AFIT/GOR/ENS/91M-11

ANALYSIS OF THE EFFECTS OF
THE COMMANDER'S BATTLE POSITIONING
ON UNIT COMBAT PERFORMANCE

THESIS

Thomas I. Pratt
Captain, USA

AFIT/GOR/ENS/91M-11

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)
2. REPORT DATE
3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

Analysis of the Effect of the Commander's Battle Positioning on Unit Combat Performance

5. FUNDING NUMBERS

6. AUTHOR(S)

Thomas I. Pratt, Captain, USA

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Institute of Technology
WPAFB, OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GOR/ENS/91M-11

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for Public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The purpose of this study was to determine the effect of the Commander's battle positioning on unit combat performance. Research was focused on analyzing the location of the Battalion/Task Force Commander during daytime deliberate attacks conducted at the U.S. Army's National Training Center, Ft Irwin, CA. Forty battles, spanning a period from January 1986 to September 1989, provided a basis for this study. Information that described the Commander's location, a general description of the battle, and unit measures of effectiveness, were collected for each battle. The study database was explored using numerous multivariate analysis techniques. Results of this analysis indicated that neither the Commander's location, nor his survival, had a measurable effect on unit combat performance. Rather, such factors as unit experience, the terrain type, and the unit's level of equipment modernization, seemed to have the most effect on unit performance.

14. SUBJECT TERMS

Leadership, AirLand Battle, the NTC, Deliberate Attacks

15. NUMBER OF PAGES

135

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

AFIT/GOR/ENS/91M-11

ANALYSIS OF THE EFFECT OF THE COMMANDER'S BATTLE POSITIONING ON UNIT COMBAT PERFORMANCE

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

Thomas I. Pratt, B.S.

Captain, USA

March 1991

Approved for public release; distribution unlimited

THESIS APPROVAL

STUDENT: Thomas I. Pratt CLASS: GOR-91M

THESIS TITLE: Analysis of the Effects of the Commander's Battle Positioning on Unit Combat Performance.

DEFENSE DATE: 25 February 1991

COMMITTEE:	NAME/DEPARTMENT	SIGNATURE
Advisor	COL Schuppe/ENS	
Reader	MAJ Garrambone/ENS	
Reader	MAJ Bauer/ENS	

Preface

The purpose of this study was to determine the effect of the Commander's battle positioning on unit combat performance. Due to limitations in available data and time, I limited my research to investigating the location of the Battalion/Task Force Commander during deliberate attacks at the National Training Center, Fort Irwin, CA, covering a period from January 1987 to September 1989. This study, sponsored by the U.S. Army Armor School, is a part of the U.S. Army's Trendline Analysis of training activities at the National Training Center.

Numerous multivariate analysis techniques were applied in an effort to determine a relationship between the Commander's location and a set of variables measuring unit effectiveness. Although the results of this analysis proved inconclusive, insights provided by this study could be valuable to further research on the topic.

I am in debt to a number of people who provided me help in completing this project. MAJ Philben and Mr. Vowels of the U.S. Army Armor School provided me guidance in developing my research proposal. CPT Ladig (Center for Army Lessons Learned) and Mr. Rick Crenshaw (ARI-POM) provided assistance in accessing the NTC database. Finally, my thesis committee provided me invaluable guidance in conducting this research.

Thomas I. Pratt

Table of Contents

List of Figures

List of Tables

AFIT/GOR/ENS/91M-11

Abstract

The purpose of this study was to determine the effect of the Commander's battle positioning on unit combat performance. Research was focused on analyzing the location of the Battalion/Task Force Commander during daytime deliberate attacks conducted at the U.S. Army's National Training Center, Fort Irwin, CA. Forty battles, spanning a period from January 1986 to September 1989, provided the basis for this study. Information that described the Commander's location, a general description of the battle, and unit measures of effectiveness, was collected for each battle and put in a format that allowed for ease of analysis. This study database was explored using numerous multivariate analysis techniques. Results of this analysis indicated that neither the Commander's location, nor his survivability, had a measurable effect on unit combat performance. Rather, such factors as unit experience, the terrain type, and the unit's level of equipment modernization, seemed to have the most effect on unit performance.

Analysis of the Effects of the Commander's Battle Positioning on Unit Combat Performance

I. Introduction

Background

Much has been theorized and written on the role of the military leader in battle. Despite this volume of existing literature, there is much we still do not know about the act of leading men in combat. Leadership questions that remain unanswered include at what point in battle, given the current U.S. Army doctrine (named AirLand Battle) of decentralized decision making, does a leader become overloaded with the mental tasks at hand and, what are the factors of human performance and behavior which substantially affect the outcome of combat. The answers to these questions are important to both the commander and the Operations Research community, who wish to model these phenomena of combat. Current U.S. Army doctrine mandates that a leader must be far enough forward to "see" the battle (14:5). How important is a leader's battlefield location and his survivability in influencing the outcome of the battle remains open to investigation.

Much of the theory on combat leadership is based on historical study and personal accounts (33:2-2). As of late, little experimentation has been done concerning combat leadership because of the lack of a credible "laboratory" in which to apply the scientific method. In recent years, however, this has changed. Now, U.S. Army unit's deploy to the U.S. Army National Training Center at Fort Irwin, CA, to conduct combat training in "the world's most realistic combat training environment" (15:Cover Letter).

Operations at the National Training Center. The National Training Center (NTC) is located in the Mojave Desert, about 32 miles north of Barstow, CA. The purpose of the NTC can be

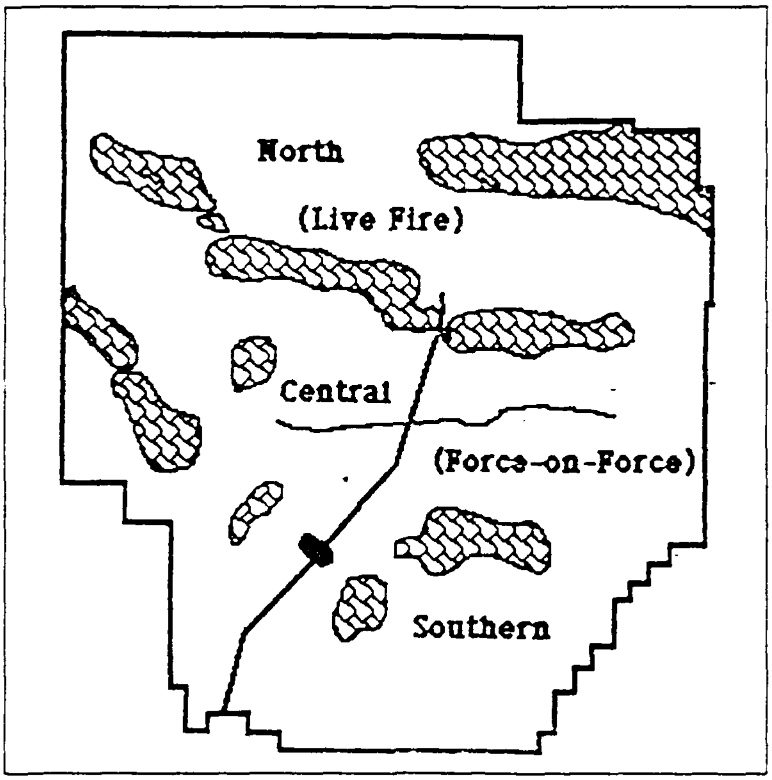

Figure 1. NTC Military Reservation (Reprinted from 8:C3).

described by the following mission objectives:

"-Increase unit readiness for deployment and warfighting.

-Train bold, innovative leaders through stressfull exercises.

-Embed doctrine throughout the Total Army.

-Provide feedback to Army participants.

-Provide a data source for lessons learned in order to improve doctrine, training, organization, material and leadership (7:3)."

Personnel involved with the training conducted at the NTC can be divided into three groups: the visiting unit being trained, the Opposing Force (OPFOR), and the Observer/Controller (O/C) Group.

The Visiting Unit. Fourteen times a year, an Army Brigade deploys to the NTC to conduct training. The brigade normally consists of a Brigade Headquarters, two heavy maneuver battalion/task forces (one Armor, and one Infantry), a Field Artillery Battalion, a Support Battalion (providing maintenance and logistical support), two Engineer Companies, and other supporting units smaller than company size (total size of approximately 3500 soldiers). A brigade's rotation lasts three weeks, one week of which is devoted to drawing and turning in equipment maintained at the NTC for training purposes. The remaining two weeks are dedicated to force-on-force training (10 days), and live fire training (4 days). During the force-on-force training, conducted mostly in the central and southern corridors, the task force conducts five or six combat operations (both offensive and defensive) equipped with the Multiple Integrated Laser Engagement System (MILES) equipment.

MILES provides individual soldiers and vehicle crews with sensory devices that assess real-time casualty-producing effects of weapons during the force-on-force training. The actual

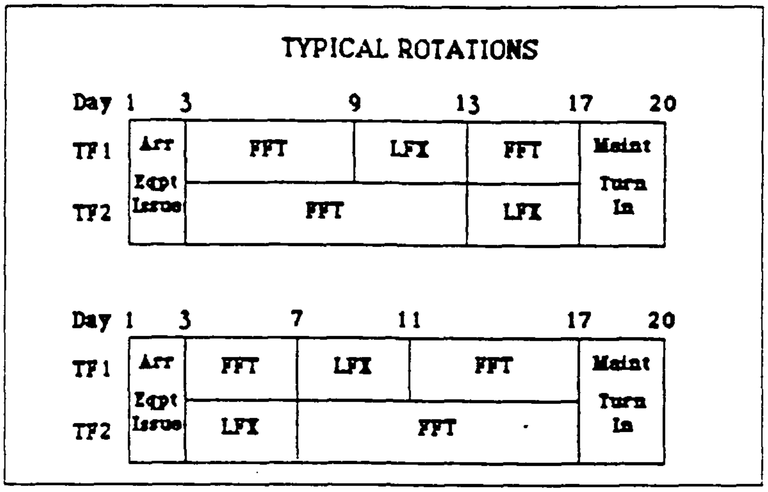

Figure 2. Rotation Schedule (Reprinted from 8:C4).

equipment consists of "an integrated family of low power, eye-safe, laser-based devices that simulate" weapon effects ranging from the individual rifle to tank fire and missiles (16:1-2). The weapon system is equipped with a transmitter that fires a laser beam each time the weapon's trigger is pulled. If the laser beam hits a laser detector mounted on a target, the result is either a near miss, a target hit, or a target kill, depending on the point of impact (16:1-3).

<u>OPFOR</u>. The opposing force at the NTC is a doctrinally trained, field experienced unit modeled after a Soviet Motorized Rifle Regiment. This unit is permanently stationed at the NTC, providing year round training support. Also equipped with MILES,

the OPFOR's mission is to provide the training task force a tough, realistic enemy during the their force-on-force battles (7:3). In as much as this unit is stationed year round at the NTC, and trains against 14 Brigades a year, it enjoys certain advantages over the visiting Task Force. Specifically, the OPFOR is very experienced in conducting combat operations, and has almost unlimited knowledge of the terrain. The OPFOR maneuvers in visually modified track vehicles that resemble Soviet T-72 Tanks, BMP Infantry Fighting Vehicles, and wheeled vehicles that resemble BRDM Armored Combat Vehicles.

The Observer/Controller Group. The mission of the Observer/Controller Group (O/C) is threefold. First, as doctrinal experts, the O/C observes all aspects of the training unit's operations, and helps conduct after action reviews (AARs) to determine what happened, why it happened, and measures of improvement. Secondly, each O/C acts as a battle arbitrator and safety agent, during the force-on-force battle. Finally, the O/C group facilitates the instrumented collection of the vast data base that ranges from the location of each vehicle during a battle, engagement statistics (i.e. the transmitted MILES data of kills, near misses, trigger pulls, etc.), to the use and effect of artillery fire and engineer obstacles (7:3).

The focus of the information gathering and mission After Action Reviews is to provide the visiting unit guidance on training strengths and weaknesses. A written record of this information is contained in the unit Take Home Package (more

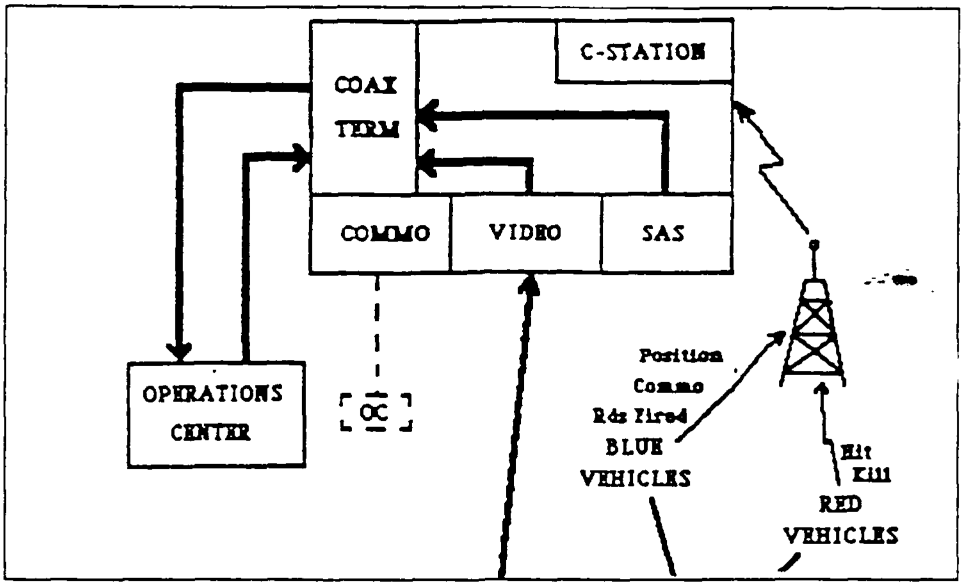

Figure 3. Instrumentation System (Reprinted from 8:C13).

information on the Take Home Package is contained in Chapter IV). As this study depends on the instrumented data collected on the NTC mock battlefield, it is important to understand this instrumentation system.

The NTC Instrumentation System. The main components of the instrumentation system are the player kits mounted on the player vehicles, the A receiving stations deployed throughout the reservation, and the C station. The player kits, also called B units, record firing events (firing, hit, near miss, kill) and the use of radio. Every five seconds, the B unit emits a range pulse which, if picked up by three A stations, allows for the player's location to be triangulated. Additionally, the pulse also transmits firing event data since the last pulse. This information is transmitted to the C station, where it is processed and put into usable form (8:C-14 to C-14).

Problem Statement

The problem is that the U.S. Army Armor School lacks a quantitative assessment of the extent to which the location of the commander impacts the outcome of battle. At issue, then, is whether the NTC data base can be used to answer this question. Thus, the purpose of this research is to determine the effect a commander's location in his unit's formation has on his unit's "success". This study will focus on studying the position of the Battalion/Task Force Commander during battle. Additionally, research will be limited to analyzing only the daytime deliberate attack scenario conducted at the National Training Center.

For the purposes of this study, the Commander's location (in his unit's formation) is defined as his distance from:

- The forward combat vehicles in his own unit formation;
- The closest enemy vehicle in the enemy's main defensive belt;
- The maneuver units' (defined here as the four maneuver companies) center mass.

