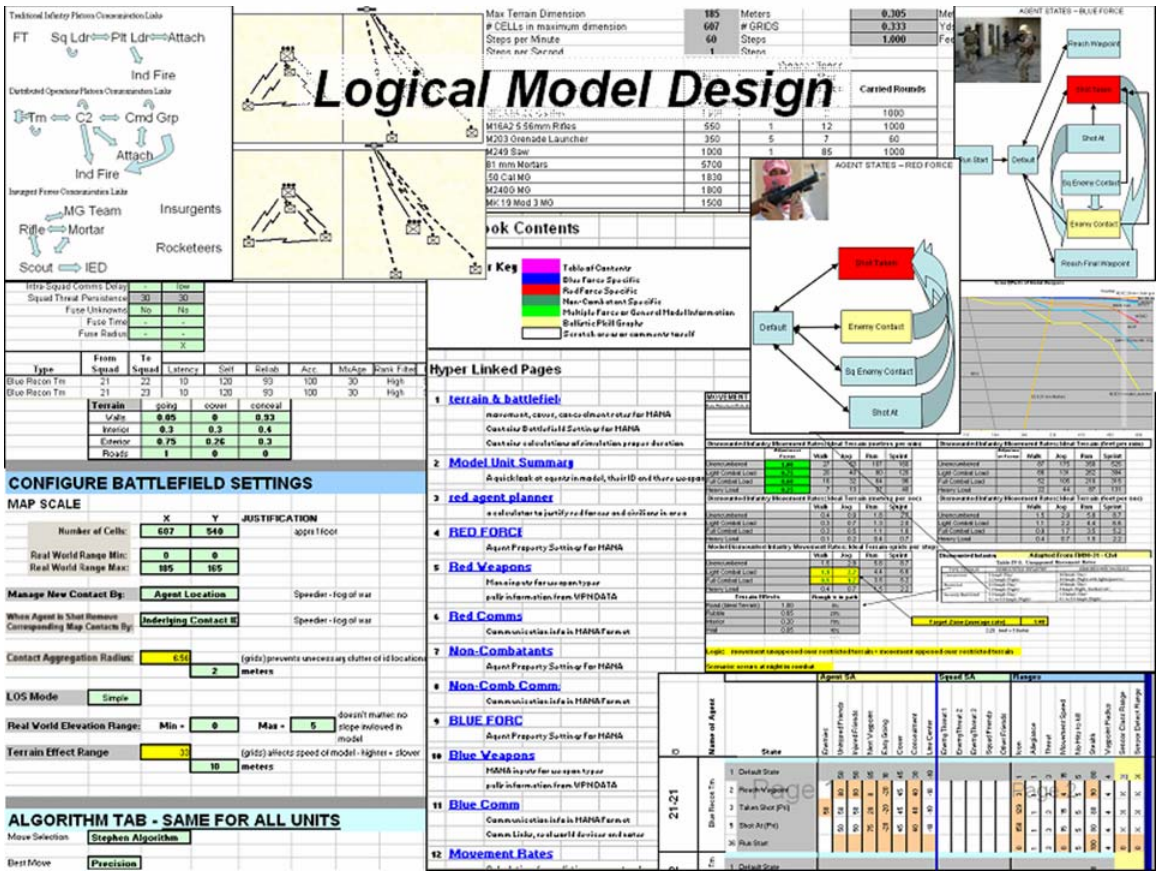
UNCLASSIFIED

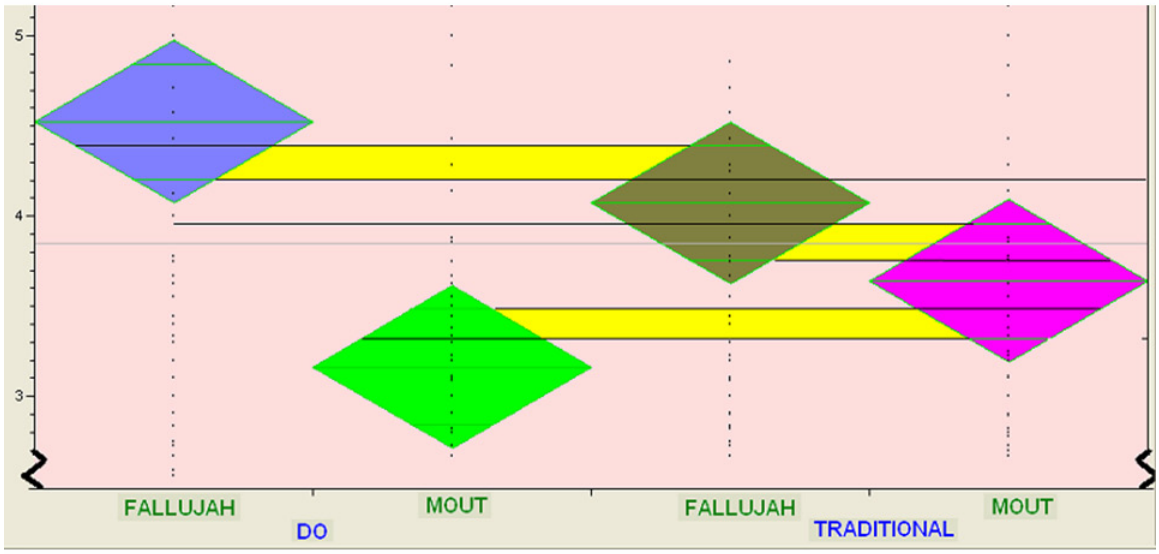
Measure of Effectiveness (MOE)