Research Objectives and Methodologies

The above research problem has been broken into seven sub-objectives that, when accomplished, provide the solution to the entire research problem. The sub-objectives are listed below.

1. Leadership in Combat. Chapter II reviews the literature concerning the effects of leadership on unit combat performance. This study has sought a wide range of views, starting in history with Attila the Hun and Carl Von Clausewitz, and progressing in time to current thought. Research included analysis on the historical evolution of U.S. Army leadership doctrine, and delves into determining the U.S. Army's current doctrine on a commander's location during offensive operations.

2. AirLand Battle and the Task Force Deliberate Attack. In Chapter III, information is presented concerning AirLand Battle's offensive tenets, and the principles of the deliberate attack. Of equal importance was determining the role that the Battalion/Task Force plays in the deliberate attack. The normal NTC deliberate attack scenario pits the attacking Task Force (TF) against an OPFOR Motorized Rifle Company in a prepared defensive position. Thus, this portion of the study includes with a description a Soviet Motorized Rifle Company deliberate defense.

3. NTC Data Description. Chapter IV provides an understanding of the range of information collected during each mock battle at the NTC. Of equal importance was determining the "environment" of the data collection process. Included in this "environment" are such considerations as method of collection, the amount of experimental control, the reliability of the data, and the format of the information available.

4. Selection of the Battles for Analysis. The major concern of this investigation was to isolate the commander's

battle positioning contribution to a battle, given the hundreds of other variables that can, and do, influence combat. In an effort to control this variability, the large set of battles stored in the archives were pre-screened against the following scope limiting criteria.

-Study only daytime deliberate attacks.

-Study only those battles that provide the identification of commander's vehicle or vehicles during the battle.

The methodology for attaining this sub-objective was to screen the NTC Take Home Packages (THP) located at Fort Knox, KY. Each THP consists of the training unit's designation, a description of the battles fought during the rotation, analysis of the training unit's performance in the eight operating systems (Command and Control, Maneuver, Fire Support, Intelligence, Air Defense, Engineer Operations, and Combat Service Support), and micro-computer based graphic display of the movement of each vehicle in the battle.

5. Data Collection and Processing. The next sequential sub-objective was to actually extract the battle data to be investigated. The following type of information proved critical for this study.

-Commander's location relative to his unit's mass and the enemy (discussion of the variables that are used to describe his location is contained in Chapter IV).

-Enemy vehicles destroyed and surviving.

-Friendly vehicles destroyed and surviving.

-Portion of the terrain objective secured.

-Information on the terrain.

Once the data was collected, it was organized into a format that allowed for ease of analysis. A description of the study database is contained in Chapter IV. It is important to note that some pieces of battle information, that would aid in this research, were not available at the NTC Archive. Factors such as the weather conditions, the number of times the commander employed his vehicle's direct fire weapon system, and an effective measure of unit cohesion were not contained in the database.

6. <u>Development of the Study Methodology</u>. This sub-objective required an understanding of the analytical techniques available to answer the research questions. Thus, Chapter V reviews the literature on multivariate methods that are applicable to this study. Given this review, Chapter V concludes with development of the research methodology.

7. <u>Determine Relationships</u>. Once the data collection process was completed and the information correctly formatted, the study focused on answering the following questions.

-Is there a relationship between a Commander's location and his unit's effectiveness?

-Can a Commander's contribution to the battle be quantified through knowledge of his location, and survival during the battle?

-What is the relationship between a Commander's location and his survival?

-Is there an "optimal" location with respect to the above mentioned concerns?

The results of this analysis are contained in Chapter VI.

II. Leadership in Combat

Introduction

The commander has two basic functions on the battlefield. First, he must be a leader to his soldiers, inspiring and motivating them to accomplish unit goals that may be contrary to their personal desires. This function is called leadership. Second, he must manage the diverse resources (time, equipment, combat power, etc.) available to achieve the unit's mission. This function is called command and control. The following paragraphs discuss literature pertinent to the subject of leadership. The discussion covers the topics of personal leadership characteristics, leadership's effect on unit combat performance, the effect of losing a commander during battle, and finally, command and control issues.

Discussion

Leadership Characteristics. Many historians and behavioral scientists have written on the characteristics, or qualities, of a successful military leader. As leadership is more art than science, abundant theories on combat leadership exist. Thus, a thorough review of the literature on this topic would require resources beyond the scope of this research. This section, therefore, will provide a small sampling of the historical evolution of thought on this subject.

Students of the military art have often studied, and determined valuable lessons from the campaigns of Attila the Hun. Wesley K. Roberts, in writing on the leadership of Attila the Hun, found the following list of qualities characteristic of his leadership style.

-Desire to lead.

-Decisiveness.

-Personal example.

-Delegation.

-Command and control.

-Learning from the past.

-Rewards.

-Surviving defeat (30:9).

As a military historian and theorist, Karl Von Clausewitz was the guiding influence of the superb German Armies of World War I and World War II. On the subject of military leadership, Von Clausewitz did not believe that a list of personal traits could accurately describe the great captains of war (4:30). Rather, Von Clausewitz described the leader under his concept of military genius. The military genius embodied a strong mind, which Von Clausewitz called character, and a strong and intense personality (6:104). Donald Chipman, in analyzing Von Clausewitz's concepts of leadership, describes the development of this character as the leader balancing "his intense emotions with self-control acting as a counter-weight" (4:32). Of critical importance to Von Clausewitz was a belief that the leader should be well versed in the military art, not so much as to bind himself by history, but rather to develop an imaginative, reflective intellect (6:111).

Military historian George M. Hall describes successful leadership characteristics as a function of what he calls the four faces of leadership. The leader accomplishes his mission, according to Hall, by:

-imposing his will on his subordinates by the sheer force of his character;

-inspiring his soldiers by the attributes of his personality or reputation;

-directing his unit by virtue of his authority;

-managing his force by using his administrative skills and persuasion (21:39).

Hall contends that the military leader uses a combination of two or more of the above mentioned faces, depending on the situation and his personal preferences (21:40).

Colonel S. L. A. Marshall is considered one of the preeminent historians on human performance in combat during World War II. Marshall analyzes the combat performance of American soldiers and small units in his book Men Under Fire. In his narrative, Marshall lists six important characteristics of strong combat leaders.

-Diligence in the care of his men.

-Administering the affairs of punishment and promotion to an equal standard for all.

-Military bearing.

-An ability to communicate with other soldiers.

-Courage, creative intelligence, and physical fitness.

-Respect for the dignity of his position and the work accomplished by his men (25:163-164).

In another effort to capture the essence, or personality traits, of the successful military leader, the Human Resources Research Office (HRRO) conducted a survey of soldiers and leaders following the Korean War in 1957. Major Jeffrey W. Anderson reported the findings of the HRRO study on successful leader characteristics as:

-A higher than average intelligence level.

-A 'doer'.

-A higher than average emotional stability.

-Health and vitality.

-Sound military knowledge (1:76).

In 1984, the History Department of the U.S. Military Academy at West Point completed a study to determine trends and characteristics in successful combat leadership. In studying over 200 examples of leadership, the study group determined five personal characteristics that were essential to successful combat leaders. These characteristics include:

-Terrain sense, or the ability to quickly judge terrain and its tactical implications.

-A single-minded tenacity that sought completion of the mission no matter the requirements.

-Audacity, or the willingness to take reasoned but enormous risks.

-Physical confidence and health.

-Practiced, practical judgement that could determine the essential from the unimportant (35).

One of the more charismatic and successful combat leaders in American history was General Matthew Ridgway, commander of the 82nd Airborne Division during WW II, and the 8th Army in Korea. In analyzing Ridgway's leadership style, Duane A. Lempke comments on the General's great "ability to communicate and project himself" (24:71). Lempke quotes Ridgway, in a letter to his son, on the importance of a leader's ability to "communicate his ideas, his knowledge, his proposed plans, and the reasons for them, to those whose cooperation is necessary for successful execution" (24:71).

The U.S. Army's current leadership doctrine is contained in Field Manual 22-100: Military Leadership. The manual defines leadership as a philosophy which provides the framework of what a leader must be, know, and do (10:2). Specifically, a leader must commit himself to the nation's ideas, and possess such professional characteristics as courage, competence, candor, commitment, and integrity. The manual defines examples of leadership knowledge as knowing human nature (human needs and emotions, reactions to stress, etc), and knowing the job (technical and tactical proficiency). Finally, the Army's current doctrine states that a leader must provide direction to his unit, and motivate his subordinates by applying such principles as developing morale and esprit, along with teaching, coaching, and counselling (10:107-111).

Leadership's Effect on Combat Performance. Unlike the topic of leadership traits, there is general agreement by military historians on the effect leadership has on a unit's performance in combat. As General George S. Patton once said:

> Leadership is the thing that wins battles. I have it - but I"ll be damned if I can define it. Probably it consists of knowing what you want to do and doing it and getting mad if anyone steps in the way. Self-confidence and leadership are twin brothers. (32:97)

The U.S. Army's conviction of the importance of leadership in combat is stated in Field Manual 100-5: Operations.

> The fluid, compartmented nature of war will place a premium on sound leadership, competent soldiers, and cohesive, well-trained units. The conditions of combat on the next battlefield will be unforgiving of errors and will demand great skill, imagination, and flexibility of leaders. As in wars of the past, however, American soldiers will fight resolutely when they know and respect their leaders and believe that they are a part of a good unit. (14:5-6)

Thus, the Army believes that combat performance will be predicated on the leadership provided to the soldiers in the unit.

The West Point study is also unequivocal in it's evaluation of a commander's effect on his unit's performance.

> In no case did a unit in combat overcome the deficiencies of its leader; in almost all cases the leader overcame startling deficiencies and incredible problems in mission definition, enemy forces, physical and moral strength, troop training, and equipment obstacles, weather and terrain conditions, bad luck, poor timing, misinformation, unreliable superiors and subordinates, and his own anxiety. (35)

S. L. A. Marshall believed that the leader's ability to communicate to his subordinates was critical to unit success in combat. Marshall contended that soldiers need to know what is happening around them during the battle (25:131). "The spoken word is the greatest of steadying forces in any time of crisis" (25:140).

Colonel William D. Henderson, in his book Cohesion: The Human Element in Combat, contends that unit cohesion is the determining factor on unit performance in combat. Colonel Henderson, who served as an infantry platoon leader and company commander in Vietnam, further argues that leadership at the platoon, squad, and section level is the most important consideration in determining unit cohesion (22:111). In describing the leadership found in the North Vietnamese Army, Henderson noted that:

> Through demonstrated expertise and an extremely demanding, almost puritanical code of professional ethics that put the leader up front where he shared equally all hardship and danger, the North Vietnamese leader usually was able to lead his unit gracefully and repeatedly in surviving difficult situations. (22:118)

As another example of an Army with excellent small unit leadership, built of the respect and admiration of their soldiers, Henderson cites the Israelis.

> While the strategic skills of Israel's top military leadership have led to impressive victories, almost all of those within the IDF recognize that the key element in these victories is the Israeli soldier and his immediate leadership at squad, crew, and platoon levels. (22:143)

Lempke, in his discussion of the leadership style of Matthew Ridgway, maintains that as the new commander of the demoralized 8th Army during the Korean War, Ridgway improved the morale and fighting spirit of his soldiers through his sheer physical presence. Part of Ridgway's technique was to visit his soldiers on the front line. Lempke quotes the General himself on this belief. "I held to the old-fashioned idea that it helped the spirits of the men to see the Old Man up there, in the snow and sleet, and mud, sharing the same cold, miserable existence they had to endure" (24:72). Thus, Ridgway felt that his own personal leadership skills had a substantial influence on his soldiers, and his unit's combat performance.

Losing the Commander in Combat. In contrast to the volumes of research available on leadership characteristics, little has been written on the effect of losing a commander in combat and how this impacts on unit performance.

Civil War historian Bruce Catton cites one example where the loss of the commander had an adverse effect on unit performance. In the Battle of Shiloh, the Confederate forces, under General Albert Sidney Johnston, attacked an unprepared Union force under the command of General Ulysses S. Grant. By late afternoon on 6 April 1862, the Confederates had driven Grant's forces to the banks of the Tennessee River. About the time Confederate victory seemed assured, however, Johnston was shot in the leg and bled to death on the battlefield. Shortly thereafter, the Confederate attack began to lose it's momentum, allowing for the arrival of Federal reinforcements, and Grant to reorganize his near beaten Army, eventually securing victory (3:219-223).

In another Civil War example, Douglass Southall Freeman contends that the loss of General Stonewall Jackson had a dramatic effect on his Confederate soldiers during the Battle of

Chancellorsville, 2 May 1863. While pursuing the beaten Federal Army, Jackson was mortally wounded by his own soldiers. Freeman concludes that the death of Jackson allowed the Union troops, from the Army of the Potomac, to escape total destruction and thus, changed the whole course of the war (19: 612-615).

Henderson (Ref. 22) contends that the loss of a leader during combat affects the cohesiveness of the unit, and thus could impact the unit's performance. Soldiers, on the small unit level, depend on the experience and expertise of their leaders. As a result, when they perceive that a new leader, thrusted into his position by the death or injury of the unit leader, lacks the experience or knowledge to be effective, the cohesion of the unit suffers accordingly. Henderson cites this trend in the NVA, whose unit's placed great importance on the expert power of their leaders (22:123-124).

Colonel Leon J. LaPorte (Ref. 23), a former Battalion Commander, writes that not enough study has been conducted concerning the effects of rapid leadership succession in combat. LaPorte contends, as Henderson does, that unit cohesion significantly affects unit performance at the NTC, citing a study conducted by the Army Research Institute for the Behavioral and Social Sciences.

> The impact of leaders on unit performance is recognized by most researchers. There appears to be some limitation from a cause and effect perspective, but there is general agreement that the concept of leadership succession influences leader-subordinate relations. (23:13)

LaPorte concludes that "the impact of leadership succession is unquestionably tied to unit cohesion and effectiveness" (23:14).

The Center for Army Lessons Learned (CALL) conducted their own study of the effect of losing a commander during the battle. This study used data collected from force-on-force battles conducted at the NTC, justifying their source as "consistent with historical experience and may be a harbinger of the casualty intensive nature of future armor battles" (15:3). The CALL study focuses on the loss in command and control presented by changing commanders during the battle. "At the NTC most task forces take from 15 to 20 minutes to reestablish command and control after a task force commander's death" (15:12)

<u>Command and Control</u>. If the leadership function of the commander seeks to inspire and motivate, then the command and control function seeks to provide purpose and direction. The U.S. Army's Training and Doctrine Command (TRADOC) defines the command and control process through the following tasks:

-Find out what is going on.

-Decide on what to do about it.

-Issue the necessary instructions.

-Keep track of how well the instructions are being carried out (34:1-2).

As noted above, determining what is happening on the battlefield, and then directing his unit to action in response to this information is of critical importance to the commander. This section will review the literature concerning the actions a commander must take to ensure his ability to perform his functions of command and control.

In his thesis, Willbanks analyzes past and present concepts in command and control (Ref. 36). In investigating the operations of the U.S. 4th Armored Division and the German 11th Panzer Division during World War II, Willbanks determined a similarity in each commander's concept of forward command.

Rather than relying on subordinates' reports on the situation, Major General Herman Balck, commander of the 11th Panzer Division, believed in leading from the front. Willbanks quotes Balck on this subject. "The secret of modern leadership is that everything has to happen in the blink of an eye. That can only be accomplished if the commander is right at the point of the action" (36:97). Likewise, the commander of the 4th Armored Division, Major General John S. Wood, believed in commanding from the front. Willbanks described Wood's method of command and control in the following excerpt:

> Having issued the order, Wood commanded from the front, using his Piper Cub or, less frequently, a jeep. He continued to control the action with oral orders by landing near the fighting and conducting 'tailgate conferences' with his subordinate commanders where he could see for himself what was happening on the battlefield. (36:58-59)

In both cases, the commanders operated well forward in order tc see the battle first hand.

Another of the great World War II leaders, Field Marshall Erwin Rommel, also believed in being forward during combat operations. His Chief of Staff, General Alfred Gause, wrote that as a matter of course, Rommel would personally direct operations from the area of main effort, often circumventing his subordinate commanders. Rommel earned the respect of his men, in large part through his absolute reliability in directing combat operations. Thus, Gause reports that the soldiers of the Africa Corps believed in Rommel implicitly, expecting him to master the situation (20:142).

Lieutenant Colonel Clayton R. Newell contends that rarely will a commander know exactly what is happening on the battlefield, no matter where he positions himself. Thus, Newell states that commanders must be prepared to make decisions without perfect information. Given this uncertainty, Newell believes that the most accurate measure of command and control is the unit's ability to react more quickly than the enemy when unexpected situations arise (28:23-26).

As mentioned in TRADOC Pamphlet 525-2, a critical task of the command and control process is to 'see' the battlefield. Parker (Ref. 29) insists that experience at the National Training Center has illustrated the need for the commander to see the battlefield (29:28). "The commander must also position himself where he can best influence the battle by virtue of the moral effect of his presence" (29:29).

In discussing an attack conducted by his Brigade at the National Training Center, Colonel Wesley K. Clark describes the positioning of himself and his subordinate commanders to control and direct combat operations.

> Leaders were well forward during the execution. The lead TF commander visually controlled team maneuvers around the

> breach site. The brigade commander trailed the lead TF, close enough to ensure concentration of combat power, and far enough forward to control the movement of the brigade near the breach site. (5:48)

Thus, Clark is also a firm advocate of the commander positioning himself far enough forward to 'see' the battle, and to control his maneuver units at the critical point.

Summary

The literature is mixed concerning the question of leadership traits. Some military writers, such as Roberts, Marshall, and the researchers for the West Point study, believe that similar leadership traits can be observed in all successful combat leaders. Others, such as Von Clausewitz, Hall, and Patton, do not believe that identifying distinct characteristics adequately describes the successful leader. The current Army policy on leadership seems to blend both trends of thought.

Most of the literature supports the concept that the leadership in a unit can have a significant effect on combat performance. The range of support for this concept varies from Henderson, and LaPorte, who consider leadership an important factor in developing unit cohesion (thus, more of an indirect effect on unit performance), to the West Point study, that contends that leadership is <u>the</u> determining factor in combat. Most of the literature contends that losing a leader during the battle can affect unit cohesion.

On the commander's function of command and control, the literature provides the following conclusions. The commander must know what is happening on the battlefield. Thus, he must position himself where he can best 'see' the battlefield. Additionally, he must be able to issue orders and provide direction to his unit in a quick and decisive manner to exploit changes in the situation. Finally, units must have an effective method of quickly changing command when a commander is lost in battle.

III. The Deliberate Attack at the NTC

Introduction

The scope of this study is centered on the Battalion/Task Force Deliberate Attack. This chapter will provide information on the doctrine, organization, and equipment of the two contending forces: the Battalion/Task Force in the deliberate attack, and the Soviet Motorized Rifle Company in a prepared, deliberate defense.

The Battalion/Task Force in the Deliberate Attack

It is important to understand the battle doctrine, the capabilities, and the organization and equipment of the Battalion/Task Force, along with the method it conducts a deliberate attack.

AirLand Battle Doctrine. The Army defines doctrine as "the condensed expression of its approach to fighting campaigns, major operations, battles, and engagements" (14:6). The Army's current expression of doctrine is called AirLand Battle, reflecting "the structure of modern warfare, the dynamics of combat power, and the application of the classical principles of war to contemporary battlefield requirements" (14:9).

At the Battalion/Task Force level, AirLand Battle Doctrine is classical maneuver warfare. As it has been practiced for centuries, maneuver warfare involves finding and fixing the enemy with a small portion of the force, and attacking him at a weak point (normally a flank or the rear) with the majority of the force (11:1-3).

Tenets of AirLand Battle. AirLand Battle embodies four basic tenets: initiative, agility, depth, and synchronization.

> **Initiative:** Forcing the enemy to act in accordance with friendly objectives and tempo of battle. Putting the enemy in a defensive frame of mind, requiring him to react to friendly actions, rather than allowing him to act in accordance with his own objectives (14:15). In offensive operations, this requires surprising the enemy as to the point and time of the attack, and then not allowing him to recover from his initial surprise.
>
> **Agility:** "The ability of friendly forces to act faster than the enemy" (14:16). Requires commanders who can make quick decisions without perfect information, and units capable of responding rapidly to changing situations. In offensive operations, this includes pursuing advantages gained, planned or unplanned.
>
> **Depth:** "The extension of operations in space, time, and resources. Through the use of depth, a commander obtains the necessary space to maneuver effectively; the necessary time to plan, arrange, and execute operations; and the necessary resources to win" (14:16).
>
> **Synchronization:** The concentration of combat power at the decisive point of the battlefield. This allows each factor to provide maximum contribution to success, without waste. In tactical offensive operations, this implies the coordinated use of reconnaissance, indirect fires, air attack, electronic warfare assets, maneuver, and direct fires at the critical time and point of attack (14:17-18).

Characteristics of Offensive Operations. Successful offensive operations, under AirLand Battle, embody certain characteristics. First, friendly attacking forces must achieve surprise over the enemy in the time, place or manner of the attack. Secondly, the attacking commander must be able to concentrate his effort at the critical time and place of the attack, in order to achieve overwhelming superiority of combat power. Thirdly, speed is essential for a successful attack, keeping the defending force from recovering from his initial surprise, and not allowing him to concentrate his combat power on the attacking force. Fourthly, successful offensive operations are characterized by flexibility. Attacking units must be ready to exploit unforseen opportunities. Finally, successful offensive operations require audacity, or the bold courage to drive the attack to it's successful conclusion (14:95-98).

The Battalion/Task Force. The Tank and Mechanized Infantry Battalion is the lowest echelon where maneuver, intelligence, firepower, and support coexist under one commander (11:1-6).

Capabilities. In offensive operations, the Mechanized Infantry Battalion is capable of closing with the enemy by means of fire and maneuver in order to destroy or capture him (11:1-2). The strength of the infantry is in it's ability to operate well in compartmentalized or urban terrain, in it's ability to gain and hold ground, and in it's ability to fight enemy infantry. Similarly, the mission of the Tank Battalion in offensive operations is to close with and destroy enemy forces through fire, maneuver, and shock effect (11:1-2). The strength of armor is in it's mobility and speed, in it's protection from the effects of conventional artillery and infantry small arms fire, and in it's ability to deliver rapid, aimed anti-tank and antipersonnel fire.

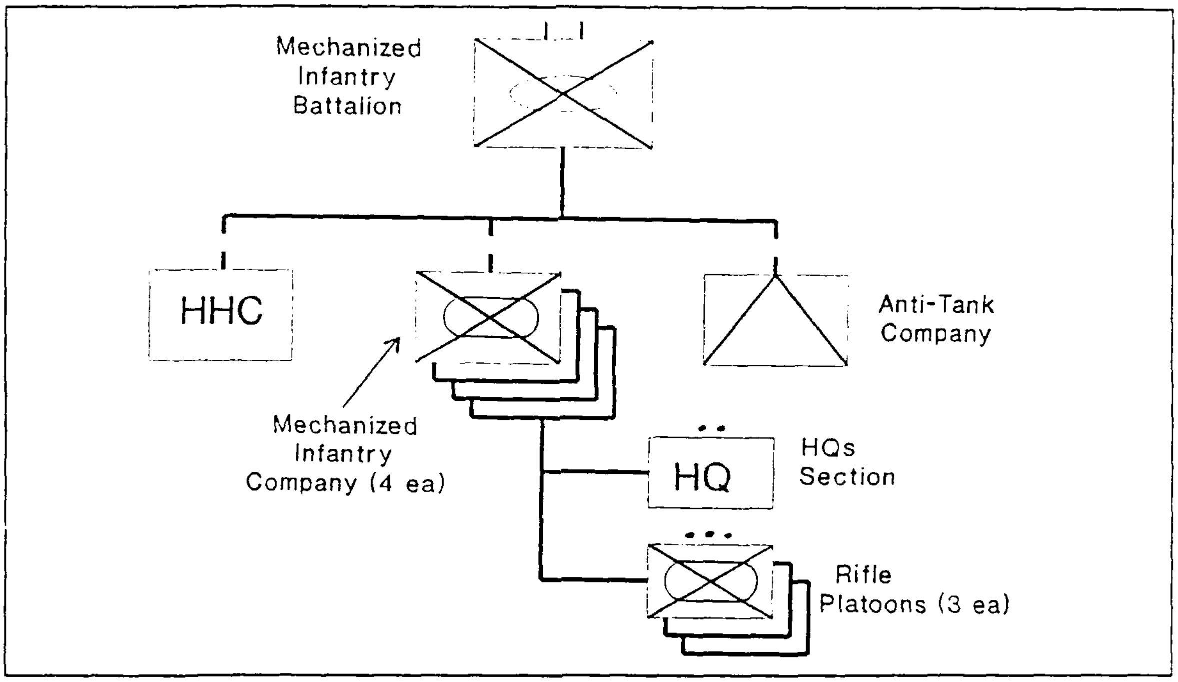

Figure 4. Mechanized Infantry Battalion.

<u>Organization</u>. The tank and mechanized infantry battalions have similar organizations. Each organization consists of four maneuver companies (tank or mechanized infantry), and a Headquarters and Headquarters Company (HHC) containing such support elements as the Battalion Staff, the Scout Platoon, the Mortar Platoon, the Medical Platoon, the Support Platoon, the Communications Platoon, and the Maintenance Platoon. The anti-tank capability of the mechanized infantry battalion is enhanced with an additional Anti-Tank Company (9:8-21 to 8-26). The capability of the tank and mechanized infantry battalion is increased through the formation of task forces. Thus, depending on the mission, commanders will cross-attach

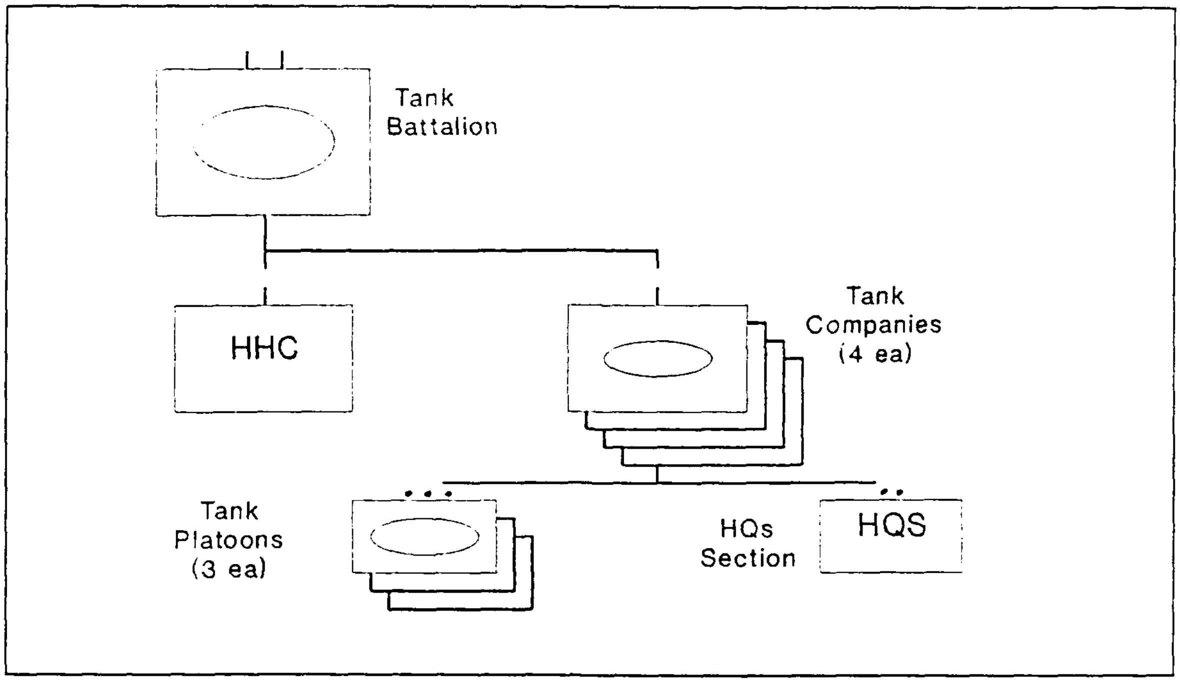

Figure 5. Tank Battalion.

companies between tank and mechanized infantry battalions. For operations at the NTC, the predominate trend has been to create balanced Task Forces, consisting of two tank companies and two mechanized infantry companies.