- **Loss Exchange Ratio**

$$\frac{\text{\# Insurgents Killed}}{\text{\# Marines Killed}}$$

  - Higher value is better
  - Relative to historical force ratio
    - 22 Battles surveyed U.S. Army Human Engineering Lab report
    - 4:1 ratio or less
- **Force Type Compared**
- **Terrain Effects Compared**
- **Sensitivity Analysis Performed**





Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Experiment1	100	22524.5	225.245	2.471
Experiment2	100	16659.5	166.595	-3.386
Experiment3	100	21885.5	218.855	1.833
Experiment4	100	19130.5	191.305	-0.918

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
16.3391	3	0.0010

UNCLASSIFIED

Research Findings

There is a significant difference between
- **MOUT & Fallujah**
- **DO & Traditional**

DO is marginally (but statistically) better that Traditional overall

The Denser the urban terrain the lower the lose exchange ratio for any force

DO more sensitive to terrain
- **Denser is worse for DO than traditional**
- **DO proved 21.3% more effective on less dense urban terrain**
- **DO was 18.8% less effective on dense urban terrain**

Clutter on the battlefield leads to a less favorable loss exchange ratio regardless of terrain and is additive to the effect of the structural density of the urban terrain

The ability of forces to be able to classify the agents in their field of view has the greatest influence on the resulting LER

When considering only terrain, forces and clutter… terrain was found to have the greatest influence on LER

Classification outweighs all other factors to include troop hardening and overall terrain in regards to its effect on LER

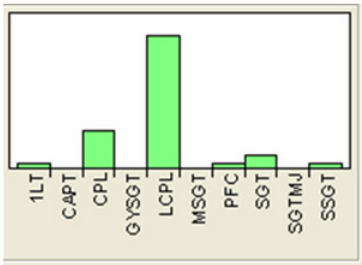
UNCLASSIFIED

MOUT Survey

Many Marines noted the difference between the Marine Corps' relatively simple and limited MOUT training facilities and the actual urban environment that they encountered in Iraq.

-OIF Lessons Learned

- **135 Question**
  - Mix
    - Scaled (best answer)
    - Open ended
- **251 Marines Surveyed**
  - Full support of Marines of MCB 29 Palms
- **Purpose**
  - **Assess perceptions of**
    - **MOUT Training**
    - **Urban Combat**
  - **Identify insights**



Rank	Count
1LT	6
CAPT	1
CPL	47
GYSGT	1
LCPL	162
MSGT	1
PFC	7
SGT	16
SGTMJ	1
SSGT	6
Total	248
N Missing	3

Unit	Count
1/4	1
1/7	80
2/7	52
3/11	52
3/7	63
Total	248
N Missing	3

UNCLASSIFIED

17 of 20

UNCLASSIFIED

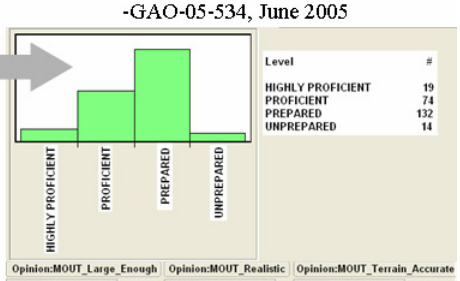
Survey Findings

MOUT training facilities not conducive to addressing current threats.
MOUT training facilities lacks appropriate density of buildings.
In addition, the urban training facilities were outdated, having been designed for Cold War scenarios that are not applicable to current military operations.