Equipment. The mechanized infantry company is divided into a headquarters section and three infantry platoons. Each infantry platoon is equipped with either four M113 Armored Personnel Carriers (APCs), or four M2 Bradley Infantry Fighting Vehicles (IFVs). The main weapon system on the M113 is the M2 50 Caliber machine gun. The M2 IFV mounts a TOW (Tube launched, Optically tracked, Wire guided) anti-tank missile launcher, and the Bushmaster 25 mm gun. Additionally, each infantry squad (three in a platoon) has the M47 Dragon anti-tank missile. In total, the mechanized infantry company goes to battle with 13

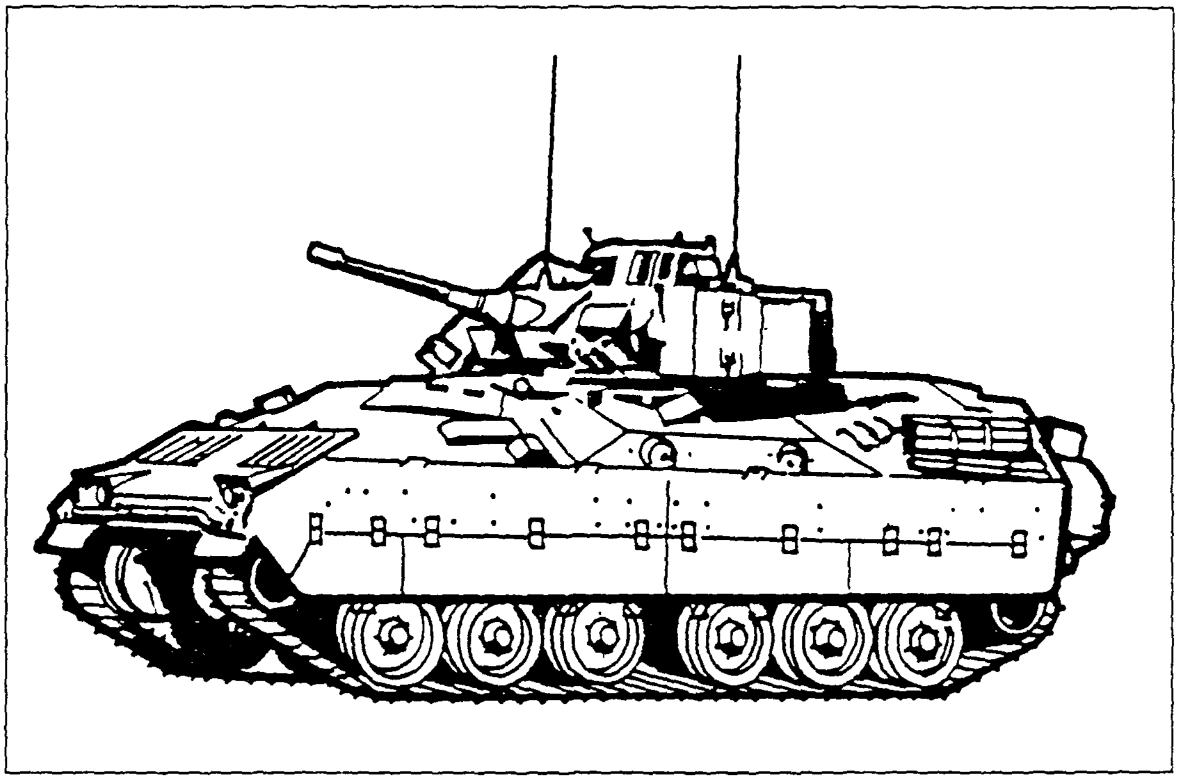

Figure 6. The M2 Infantry Fighting Vehicle.

M113 APCs or M2 IFVs (one vehicle for the Company Commander), and nine M47 Dragons (9:8-26).

The tank company consists of three tank platoons and a headquarters section. Each platoon is equipped with four tanks, either the M60A3, the M1 (both mounting a 105 mm main gun), or the M1A1 (mounting a 120 mm main gun). Thus, the tank company goes to battle with 14 tanks (one each for the Company Commander and the Company Executive Officer) (9:8-41). The anti-tank company, found only in the mechanized infantry battalion, is equipped with 12 M901 Improved TOW Vehicles (ITVs), mounting a TOW anti-tank missile launcher turret on an M113 chassis. The

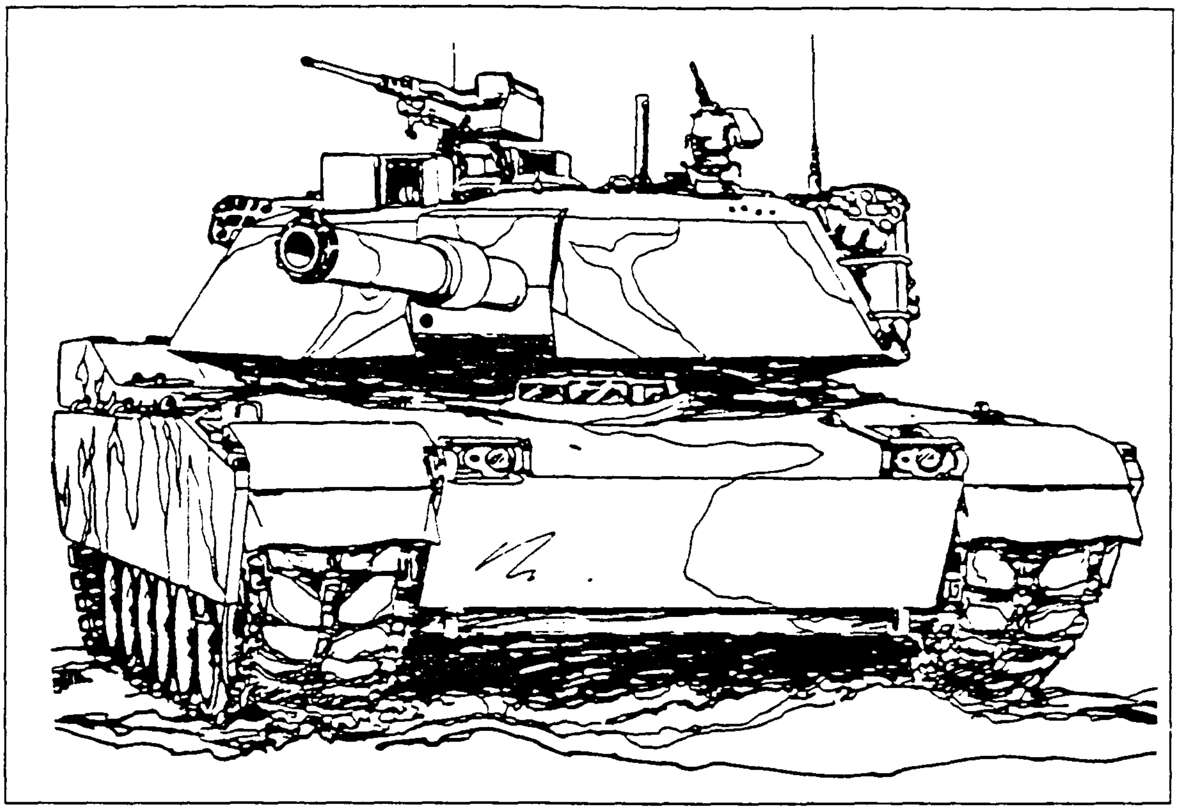

Figure 7. The M1 Abrams Tank.

anti-tank company can be employed by attaching sections (2 M901s) or platoons (4 M901s) to maneuver companies to augment their anti-tank capability. In offensive operations, given the M901's inability to fire on the move, the predominate trend has been to use the Anti-Tank Company as a direct fire support unit, allowing the mechanized infantry and tank companies to maneuver (9:8-26). Thus, a balanced task force, when at full strength, will go into battle with the following major weapon systems:

- 28 or 30 tanks.

- 34 M2 IFVs (2 mechanized infantry companies, a scout platoon, and battalion headquarters).

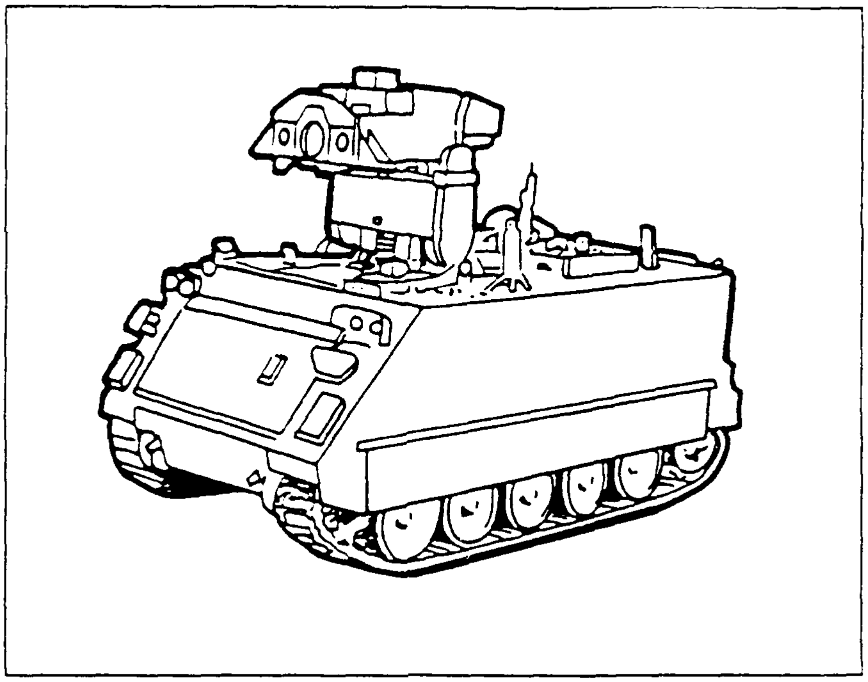

Figure 9. The M901 Improved TOW Vehicle.

or

- 31 M113 APCs.

- From 3 to 23 M901 ITVs (depending on the task organization).

- 21 M47 Dragon Anti-Tank Missile launchers.

The Deliberate Attack. The Battalion conducts five different types of offensive operations, of which one is the deliberate attack. Other offensive operations not included in this discussion are the movement to contact, the hasty attack, the exploitation, and the pursuit (11:3-4).

A deliberate attack differs from other offensive operations in that it entails precise planning and preparation based on detailed information. Time is required to collect information on the enemy defensive force (types of weapons, locations, defensive obstacle plan, etc.), the terrain for the operation (avenues into and out of the objective area, natural obstacles, observation, cover and concealment, etc.), and for coordinating the attack (integrating the combat units, the combat support units, and the combat service support). The enemy encountered in a deliberate attack is normally occupying a prepared defensive position. In this type of operation, the attacking task force is expected to defeat a defending enemy company (11:1-7, 3-52 to 3-53).

A task force deliberate attack can normally be broken down into six distinct phases.

1. **Reconnaissance:** Information is collected on the terrain and the enemy force to aid in the planning of the attack. Information gathering continues throughout the attack.

2. **Movement to the Line of Departure (LD):** May entail conducting a forward passage of lines through friendly units currently in contact with the enemy force.

3. **Maneuver:** The task force moves to the point of attack in a way that achieves a position of advantage.

4. **Deployment:** The task force assumes it's attack formation.

5. **Attack:** The enemy position is attacked by fire or assaulted.

6. **Consolidation and Reorganization:** Actions are taken to eliminate enemy resistance and prepare for future operations (11:3-4 to 3-5).

The Motorized Rifle Company in the Deliberate Defense

Deliberate attacks at the NTC are normally opposed by a Motorized Rifle Company (MRC) augmented with a platoon of tanks and other battalion assets (anti-tank missiles, artillery fire support, engineer assets, etc) in a deliberate defence. The following sections will provide information on the organization, equipment, and capabilities of the MRC, in addition to Soviet defensive doctrine.

<u>The Motorized Rifle Company</u>. The MRC is organized into a headquarters section, three motorized rifle platoons (MRP), and a machine gun/anti-tank platoon. At full strength, the MRC is equipped with 12 BMP Infantry Fighting Vehicles, and 9 man carried RPG-7 anti-tank weapons. The BMP mounts a 73mm gun and the SAGGER Anti-Tank Guided Missile (ATGM), with a range of 3000 meters. In addition, this MRC is normally augmented in it's defense with a platoon of 3 T-72 tanks, and elements of the battalion's anti-tank company, equipped with the SPANDREL ATGM (range of 400 meters), mounted on BRDM Armored Vehicles (13: 3-23 to 3-31).

<u>The Soviet Deliberate Defense</u>. Soviet doctrine prescribes offensive operations as the primary means of achieving decisive success. However, the defense is used when resources are unavailable for offensive operations, as an economy of force measure, or in order to gain time (12:81).

At the battalion and company level, the defensive force is organized into a security zone and a main defensive belt. The mission of the security zone is to delay attacking forces, deceive them as to the location on the main defensive belt, and to provide the defending commander information on the attacking

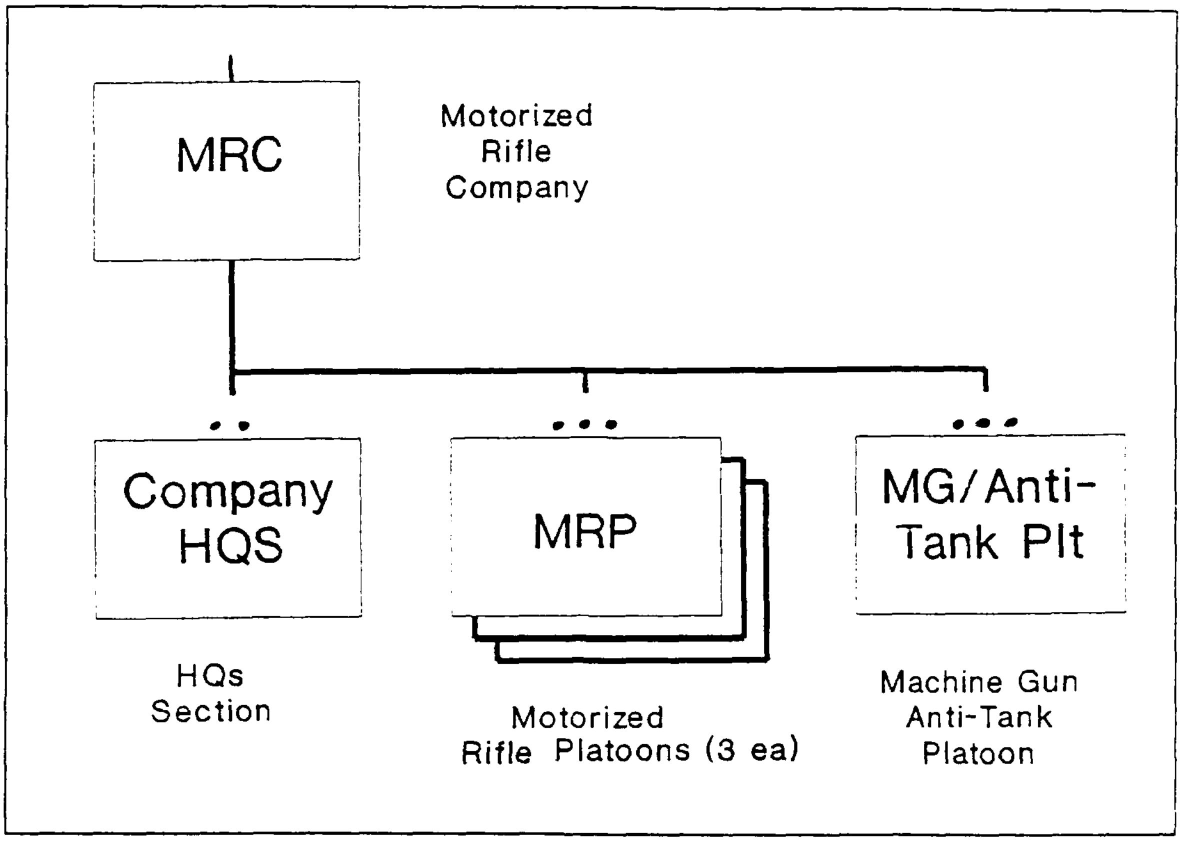

Figure 9. The Soviet Motorized Rifle Company.

force. The security zone of an MRC defense normally consists of one or two combat outposts, normally composed of a BRDM Armored vehicle mounting the SAGGER or SPANDREL Anti-Tank Guided Missile. Obstacles are prepared forward of and with the main defensive belt in order to channelize the attacking force into fire sacks. The majority of the MRC is deployed in the main defensive belt, orienting their fires into these fire sacks (locations where the defending commander wants to kill the attackers). Survivability is enhanced for the defenders through the use of entrenchments for both vehicles and personnel. If augmented with tanks, the MRC Commander will try to leave some of his tank force in reserve

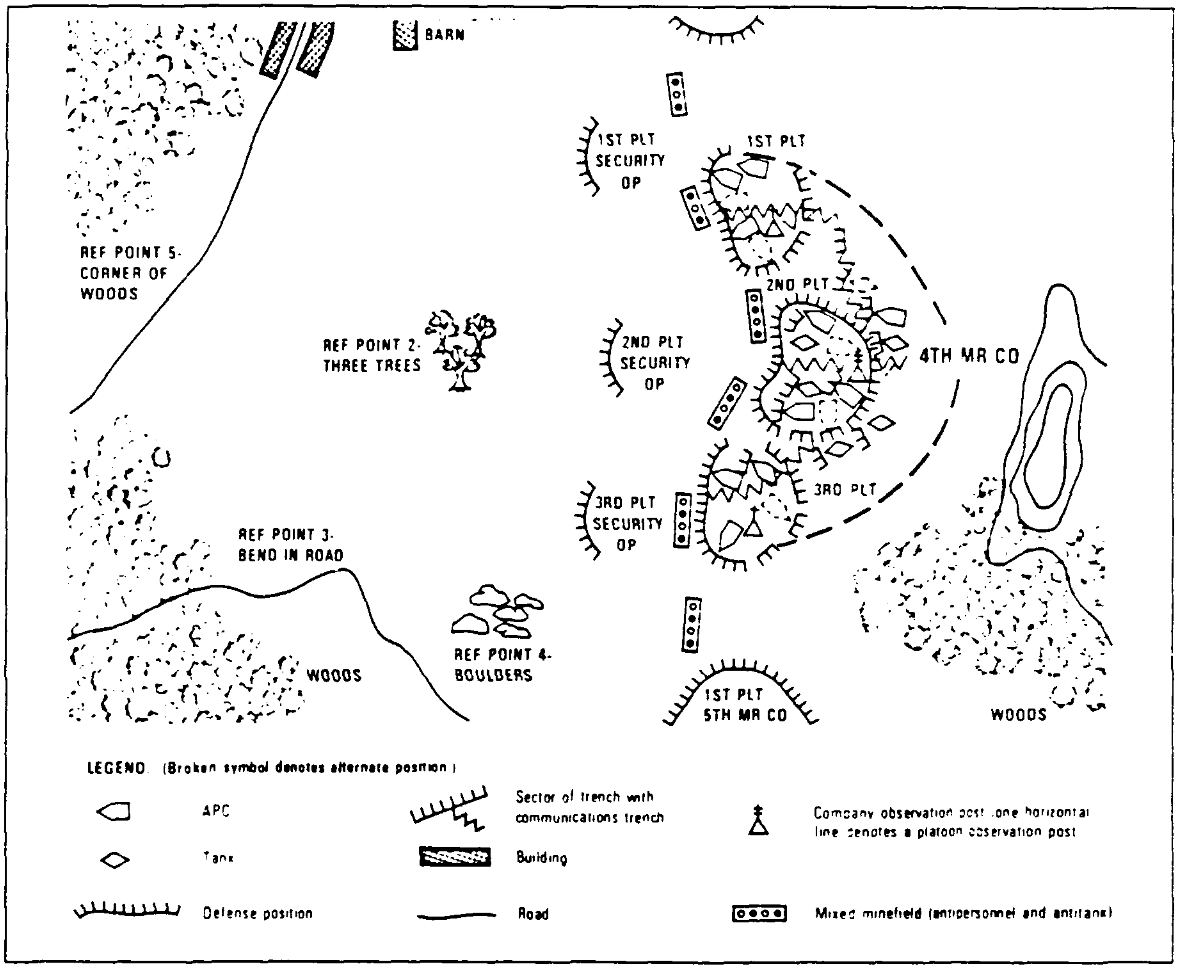

Figure 10. Soviet Motorized Rifle Company Deliberate Defense (Reprinted from 12:6-9)

to conduct local counterattacks. A company defense normally has a frontage of 500-1000 meters, and a depth of 500 meters. The battalion will defend a front of 3-5 kilometers, and a depth of upwards of 2 kilometers (12:6-8 to 6-10).

IV. The Database

Introduction

The data used in this study was collected in raw form from the NTC Archives at the Army Research Institute, Presidio Monterey, CA (ARI-POM). Digitized data was available from battles conducted as early as October 1985 through September 1989. It must be noted, however, that standardization of data collection and storage procedures did not occur until October 1986. Forty battles were chosen for analysis, given the constraints of analyzing only daytime deliberate attacks having complete data sets. The battles cover a span from January 1987 to September 1989. The purpose of the following sections is twofold. First, to discuss the data collected at the NTC and possible limitations to this data set. Next, to provide a description of the methods used to transform the raw data collected from the Archives into a format that can be analyzed.

The NTC Database

The NTC database, located at the ARI-POM Archives, can be divided into three broad categories: the Instrumented Digital Data, the General-purpose NTC Analysis and Training Tool (GNATT) program, and Take Home Packages (THP). The following paragraphs will discuss the data provided by these three sources, and limitations inherent in this data set.

Instrumented Digital Data. The primary reason the NTC has taken great pains to instrument the units and their equipment is for the purpose of providing a digital database in which to improve doctrine, training, organization, material and leadership (7:3). Beginning with training unit rotation 8601 (September 1985), instrumented data has been collected on such information as mission types, unit types, ground and air player locations, weapon system firing events, indirect fire missions, etc (8:G-11).

For each mission, the digital data is stored into nineteen tables (see Figure 11), and was accessed using the Ingress Relational Database Language (8:G-10 to G-12).

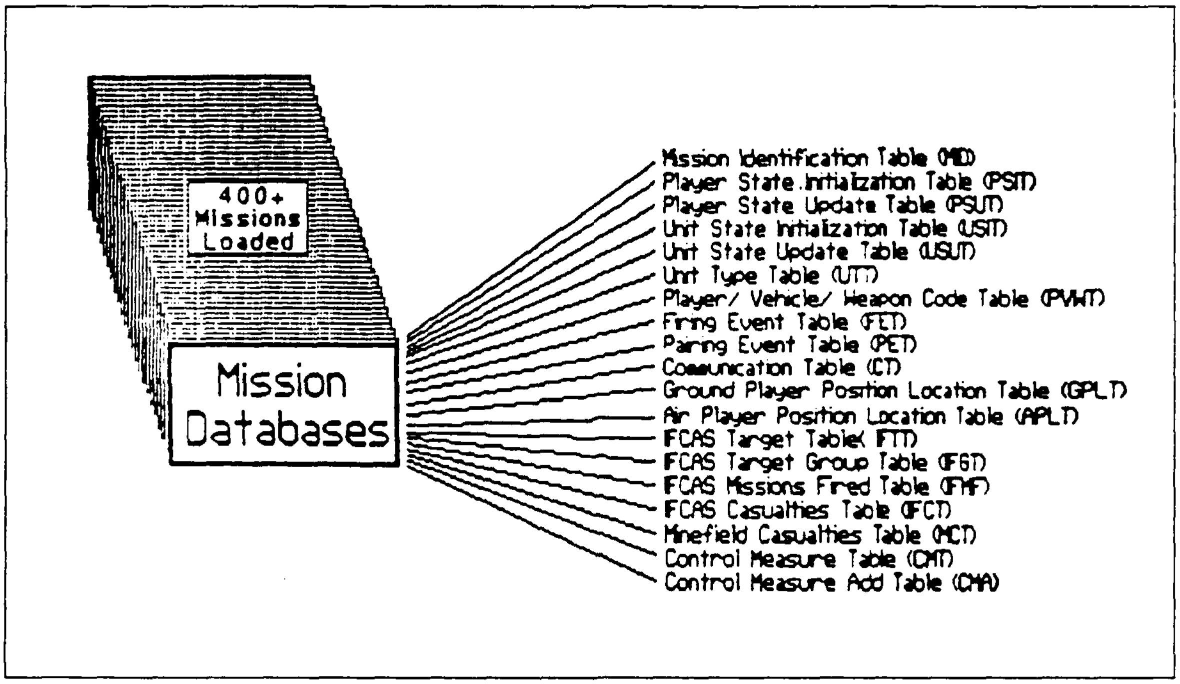

Figure 11. Ingress Database Tables (Reprinted from 8:G-10).

For this study, information was collected from the following tables:

-Mission Identification Table (MID): Provided the type of mission conducted (deliberate attack, movement to contact, defense in sector, etc).

-Player State Initialization Table (PSIT): Provided player identification (vehicle bumper number), unit, weapon system and vehicle type.

-Player State Update Table (PSUT): Provided player status updates (the source of player death times).

-Ground Player Location Table (GPLT): Provided player grid locations, updated every five minutes during the battle.

Information was also collected from the Firing Event Table (FET), and the Pairing Event Table (PET), however, this data proved to be unreliable, and thus, was not used for this study (8:G-11). The Ingress query language commands used to collect information are contained in Appendix A.

The GNATT Battle Playback Program. The purpose of the GNATT program is to replay NTC force-on-force battles on an MS-DOS computer. Developed by Mr. Rick Crenshaw at ARI-POM, GNATT has the capability of displaying vehicle locations, vehicle types, selected units, MILES engagements, and killed players. Additionally, GNATT users can select specific units to be displayed, specific battlefield graphics to be displayed, and can pause action and print the computer screen at any time (8:J-2).

Five data files, contained on micro-computer disks and available at ARI-POM, are required to replay a battle using GNATT (this information comes directly from the Ingress digital database):

-PL.DAT: Player position location data.

-ENG.DAT: Engagement positions.

-ORG.DAT: Organization list.

-CMT.DAT: Control measure locations.

-MORTALTY.DAT: Player death time (8:J-2).

An example of a computer screen from GNATT is Figure 12 (Friendly vehicles are represented by solid boxes).

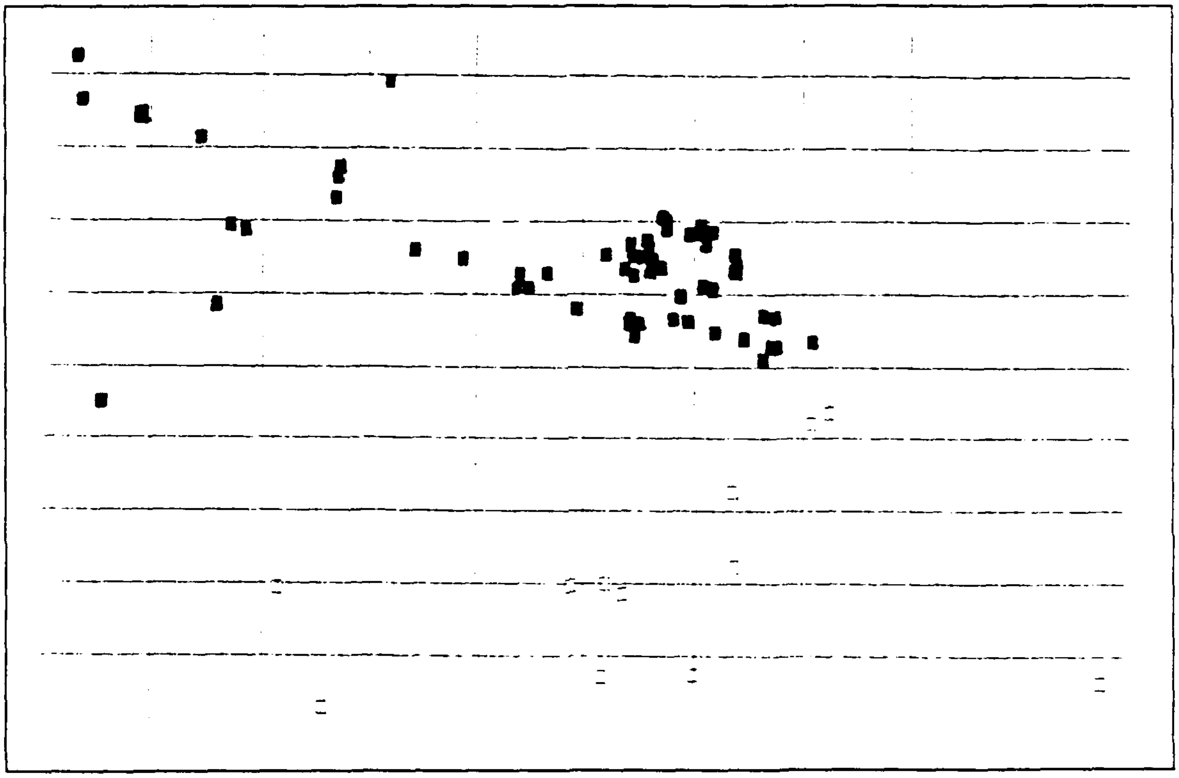

Figure 12. GNATT Playback Screen.

Take Home Package (THP). The primary purpose of the THP, written by the O/Cs, is to provide the training unit a document summarizing their missions and performance during the rotation. For the purposes of this study, the THP provides analysts more accurate data concerning battle statistics, such as a killer-victim scoreboard, than the basic/raw digital database. The THP is organized in the following format:

Section I - General Summary of the Mission

Section II - Mission Statement

Section III - Battlefield Operating System/Lessons Learned

Tabs:
- A - Command and Control
- B - Maneuver
- C - Fire Support
- D - Intelligence
- E - Air Defense
- F - Mobility, Countermobility, and Survivability
- G - Combat Service Support
- H - NCO Support Channel

Section IV - Statistical Analysis
1. Task Force Losses
2. Company/Team Losses
3. Weapon Systems Causing OPFOR Losses
4. Battle Loss Ratio

Annexes 1-4 - Company Team AARs

The THPs proved to be an excellent source for actual battle losses (Section IV), in addition to providing an accurate location of the Task Force objective (Section II) (8:D-1).

Database Limitations. As with most sources of information, the data collected at the ARI-POM Archives was limited in accuracy and some data was unavailable.

Data Inaccuracies. The digital database has limitations due to problems inherent in the data collection effort at the NTC.

MILES Direct Fire Engagement Events. Direct fire events, collected in both the FET and PET tables of the digital database, have inherent inaccuracies that must be understood.

First, it is possible to record erroneous multiple trigger pulls that exceed the capability of the weapon system (such as a tank firing it's main gun quicker than it is possible for the crew loader to load ammunition) in the FET. Secondly, only about 20 to 30 percent of the firing events in the FET are actually paired (that is, a firing weapon system is paired with target). Thus, although the MILES system records the type of weapon system that "killed" it, only a small portion of the engagements can reflect the vehicle bumper number that did the actual killing (8:G-13 to G-15). Due to this inability to assess kills to certain vehicles, analysts are unable to ascribe friendly lethality lower than the task force level. This limitation precludes any study of the effect a leader's location has on unit performance at company, platoon, and squad level.

For the purposes of this study, it was initially desired to record the number of times the Battalion/Task Force Commander employed his direct fire weapon system (be it the main gun on his tank, the M2 machinegun on his M113 APC, or the TOW launcher and 25 mm canon on his IFV). Unfortunately, in the vast majority of battles studied (36 out of 40), the Battalion/Task Force Commander's vehicle was not instrumented (carried a player unit that allowed for it's location, and direct firing events to be monitored). Rather, most Battalion/Task Force Commanders were monitored by manpacks mounted on the vehicle they were riding. Although manpacks provide accurate location information, they do not record the firing of the weapon systems on the vehicle.