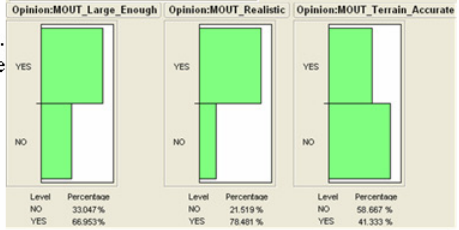
-GAO-05-534, June 2005

- Nearly 95% of the Marines surveyed felt that MOUT training had prepared them for urban combat.
- The majority of the respondents felt that the facilities they trained at were large enough and realistic, they felt that the facilities were not an accurate representation of the terrain they experienced in Iraq.

Marines did note the difference between the urban terrain they encountered and their relatively simple and limited urban training facilities. *- Current Operations, USMC 2004*



Level	#
HIGHLY PROFICIENT	19
PROFICIENT	74
PREPARED	132
UNPREPARED	14



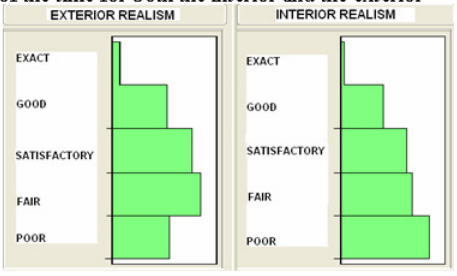
Level	Percentage
NO	33.047%
YES	66.953%

Level	Percentage
NO	21.519%
YES	78.481%

Level	Percentage
NO	58.667%
YES	41.333%

BGen Zilmer's request: Quantify and identify a context to the differences.

- MOUT facilities were rated as fair or poor significantly more than 50% of the time for both the interior and the exterior



18 of 20

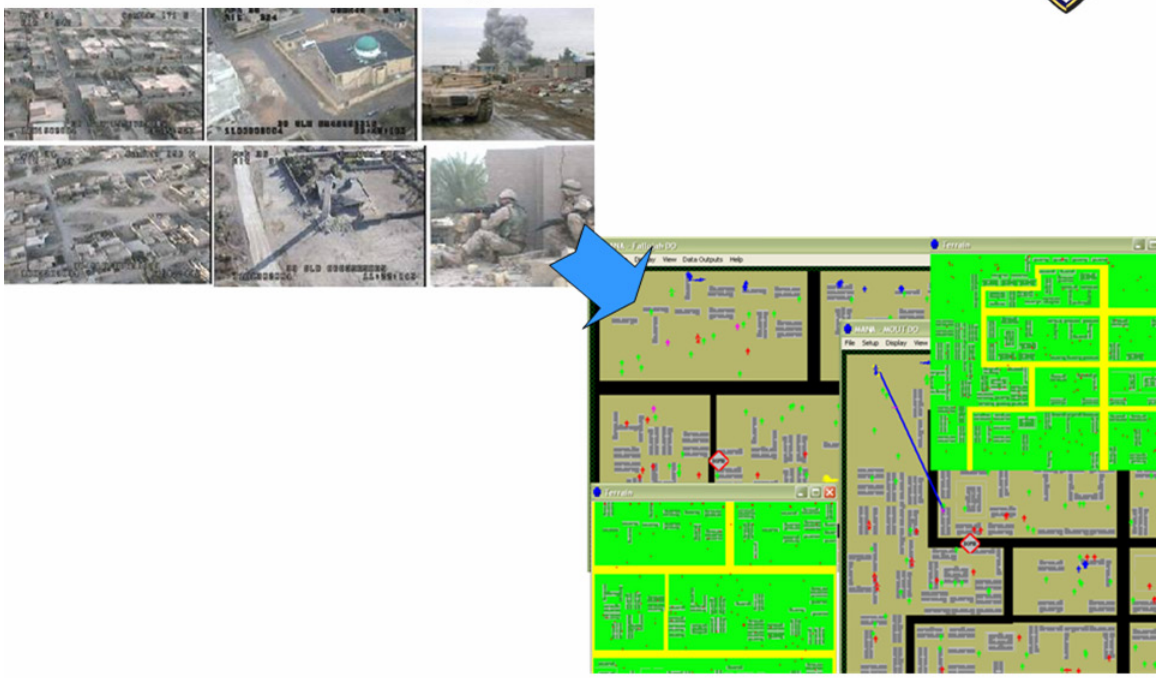
UNCLASSIFIED

Follow-on Research Topics

- Additional Analysis of Survey Data
- Casualty effects in urban environment
- Further Terrain Exploration
  - Unit movement and effect on tactics
  - Line of sight and field of view
  - Multiple storied building effects
- Examination of possible DO tactics
- Examination of potential MOUT tactics
- Comparative modeling in Combat XXI or Pythagoras or other modeling environment

UNCLASSIFIED

Questions



THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

21st Century Marine Corps: Creating Stability in an Unstable World. May 12, 2005. Available: http://www.marines.mil/marinelink/mcn2000.nsf/CMCUpdatedGuidance2005.pdf

Aragon, Arthur R. "Agent-Based Simulation of a Marine Infantry Squad in an Urban Environment." Master's thesis. Naval Postgraduate School, Monterey, CA, 2001.