Collection and Instrumentation Problems. Digital data collection at the NTC solely depends on the instrumentation system (see Chapter II). Problems with the instrumented player B units, though normally small and quickly remedied, occur due to the harsh conditions of the training environment. When this happens, information on player locations and firing events would not be recorded and can be lost to the system. MILES equipment also malfunctions, causing some players to be registered as "killed" for no apparent reason. Thus, O/Cs check every vehicle that has been killed to determine if the "death" was due to a valid reason, or equipment malfunction. MILES malfunction deaths are restored to life. Additionally, terrain at certain locations on the NTC reservation prevent accurate triangulation in determining a player's location, the player's firing events, or a player's "death" (8:C-13 to C-15).

Unavailable Data. Certain information, that may have provided understanding and insight to this study, was unavailable at the archives. Specifically, information on unit cohesion, battlefield/scenario conditions, and TF Commander information is not contained in any known database. Recommendations on recording information that would be useful for future studies are contained in Chapter VII.

Unit Cohesion. Some studies (see Henderson and LaPorte), contend that unit performance in combat is predicated on unit cohesion. Cohesion, here defined as the bonding of soldiers in a unit such that commitment to each other, their mission, and their unit are sustained (22:4), has some indicators. The length of time the unit has been together is one. The time of service of subordinate leaders in their current positions at company, platoon, and squad level, along with their experience level, is another. Unit information of this type, however, was unavailable at the archives.

Battlefield and Scenario Conditions. Knowledge of the environmental conditions, such as the weather, precipitation, and ambient light, at the time of battle may have also proved useful for this study. Additionally, although preparation time for the deliberate attack is assumed to be 20 hours (see Battle Description, Time below), no information is available as to the exact amount of time given to both the attacking and defending unit.

Task Force Commander Information. As the focus of this study is the TF Commander, information concerning this individual may have provided some insights. Some factors that might predict a Commander's effectiveness are his previous experience at the NTC, or his time of service in maneuver units. Intuition would indicate that the aptitude of the commander could affect unit combat performance. Again, however, this type of information was unavailable.

Formatting the Data Set

For each battle, information was collected in three general areas:

-A general description of the battle in terms of the Army acronym METT-T (Mission, Enemy forces, Terrain, Troops available, and Time).

-Specific information on the Task Force Commander, such as his location, and his survivability.

-Information on the unit's effectiveness in the battle.

This section will describe the sources of information, and how the information was transformed into a useable data set.

Battle Description. The critical task in this study is trying to isolate the commander's effect on unit performance. Given the lack of experimental control at the NTC, however, only a few of the numerous factors that affect combat performance can be held constant from battle to battle. It is important, therefore, to describe each battle scenario as closely as possible to avoid confounding unrelated factors with the hypothetical commander's effect. Each battle will be described using the factors of METT-T.

Mission. All battles observed were deliberate attacks, thus this factor remains constant during the analysis.

Enemy. The Task Force can face either an OPFOR company, an OPFOR battalion, or portions of an OPFOR battalion in a doctrinally prepared deliberate defensive position. Thus, the number of OPFOR combat vehicles (T-72 Tanks, BMP Infantry Fighting Vehicles, and BRDM Armored Vehicles) will range from 18 to more than 70. The number of OPFOR combat vehicles will be obtained from the Take Home Packages. Thus, the enemy will be represented in the data base as a total number of combat vehicles.

Terrain. The NTC has a wide variety of desert terrain, ranging from mountains, flat desert valleys, and numerous dry waterways, or wadi systems (8:C-3) Force-on-force training is conducted in the central and southern corridors, which can be divided into ten primary training areas. The BDM Corporation, as a part of their study on unit measures of effectiveness, analyzed each one of the ten training areas (five in both the central and southern corridors) using the Army's format for terrain analysis, OCOKA (Observation and fields of fire, Cover and concealment, Obstacles, Key terrain, and Avenues of approach) (2:14).

For this study, terrain will be represented by the effects that the factors observation and fields of fire, and cover and concealment have on the attacking task force. Specifically, each factor was rated using the following format:

Greatly enhances the task force attack:	5
Marginally enhances the task force attack:	4
No effect on the attack:	3
Marginally enhances the OPFOR's defense:	2
Greatly enhances the OPFOR's defense:	1

Additionally, the terrain is generalized in the following manner:

Open/Flat terrain with no significant natural obstacles:	1
Rolling terrain with some natural obstacles:	2
Cut up/compartmentalized terrain with numerous obstacles:	3

Troops Available. A characterization of the task force was described in two distinct categories of variables: unit equipment type, and unit experience/effectiveness. The task forces examined in this study where equipped one of three different ways, depending on the unit's level of modernization. This variable was described as follows:

M60 Series Tank and M113 Armored Personnel Carrier:	1
M1 Tank and M113 Armored Personnel Carrier:	2
M1 Tank and M2 Infantry Fighting Vehicle:	3

Information on the cohesion and experience level of a unit prior to arriving at the NTC was unavailable. However, analysis of each unit's THP provided enough information to determine the following measures of unit experience and effectiveness.

-The unit's battle experience at the NTC. Given that most units have six force-on-force battles during their rotation, this variable indicates when in a unit's rotation the particular battle occurs. It's expression is as a percentage of the rotation when the battle occurred, i.e. the second battle of a six battle rotation is expressed as 0.3333.

-The number of times a unit conducted a deliberate attack during it's rotation varied from one to four. Thus, a unit's experience in conducting deliberate attacks was recorded as the integer 1 (for first), 2, 3, or 4.

-Finally a unit's proficiency, or level of effectiveness, during it's rotation, was captured by determining the unit's aggregate Loss Exchange Ratio (LER) for the entire rotation. The LER was determined as friendly losses in combat vehicles divided by enemy losses in combat vehicles.

All of the information necessary for this category was provided the unit THPs.

<u>Time</u>. Normally, each Task Force is given 20 hours to prepare for a deliberate attack (2:22). As this information is not specifically contained in any of the data sources, it will be assumed as a constant and will not be reflected in the study data base.

<u>Unit Mass</u>. One more variable, while being a battle descriptor, does not adequately fall under one of the METT-T

categories. This variable describes the attacking unit mass as a measure of the area of the ellipse that contains the major

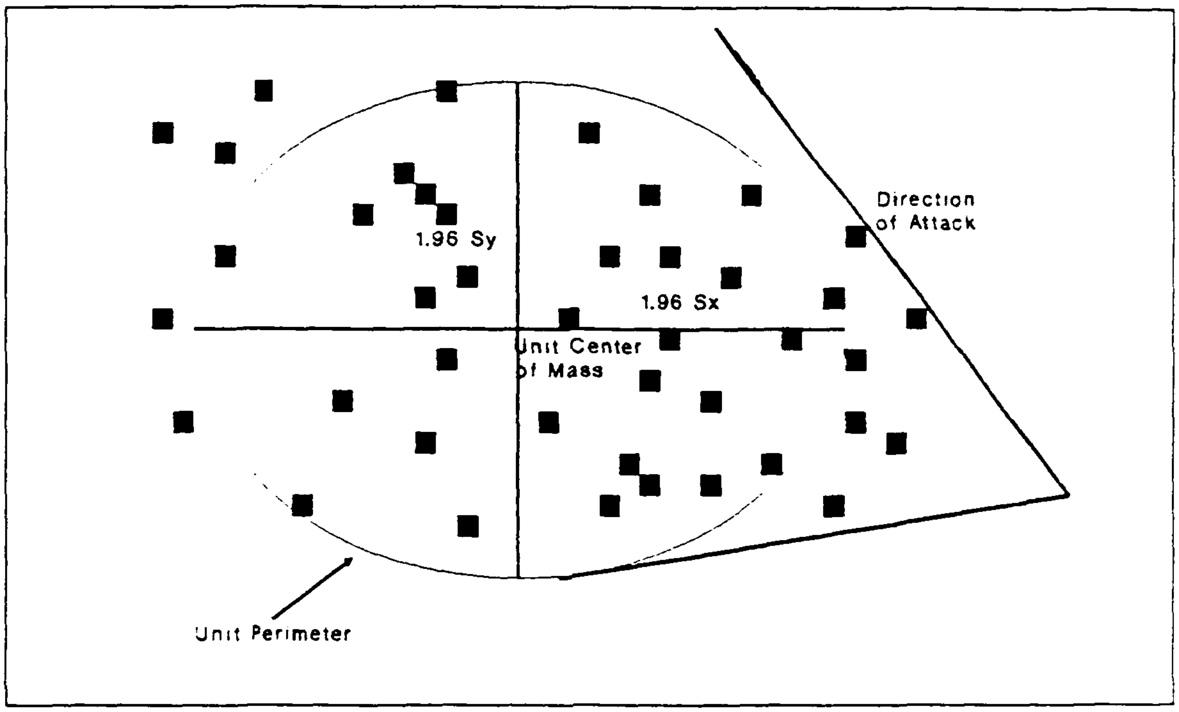

Figure 13. Unit Mass Variable.

portion of the maneuver units (90 percent) of the attacking force. This information was calculated using the standard deviations determined in unit center mass calculations Commander Information, Location Variables, below). From simple geometry, this area was determined by:

$$\text{Unit Mass} = \pi ab$$

where:

π = Pi
a = 1.96s (in the x direction)
b = 1.96s (in the y direction)
s = standard deviation in the indicated direction

Table 1. Battle Description Variables.

Variable Description	Unit of Measure
Enemy	
Number of Enemy Combat Vehicles (T-72s, BMPs, BRDMs, MTLBs)	Each
Terrain	
Observation and Fields of Fire Cover and Concealment	Indicator Variable (1-5)
General Characterization	Indicator Variable (1-3)
Troops Available	
Equipment Type	Indicator Variable (1-3)
Unit Battle Experience at the NTC	Percent of rotation when battle occurs
Deliberate Attack Experience	Deliberate attack of this rotation
Unit Proficiency	LER of unit for entire rotation
Miscellaneous	
Unit Mass	Perimeter in 10 km

Task Force Commander Information.

Position During the Battle. The thesis of this study is to determine the effect of the Task Force Commander's battle positioning on the Task Force's combat performance. Of critical importance, therefore, is determining an appropriate variable (or set of variables) that describe the commander's location, and then determining when to measure this location variable.

Location Variables. After studying numerous battle playbacks using GNATT, it became apparent that a commander's position could not be adequately described by one variable.

Thus, this study will used four variables to describe the commander's battle location and activity.

-The distance (in meters) the commander is from the forward line of his own troops (represented as X1).

-The distance (in meters) the commander is from the nearest enemy located in the main defensive belt (represented as X2).

-The distance (in meters) the commander is from

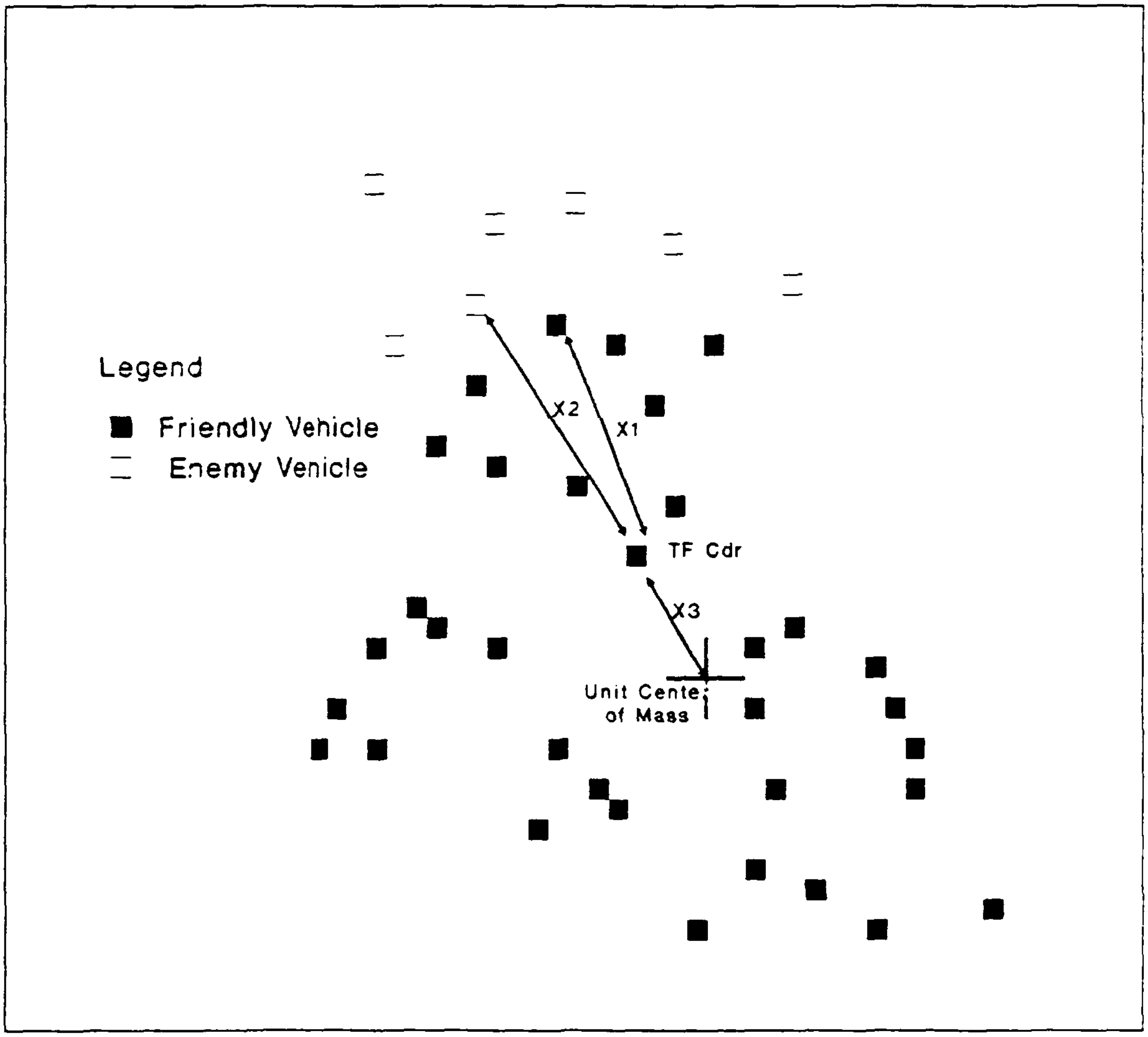

Figure 14. Distance Variables.

the center of mass of his maneuver units (represented as X3). Vehicle locations of the maneuver units was provided by the GPLT of the Ingress digital database. Unit center mass was defined as the average grid coordinate in both the x (horizontal) direction and the y (vertical) direction. Positive numbers will reflect the commander being forward of his unit's center of mass; conversely negative numbers will reflect being to the rear of the unit's center of mass.

Critical Ground Force Battle Time. In review, the six phases of an attack are; (1) reconnaissance, (2) movement to the line of departure, (3) maneuver, (4) deployment, (5) attack, and (6) consolidation and reorganization (see p. 36). This study's goal was to take measurements of location distances at the time a unit begins it's attack phase. One method of determining this time was developed by Dryer (Ref. 18). In his thesis, Dryer determines first a critical ground force attrition area, or the location where the majority of combat kills take place during a battle. He then plots the number of kills on the entire battlefield over time, and compares that plot to the one of combat kills in the critical area over time. Dryer concluded that the critical time plot effectively filters out early kills. As he was trying to determine maneuver force concentration just prior to the critical attrition period, Dryer defines the critical ground force attrition time "when 25 percent of kills had occurred in the critical ground force attrition area" (18:48-49).

For the purposes of this study, the 25 percent attrition level time proved to be too soon, however, normally during the maneuver or deployment phase. Five randomly selected battles were analyze to determine when the attacking task force began it's attack phase (a subjective evaluation using the graphical playback of the battle). This time was then related to the percentage of total attrition that had occurred to that point in time. The percentages ranged from 36 percent to 61 percent, with a mean value of 53 percent (see Table 2).

Table 2. Critical Time Calculations.

Battle ID	Percent of Attrition at the Critical Time
MA870414	57%
MA880212	61%
MA881326	36%
MA890549	53%
AA891037	58%
Mean	53 +/- 6.57%

Given these results, this study defines the critical ground force battle time as when 50 percent (within the confidence interval) of the kills have occurred in the entire battle area. The commander's location variables have been measured at the critical ground force battle time. The only exception to this rule was when the commander was "killed" prior to the critical time. Then, all location variables were measured at the time of the commander's "death".

Activity Level. This variable measures the commander's activity level during the attack. This information is portrayed in the following manner:

Remains stationary, far to the rear of the battle:	5
Moves infrequently, normally behind 3/4's of the maneuver elements:	4
Moves with his maneuver units, normally behind the two lead companies:	3
Active in the battle, moves with the lead elements:	2

Very active, many times leads the attack: 1

This information was derived from viewing the battles using the GNATT playback program.

Survivability. This variable reflects the percentage of time the commander remains alive during the battle. This variable was calculated as simply:

Survivability = Time Alive / Total Mission Time

where:
Time Alive = Commander's Time of Death - LD Time
Total Mission Time = End of Mission Time - LD Time
LD Time = Time unit crosses the line of departure

Information concerning the time of the Commander's death (if applicable), was provided by the PSUT in the Ingress digital database.

Table 3. TF Commander Variables.

Variable Description	Unit of Measure
Commander Location	
Distance from forward line of own troops	Meters
Distance from forward enemy in main defensive belt	
Distance from unit center of mass (CM)	+ forward of CM - rear of CM
Activity Level	Indicator Variable (1-5)
Commander Survivability	Percent of battle remains alive

Task Force Measures of Effectiveness. Four variables were used in determine the task force's success in their battle. The basis for developing the first three measures of effectiveness is contained in reference 2. This report focuses on three criteria (friendly forces, enemy forces, and terrain objective) and develops numerical standards for each criteria. The fourth variable is the Loss Exchange Ratio (LER) of the battle. The information used to determine the following variables was extracted from the Take Home Packages (Section IV).

Friendly Forces. For the deliberate attack, the authors conclude that an effective measure is the percentage of friendly forces still combat effective at the end of the battle. Friendly forces are measured in combat vehicles (tanks, armored personnel carriers/infantry fighting vehicles, and TOW anti-tank systems). Analysis of battles that were determined either as a success or failure (based on whether the attacking force secured it's terrain objective) allowed the study to conclude that a unit achieves a success if this percentage of survival is 0.4 or higher (2:33-35).

Enemy Forces. This factor is reflected in the percentage of enemy combat vehicles (tanks, infantry fighting vehicles, and anti-tank missile systems) destroyed during the battle. In a manner similar to the method described in the paragraph above, namely determining whether the attacking force secured it's terrain objective, the authors conclude that a score of .75 or higher can be equated to a success in this criteria (2:32).

Terrain. The BDM study contends the purpose of the attack, in terms of terrain, is to secure the mission's objective (2:30). Thus, this criteria will be reflected in the database as either a one (objective secured), or zero (failure to secure the objective).

Loss Exchange Ratio. The LER is reflected as the friendly losses in combat vehicles divided by enemy losses in combat vehicles. Friendly combat vehicles are defined as tanks (M60 or M1 series), Armored Personel Carriers (M113s), or Infantry Fighting Vehicles (M2s), and M901 ITVs. Enemy combat vehicles are defined as T72 tanks, BMP Infantry Fighting Vehicles, and BRDM Armored Vehicles.

Table 4. MOE Variables.

Variable Description	Unit of Measure
Friendly Forces alive at the end of the battle	Percent of Total Force
Enemy Forces destroyed at the end of the battle	
Terrain Objective Secured	Indicator Variable (0 or 1)
Loss Exchange Ratio	$\frac{\text{Friendly Losses}}{\text{Enemy Losses}}$

A recap of the entire study database is provided in Table 5, on the next page.

Table 5. Study Database.

Variable	Description
TF Commander Variables	
X1	Commander's distance from forward line of own troops.
X2	Commander's distance from forward enemy in main defensive belt.
X3	Commander's distance from unit center mass.
X4	Commander's activity level.
X5	Commander's survivability.
Battle Description Variables	
X6	Enemy strength.
X7	Terrain observation and fields of fire.
X8	Terrain cover and concealment.
X9	Terrain type.
X10	Equipment type.
X11	Unit rotation experience.
X12	Deliberate attack experience.
X13	Unit proficiency,
X14	Unit mass.
Measures of Effectiveness Variables	
Y1	Friendly forces.
Y2	Enemy forces.
Y3	Terrain objective.
Y4	Loss exchange ratio.

V. Analytic Techniques and Methodology

Introduction

Numerous mathematical techniques exist in which to determine the effect a commander's location has on unit combat performance. This chapter will discuss some of the multivariate methods that are available for this study. The following paragraphs conclude with discussion of the methodology used to answer the questions of this study.

Multivariate Analysis Methods

Multivariate analysis techniques can be grouped into two broad categories: dependence methods and interdependence methods. When the investigation includes two sets of variables, one of which is dependent on the other set, dependence methods are appropriate. Conversely, if there is no dependence distinction between the variables, then interdependence methods are appropriate. The following sections will review four dependence methods and one interdependence technique; multiple regression analysis, logistic regression analysis, canonical correlation analysis, discriminant analysis (dependence methods), and factor analysis (interdependence method) (17:19-21).

Multiple Regression Analysis. Multiple regression analysis can be defined as a tool that utilizes the statistical relationship between a set of quantitative variables such that one variable can be predicted from the others (27:23). The variable that we wish to predict is called the dependent variable. The set of variables used to predict the dependent variable are called the independent variables. The first order normal error multiple regression model with j independent variables is of the form:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + \ldots B_jX_{ij} + e_i$$

where:

Y_i is the ith observation of the dependent (response) variable

B_j is the regression coefficient for the jth independent (predictor) variable

X_{ij} is ith observation of the jth independent variable

e_i is the error term of the ith observation and the error terms are normally distributed with:

$$E(e_i) = 0$$

Estimates for the regression coefficients are determined using the method of least squares (for a mathematical description, see Ref. 27, pp. 36-42) (27:227).

Inferences from the Regression Coefficients. Any inferences drawn from the estimates of the regression coefficients depend on the correlations (p) between the independent variables. Ideally, we wish to use independent predictor variables, i.e. p = 0. In that case, the parameter B_j reflects the change in the response variable per unit increase in the jth predictor variable, given that all other predictor variables are held constant (27:228).

Many times, however, we are faced with the fact that two or more independent variables are in some ways correlated ($p > 0$). This situation is called multicollinearity. When multicollinearity exists in the data set, the regression coefficient of any independent variable depends on which other independent variables are included in the model. Thus, the parameter B_j reflects only a partial effect of the jth predictor variable on the response variable (27:228).

Aptness Testing. Once a model has been fitted using the methods described above, statistical testing is conducted to determine, (1) whether the data conforms to the assumptions of the normal error model, and (2) the model adequately describes the relationship between the predictor, or independent, variables and the response, or dependent, variable.

In the first instance, determining if the fitted model conforms to the assumptions of the model, the following departures are evaluated:

1. The regression function is not linear.
2. The error terms do not have constant variance.
3. The error terms are not independent.
4. The model fits all but a few outliers.
5. The error terms are not normally distributed.
6. One or more independent variables are not included in the model (27:111).

Statistical tests used to evaluate the adequacy of the model's fit to the data set include evaluation of the coefficient of determination (r^2), and the F test for lack of fit. A detailed discussion of these tests is contained in reference 27, Chapter 4 (pp. 101-141).

Derivations of the First Order Model. It becomes a resonably simple matter to determine other multiple regression models from the first order model. In the case of two independent variables, a polynomial regression model can be determined as:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + B_3(X_{i1})^2 + B_4(X_{i2})^2$$

If we define $X_{i1}^2 = X_{i3}$, and $X_{i2}^2 = X_{i4}$, we have nothing more than the first order model, with four independent variables. Similarly, a model with interaction effects, such as:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + B_3X_{i1}X_{i2}$$

can be reduced to the first order model by defining $X_{i1}X_{i2} = X_{i3}$. A combination model, in which both polynomial and interaction effects are present, can also be reduced to the first order model using the above described techniques (27:231-236).

A final derivation of the simple first order model is the log linear, or the multiplicative, model.

$$Y_i = B_0X_{i1}^{B1}X_{i2}^{B2}$$

If we take the log of each side, we can reduce this model into the linear equation:

$$\ln(Y_i) = \ln(B_0) + B_1\ln(X_{i1}) + B_{i2}\ln(X_{i2})$$

Logistic Regression Analysis. Logistic regression analysis is a special subset of multiple regression technique described above. The difference is that the dependent variable is binary, with only 0, 1 responses. Thus, we seek a function that is S shaped. In the case of two predictor variables, the model is given by:

$$E(Y) = K / (1 + K)$$

where:

$$K = \exp(B_0 + B_1X_1 + B_2X_2)$$

This function can be linearized. Thus, using the transformation:

$$[E(Y)]' = \log_e[E(Y) / (1 - E(Y))]$$

we can obtain:

$$[E(Y)]' = B_0 + B_1X_1 + B_2X_2$$

The assumptions of the normal error model apply (27:361-363).

Canonical Correlation Analysis. In multiple regression analysis, we consider a set of variables in which one variable is the dependent, or response variable, and the remaining variables are the predictors. The difference in canonical correlation analysis is that rather than having only one response variable, we now have a set of response variables. Thus, canonical correlation attempts to determine the relationship between two sets of variables, in which one set is termed the independent variables, and the other set is called the dependent variables. Specifically, this technique seeks to determine a linear combination for each set of variables, such that the correlation between the two linear combinations (canonical variates) is as large as possible (17:337-338).

Model Assumptions. For strictly descriptive purposes, the model does not assume any distribution for the variables.

Indeed, the variables may be both nominal and ordinal. Both sets of variables must meet the assumption of multivariate normality and homogeneity of variance (as with the normal error regression model), however, in order to determine the significance of the canonical variates (17:339).

Interpretation of the Results. Normally, three methods are used to evaluate the canonical correlation model. Canonical loadings are nothing more than the correlation between the original variables and their respective canonical variate. This provides an accurate measure of the degree in which an original variable influences the canonical variate (17:345). The second method is determining the proportion of the total amount of variance in the original variables explained by their respective canonical variate. This proportion of explained variance is an accurate measure of how well the canonical variate models the original variables (17:347). A third method of evaluating the model is the redundancy coefficient, directly analogous to the coefficient of determination (r^2) discussed in multiple regression model.

Discriminant Analysis. The final dependent method to be discussed is discriminant analysis, which entails classifying objects into two or more distinct groups, or responses. Dillon defines descriminant analysis as "deriving linear combinations of the independent variables that will discriminate between the a priori defined groups in such a way that the misclassification error rates are minimized" (17:360).

This type of multivariate analysis normally has two objectives. The first objective is to accurately predict the grouping of a specific object given it's predictor variables. The second objective is, through analysis of the parameters of the descriminant functions, determine those independent variables that have the biggest effect on an object's grouping.

Assumptions of the Model. In order to achieve optimal results, defined here as the smallest possible rate of misclassifications, two assumptions must be met. First, the set of independent variables must be multivariate normal. Secondly, the variance-covariance matrix within each of the different groups must be the same (17:362).

Factor Analysis. As discussed at the beginning of this section, factor analysis is an interdependence technique. Dillon defines factor analysis as "the study of interrelationships among the variables in an effort to find a new set of variables, fewer in number than the original set of variables, which express that which is common among the original variables" (17:53). Thus, factor analysis seeks to find the underlying factors that are reflected in the observable variables of the data set. Mathematically, this is expressed as:

$$X_i = v_{i(1)}CF_{(1)} + v_{i(2)}CF_{(2)} + \ldots + v_{i(j)}CF_{(j)} + e_i$$

where:

X_i is the ith observable variable

$CF_{(j)}$ is the jth common factor

$v_{i(j)}$ is the weight (loading) of the jth common factor associated with the ith observable variable

e_i are the unique factor effects

In addition to determining these underlying common factors, the main purpose of factor analysis is to reduce the dimensionality of the data set, reflected by the observable factors (17:57). Another useful result of this procedure is that the common factors are uncorrelated, or orthogonal. For a full description of the mathematical techniques used to determine estimates for parameters of the common factor model, see reference 17, Chapter 3 (pp. 53-99).

Evaluating the Solution. When we evaluate the fit of the common factor model to the data set, we wish to determine first, how well the data is explained by the model. This is done through evaluation of the total communality (defined in the following paragraph). Satisfied with this, we then turn our attention drawing inferences from the loadings of the common factors with the observable variables. This is done through analysis of the loadings matrix.

The total variance of the original, observable variables can be broken into two groups; the variance due to all of the common factors (communality), and the unique variance of the original variable. We seek common factor solutions in which the total communality is high (17:66-68).

Factor Rotation. In evaluating the loadings matrix, we seek a simple structure, or one in which relatively few original variables have high loadings on a common factor (approaching one), while the rest of the variables' loadings approach zero. The concept of orthogonal factor rotation allows for the formation of this type of structure, without altering the values of the communalities, or the orthogonality of the common factors (17:87-91).

Methodology

Given knowledge of the type of multivariate techniques available to provide insight to this study, we now seek to determine inferences from the study database using the following sequential methodology.

1. Initial Investigation of Relationships. The purpose of this first step in the methodology was to acquire an initial impression of possible relationships within the study database.

a. TF Commander Variables v. MOE Variables. This first step focused on determining possible relationships between the TF Commander variables (X1-X5), and the MOE variables (Y1-Y4). Refer to table 5, p. 58, for a description of the variables. A correlation matrix (given the diversity in variable units of measurement) was developed, and then the TF Commander variables were plotted against the MOE variables. This investigation included determining possible multicollinearity problems with the TF Commander variables.

b. Battle Description Variables v. MOE Variables. As with the first step, we again focused on determining possible relationships between the Battle Description variables (X6-X14), and the MOE variables (Y1-Y4). A correlation matrix was developed, and then the Battle Description variables were plotted against the MOE variables.