"Battle for Fallujah." *The Old Dominion Post*, Wellington, New Zealand, November 09, 2004.

Bellon, David G. "Fighting the Battle of Fallujah." email dtd November 19, 2004, Available: http://www.thegreenside.com/story.asp?ContentID=11151.

Center for Naval Analysis (CNA). "Measures of Effectiveness for Humanitarian Assistance Operations." CRM 95-166.10. April 1996.

"Chairman of the Joint Chiefs of Staff Instruction: Joint Capabilities Integration and Development System." CJCSI 3170.01E. May 11, 2005. Available: http://www.dtic.mil/cjcs_directives/cdata/unlimit/3170_01.pdf

Clausewitz, Karl Von. *On War*. Translated by O.J. Matthijs Jolles, Random House. 1827.

"Combined-Arms MOUT Functional Analysis Concept Development (FACD) Final Report." MAGTFTC MCAGCC Twentynine Palms, California. May 05, 2005.

Defense Acquisition University 10th edition Glossary. Available: https://acc.dau.mil/simplify/ev.php?ID=23461_201&ID2=DO_PRINTPAGE

"Distributed Operations 2006 Capabilities and Enhancements Report." Marine Corps Warfighting Laboratory. November 2004.

"Doctrine for Joint Urban Operations." *Joint Publication Vol. 3-06*. 2002.

Easton, Valerie J. and John H. Mccoll. *Statistics Glossary V1.1*. Available: http://www.stats.gla.ac.uk/steps/glossary/nonparametric.html

FM 3-22.9 Rifle Marksmanship M16A1, M16A2/3, M16A4 and M4 Carbine. April 24, 2003.

French, Matthew. "DARPA Plans for Urban War." March 09, 2004, Available: http://www.fcw.com/fcw/articles/2004/0308/web-tether-03-09-04.asp

Fuentes, Gidget. "Hard as Hell." *Marine Corps Times*: Army Times Publishing Company. March 2005.

Fuentes, Gidget. “Mega MOUT: Urban Combat Center Growing at Desert Base.” *Marine Corps Times*: Army Times Publishing Company. June 2005.

Galligan, David P., Mark A. Anderson and Michael K. Lauren. *Map Aware Non-uniform Automata Version 3.0 Draft Users Manual*. July 2004.

Goulding, Vince. Comment made in Sea Viking 06: The MAGTF and Distributed Operations Brief, 2004.

Gray, A. M. Comments from the former Commandant of the Marine Corps during a ceremony commemorating the anniversary of the groundbreaking for the Marine Corps Research Center, June 20, 1997.

Harnden,Toby. “I got my kills ... I just love my job.” November 09, 2004. Available: http://www.telegraph.co.uk/news/main.jhtml?xml=/news/04/11/09/wirq109.xml&sSheet=/news/04/11/09/ixnewstop.html

Harp, Seth. “A Week in Samarra.” *The Daily Texan*. November 05, 2004.

Holzer, Robert. “Krulak Warns of Over-Reliance on Technology.” *Defense News*. October 07, 1996.

Johnston, Adam. “2nd AABN Marine Receives Purple Heart.” June 08, 2005 Available: http://www.marines.mil/marinelink/mcn2000.nsf/0/F853461B699C047D85257021006A199E?opendocument

Keiler, Jonathan F. “Who Won the Battle of Fallujah?” *Proceedings,* U.S. Naval Institute. January 2005 Available: http://www.armyonline.com/NewContent/0,13190,NI_0105_Fallujah-P1,00.html

Kelly, Jack. “US Tactics, Training Kept Casualties Down in Fallujah.” *Pittsburgh Post-Gazette.* November 21, 2004.

Krane Jim. “US Forces Press Offensive in Insurgent-Held Districts of Fallujah, Opening Major Ground Assault.” *Associated Press*. November 09, 2004.

Krane, Jim. “US Forces Storm Fallujah.” *Associated Press*. November 08, 2004.

Lauren, Michael K. and Roger T. Stephen. “Map-Aware Non-Uniform Automata (MANA)—A New Zealand Approach To Scenario Modeling.” *Journal Of Battlefield Technology*, Vol 5, No 1. March 2002.

“Marine Corps Concepts and Programs 2005.” Available: http://hqinet001.hqmc.usmc.mil/p&r/concepts/2005/TOC1.HTM

"MCCS Demographics." Available: http://www.usmc-mccs.org/buspartners/sponsorship_demographics.cfm

McLaurin, R.D., Paul A. Jureidini, and David S. McDonald. *Modern Experience in City Combat*. Aberdeen Proving Ground, Maryland: U. S. Army Human Engineering Laboratory. 1987.

Mert, Esref and Erik W. Jilson, "Modeling Conventional Land Combat in a Multi-Agent System Using Generalization Of The Different Combat Entities and Combat Operations." Master's Thesis. Naval Postgraduate School, Monterey, CA. 2001.

"Military Operations on Urban Terrain [MOUT]." GLOBALSECURITY.ORG Available: http://www.globalsecurity.org/military/ops/mout.html

Navy League 05 Almanac Available: http://www.navyleague.org/sea_power/almanac_jan_04.php

Project Albert, US Marine Corps Warfighting Laboratory. Available: http://www.mcwl.quantico.usmc.mil/Albert/home.cfm

Rothenberg, Jeff. "Object-Oriented Simulation: Where Do We Go from Here?" *A RAND Note*. The Rand Corporation. October 1989.

S-PLUS 4 Guide to Statistics. Data Analysis Products Division, MathSoft. Seattle, Washington. July 1997.

Scarborough, Rowan and Bill Gertz. "Coalition Uses Divide-Conquer Plan in Fallujah." *The Washington Times*. November 09, 2004.

Schmidle, Robert E. comments to the Defense News Media Group conference, Joint Warfare: Transformation and New Requirements, June 22, 2004.

Schmidle, Robert E., and Frank G. Hoffman. *Commanding the Contested Zones*. 2004.

Schwarzkopf, H. Norman, and Peter Petre. *General H. Norman Schwarzkopf: The Autobiography: It Doesn't Take A Hero*. New York: Bantam Books., 1992.

Skelton, Isaac Newton. "Chapter 10 Military Lessons from Desert One to the Balkans." *Whispers Of Warriors: Essays On The New Joint Era*. November 2004.

Spiller, Roger J. *Sharp Corners: Urban Operations At Century's End*. 2000.

Spinner, Jackie, Karl Vick and Omar Fekeiki. "US Forces Battle into Heart of Fallujah." *Washington Post, Foreign Service*. November 10, 2004.

"Tactics." *Encyclopedia Britannica 2005: Encyclopædia Britannica Premium Service*. July 16 2005 Available: http://www.britannica.com/eb/article?tocId=52999

Toolan, John, Colonel, USMC. Comment made in briefing at Modeling and Simulation Urban Summit IV. January 19, 2005.

"UN Press Release." *POP/899*. March 24, 2004.

Ware, Michael. "Into the Hot Zone." *Time*, Vol. 164 No. 21. November 22, 2004.

Weber, Joseph F., Brigadier General. Statement to the House Armed Services Committee, March 08, 2002 Available: http://www.house.gov/hasc/openingstatementsandpressreleases/ 107thcongress/02-03-08weber.html

Weiss, Gerhard. "Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence." *The MIT Press*. Cambridge, Massachusetts. 1999.

Wells II, Linton. "An Information Age DoD: Turning Vision into Reality: a Briefing from the Assistant Secretary of Defense, Networks and Information Integration"

Whittaker, L. "Data Analysis: OA3103 Class Notes." Naval Postgraduate School, Monterey, CA, January 2005.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Marine Corps Representative
   Naval Postgraduate School
   Monterey, California

4. Director, Training and Education, MCCDC, Code C46
   Quantico, Virginia

5. Director, Marine Corps Research Center, MCCDC, Code C40RC
   Quantico, Virginia

6. Marine Corps Tactical Systems Support Activity (Attn: Operations Officer)
   Camp Pendleton, California

7. Director, Studies and Analysis Division, MCCDC, Code C45
   Quantico, Virginia

8. Dr. Gary Horne, Director, Project Albert, MCWL
   Quantico, Virginia

9. Colonel James Seaton, Director, MAGTFTC
   Twentynine Palms, California

10. Colonel Jeff Schamburg, Director, TRAC-Monterey
    Monterey, California

11. Lieutenant Colonel Robert Armstrong
    Norfolk, Virginia

12. Doctor Thomas Lucas
    Monterey, California

13. Lieutenant Colonel Ed Lesnowicz
    Monterey, California

14. Major William Yates,
    Twentynine Palms, California

THIS PAGE INTENTIONALLY LEFT BLANK