2. Quantify TF Commander Variables' Effect of Unit Performance. This step sought to determine a mathematical model, using just the TF Commander variables (predictor variables) and the MOE variables (response variables).

a. Dimensionality Reduction. Factor analysis was applied to the MOE variables (Y1-Y4) to reduce their dimensionality from four to one or two (FY_i). These new factored MOE variables were classified with respect to their contributing original variables. Additionally, if step 1.a. indicated possible problems with multicollinearity, the techniques of factor analysis will be applied to the TF Commander variables, seeking to reduce their numbers from five (X1-X5) to a smaller number (FX_i). Again, these new factored TF Commander variables were classified with respect to their contributing original variables.

b. Fit the First Order Model and Determine Aptness. Regression analysis was used on the new factored variables in order to fit a first order multiple regression normal error model of the form:

$$FY_i = B_0 + B_{1F}X_{i1} + B_{2F}X_{i2} + \ldots B_{jF}X_{ij} + e_i$$

where:

FY_i is the ith observation of the factored MOE (response) variable

B_j is the regression coefficient for the jth independent (predictor) variable

X_{ij} is ith observation of the jth factored TF Cdr variable

e_i is the error term of the ith observation and the error terms are normally distributed with $E(e_i) = 0$

Once fitted, measures were taken to determine the aptness of the model. Appropriate remedial measures were taken to improve the fit of the factored variables, and to ensure the assumptions of the model were met. If analysis of the residual plots indicated a model other than the first order model was appropriate, this model was also investigated.

c. Fit the Canonical Correlation Model and Determine Aptness. With more than one response variable present (Y_i), it is appropriate to investigate the relationship between the predictor variables and the response variables using canonical correlation. As with the regression model, steps were taken to determine the aptness of the model in terms of model assumptions and data fit.

d. Determine a Discriminate Function and Evaluate Aptness. The final step in quantifying the relationship between the TF Commander and unit success was the use of discriminant analysis.

1) The battles were classified into groups that indicated TF success. Success groupings were based on the measures of success proposed by Zimmerman and Root (Ref. 2), and described in Chapter IV. Classification groups were defined as:

Failure: Did not achieve a success in any of the three (friendly forces, enemy forces, objective) criterion.

Stalemate: Achieved success in one or two of the three criterion.

Victory: Achieved success in all three criterion.

2) The next step included determining a discriminate function using the TF Commander variables (X1-X5). The function was evaluated to determine if the differences in group centroids were statistically significant. Finally, the model was evaluated to determine if the underlying assumptions were met, and efforts were taken to validate the discriminate function.

3. Investigation of the Entire Study Database. Steps 2.a-d were repeated on the entire set of predictor variables (TF Commander, Battle Description and MOE variables).

4. Determine the Variables that Affect Survival. The final step of the methodology was to determine the significant factors that affect Commander survival in the deliberate attack. This was accomplished by conducting a discriminant analysis on the factored study database (determined in 3.a. above). The battles were divided into two discriminate groups; (1) the Commander survived during the battle, and (2) the Commander is "killed" sometime during the battle. As above, the function was evaluated to determine if the differences in group centroids were statistically significant. Additionally, the model was evaluated to determine if the underlying assumptions were met, and efforts were taken to validate the discriminate function.

VI. Analytic Results

Introduction

The purpose of this chapter is to provide the results of the analysis described in the methodology portion of the previous chapter (pp. 67-70). Specifically, this presentation will mirror the order of analysis described in the methodology section:

-Initial investigation of relationships.

-Quantification of the TF Commander variables' effect on unit combat performance.

-Investigation of the entire data base (both TF Commander variables and Battle Description variables) to determine their effect on unit combat performance.

-Determination of the variables that affect TF Commander survival.

The entirety of the analysis was conducted using the SAS, Version 6.06, software package. All SAS programs are contained in Appendix B. Following this chapter focusing on results will be the inferences and conclusions drawn from these results presented in Chapter VII.

Initial Investigation of Relationships

This initial investigation of the study data base sought to acquire impressions of possible relationships between variables. First, a correlation analysis was conducted between the TF Commander variables (X1-X5) and the MOE variables (Y1-Y4). Results of this analysis are shown in Table 6.

Table 6. Correlation Matrix (X1-X5, Y1-Y4).

	X1	X2	X3	X4	X5
Y1	-0.10142	-0.12425	0.01003	-0.20736	-0.16443
Y2	-0.20082	-0.20609	0.19569	0.03503	-0.13088
Y3	-0.06307	-0.09760	0.06756	0.11269	0.05061
Y4	0.21102	0.21622	-0.19083	0.04971	0.20030

As Table 6 indicates, the correlations between the TF Commander variables (X1-X5) and the MOE variables (Y1-Y4) are all weak. The strongest correlations are of the order of 0.2, and thus are not statistically significant (here defined as the 0.1000 level of significance).

Next, a correlation matrix was developed between the Battle Description variables (X6-X14) and MOE variables (Y1-Y4). This information is illustrated in Table 7 (page 73), with those correlations that are statistically significant in bold print. Table 7 indicates the following results.

-There are significant, although not particularly high, negative correlations between Y4 (the loss exchange ratio reflected as friendly losses divided by enemy losses) and X11 (unit battle experience at the NTC), X12 (deliberate attack experience), and X6 (number of enemy combat vehicles). A negative correlation indicates that as one variable increases in value, the other variable decreases in value.

-There is a positive correlation between Y4 and X10 (unit equipment type). In other words, as one variable increases in value, the other variable also increases.

-There is a positive correlation between Y2 (percentage of enemy vehicles destroyed) and X11.

Table 7. Correlation Matrix (X6-X14, Y1-Y4).

	Y1	Y2	Y3	Y4
X6	-0.04383	-0.20383	0.24246	**-0.39162**
X7	-0.23035	-0.11736	0.10836	-0.22137
X8	0.08001	0.31481	-0.01302	-0.09512
X9	0.20528	-0.20291	-0.05655	0.03967
X10	0.09005	-0.28272	-0.24499	**0.30971**
X11	0.03590	**0.40649**	0.17559	**-0.57369**
X12	0.16330	0.26686	0.02902	**-0.50550**
X13	0.23590	-0.25492	-0.25123	0.19505
X14	-0.00575	-0.07229	-0.07035	0.21283

Finally, a correlation matrix was determined amongst the entire set of independent variables (X1-X14). This information is reflected in Table 8 (page 74), with statistically significant correlations in bold print. As this matrix is symetric, only the upper triangle of the matrix is provided.

Analysis of the above correlation matrix indicates the following results.

-There are relatively high correlations amongst the variables X1 (Commander distance from the forward line of own troops), X2 (Commander distance from the enemy in the main defensive belt), X3 (Commander distance from the maneuver units' center of mass), and X4 (Commander activity level). This is indicated as positive correlations between the group X1, X2, and X4, and negative correlations between X3 and the other three variables.

Table 8. Correlation Matrix (X1-X14).

	X1	X2	X3	X4	X5	X6	X7
X1	**1.0000**	**0.9864**	**-0.9421**	**0.7542**	0.2250	0.1603	-0.1124
X2		**1.0000**	**-0.9364**	**0.7512**	0.2448	0.1377	-0.1157
X3			**1.0000**	**-0.6811**	-0.1499	-0.2037	0.1385
X4				**1.0000**	**0.3144**	0.1730	-0.0641
X5					**1.0000**	-0.1780	-0.1358
X6						**1.0000**	0.1956
X7							**1.0000**
	X1	X2	X3	X4	X5	X6	X7
X8	**-0.3885**	**-0.3828**	**0.4080**	-0.1848	0.1750	-0.2209	-0.0543
X9	-0.2879	-0.2436	0.1952	**-0.5353**	0.0140	-0.0386	0.0679
X10	-0.0498	-0.0099	0.0438	-0.1976	0.0939	-0.1667	0.0760
X11	-0.2315	-0.2429	0.2509	-0.0686	-0.0414	0.0982	0.0385
X12	**-0.3226**	**-0.3240**	**0.3314**	-0.2403	0.0374	0.0647	0.0477
X13	-0.0343	-0.0050	0.0866	-0.1419	0.2391	0.0314	**-0.3641**
X14	0.1469	0.1272	-0.0511	0.0094	0.2866	-0.1848	-0.2614
	X8	X9	X10	X11	X12	X13	X14
X8	**1.0000**	-0.0876	-0.1461	-0.0952	-0.0344	-0.0559	-0.2398
X9		**1.0000**	**0.6887**	0.1571	0.2910	0.0147	0.1854
X10			**1.0000**	0.0596	0.1221	0.0439	**0.3604**
X11				**1.0000**	**0.8366**	-0.1475	0.21278
X12					**1.0000**	0.1005	0.2192
X13						**1.0000**	**0.3714**
X14							**1.0000**

-There is a relative high positive correlation between X11 (Unit Battle Experience) and X12 (Deliberate Attack Experience).

-There is a positive correlation, although of a lesser magnitude than described above, between X4 (Commander activity level) and X5 (Commander survival variable).

-There is a weak correlation between X8 (Terrain Cover and Concealment) and the group X1 (Commander distance from the forward line of own troops), X2 (Commander distance from the enemy in the main defensive belt), X3 (Commander distance from the maneuver units' center of mass). This correlation is positive between X8 and X3. This correlation is negative between X8 and X1, and X8 and X2.

-There is a weak correlation between X12 (Unit Deliberate Attack experience) and the group X1, X2, and X3. This correlation is negative between X12 and X3. This correlation is positive between X12 and X1, and X12 and X2.

-There is a weak negative correlation between X4 (Commander activity level) and X9 (Type of terrain).

-There is a positive correlation between X9 (Type of terrain) and X10 (Unit Type of Equipment).

-There is a weak negative correlation between X7 (Terrain Observation) and X13 (Unit Proficiency).

- There is a weak positive correlation between X10 (Unit Type of Equipment) and X14 (Unit mass).

These results indicate that the effects of multicollinearity could exist if a regression analysis was conducted on this data base. It is important, therefore, that the original variables be transformed into independent variables, or common factors, prior to any regression analysis. Plots of the set of independent variables (X1-X14) and the dependent variables (Y1-Y4) revealed nothing in the way of linear, or multiplicative, relationships.

<u>TF Commander Variables' Effect on Unit Combat Performance</u>

Part two of the methodology sought to evaluate the relationship between the TF Commander variables (X1-X5), and the MOE variables (Y1-Y4). This section has been broken into four sets of results:

-A review of the results of the factor analysis conducted on both sets of variables separately.

-A review of the aptness of regression models using the common factors determined in the factor analysis above.

-An explanation of the results of the canonical correlation analysis using the two sets of original variables.

-An evaluation of the appropriateness of the linear discriminate function that seeks to determine unit mission success.

<u>Factor Analysis</u>. A factor analysis was conducted on both the TF Commander variables, and the MOE variables separately. The reasons for this analysis on both sets are as follows:

-To reduce the dimensionality of the MOE variables from four (Y1-Y4) to one, if possible. Regression analysis is constrained to only one response variable, requiring this step.

-To account for the multicollinearity found amongst the TF Commander variables (see p. 75) through the suggested linear transformation. This will allow for clear inferences to be drawn from the regression coefficients determined in the later regression analysis. An important result of factor analysis is that it produces independent common factors.

<u>MOE Dimensionality Reduction</u>. An initial factor analysis was conducted on all four MOE variables. Evaluation of the eigenvalues of the correlation matrix are contained in Table 9. Using the Kaiser criterion (17:48) of keeping those common factors with eigenvalues ≥ one, two common factors were retained. Table 9 illustrates that the two retained factors explain 0.7572 of the total variance of the original data set (Y1-Y4).

Table 9. Eigenvalues of the MOE Correlation Matrix.

	Factor 1	Factor 2	Factor 3	Factor 4
Eigenvalue	1.9941	1.0349	0.6577	0.3133
Proportion of Total Variance	0.4985	0.2587	0.1644	0.0783
Cumulative Variance	0.4985	0.7572	0.9217	1.0000

A varimax orthogonal rotation was conducted on the two retained factors in order to achieve a simple structure (see p. 66). The subsequent factor loadings matrix and communality estimates are reflected in Table 10 (bold type indicates statistically significant loadings). As illustrated in the

Table 10. MOE Loadings Matrix and Communalities.

	Factor 1	Factor 2
Y1	0.00041	**0.96763**
Y2	**0.83884**	0.13483
Y3	**0.69427**	-0.28812
Y4	**-0.89712**	-0.03111

Y1	Y2	Y3	Y4
0.936315	0.721840	0.565017	0.805798

loadings matrix, Y2 (Percent of Enemy Destroyed) and Y3 (Terrain Objective Secured) positively load and Y4 (Loss Exchange Ratio) negatively loads on factor one. This makes sense in that as the percentage of enemy destroyed increases and the terrain objective is secured (indicator variable 1), the LER (ratio of friendly losses divided by enemy losses) would decrease. Y1 (Percent of Friendly Alive) positively loads on factor two. Evaluating this matrix allows for the classification of the common factors and the subsequent factor scores as follows:

Factor	Name	Score
One	Mission Success	High positive scores indicate mission success
Two	Preservation of Friendly Forces	High positive scores indicate a large percentage of force preservation

A possible explanation for Y3 (Terrain Objective secured) having the lowest communality score (see Table 10) is that it is the only variable in the MOE set that was determined subjectively (see p. 57 for a description of the variable).

As this study's focus is on the effect of the Commander's location on unit mission success, a second factor analysis was conducted on only those variables that significantly contribute to the factor mission success (Y2-Y4). This was done in order to eliminate the noise of the variable Y1 imposes on the factor mission success. Again using Kaiser's criterion, one factor (eigenvalue of 1.9924) was retained, explaining 0.6641 of the total variance in the three original variables. Table 11 provides information on the retained factor (loadings vector, standardized scoring coefficients, and communality estimates), again termed as mission success. Note that there are slight changes in both the loading coefficients and the communality estimates. The less than desired amount of total variance explained by the factor mission success (0.6641) is reflected in the relatively small communality estimates. Interpretation of mission success scores remains as before.

Table 11. Mission Success.

	Loadings	Standardized Coefficients
Y2	0.83193	0.41756
Y3	0.70666	0.35468
Y4	-0.89493	-0.44918

Y1	Y2	Y3
0.692106	0.499373	0.800901

<u>TF Commander Multicollinearity Reduction</u>. A procedure similar to the one conducted above was used on the TF Commander variables (X1-X5). Evaluation of the eigenvalues of the TF Commander Correlation Matrix is found in Table 12. Using

Table 12. Eigenvalues of the TF Cdr Correlation Matrix.

	Factor1	Factor2	Factor3	Factor4	Factor5
Eigenvalue	3.6198	0.9498	0.3496	0.0675	0.0132
Proportion of Total Variance	0.7240	0.1900	0.0699	0.0135	0.0026
Cumulative Variance	0.7240	0.9139	0.9839	0.9974	1.0000

Kaiser's criterion, and evaluating the scree plot, it was determined to retain two factors. These two factors explain 0.9139 of the total variance contained in the original variables (X1-X5).

A varimax orthogonal rotation was conducted on the two retained factors in order to achieve a simple structure. The subsequent factor loadings matrix and communality estimates are reflected in Table 13 (bold type indicates statistically significant loadings). As illustrated in the loadings matrix,

Table 13. TF Cdr Loadings Matrix and Communalities.

	Factor 1	Factor 2
X1	**0.97970**	0.10255
X2	**0.97472**	0.12259
X3	**-0.96090**	-0.01414
X4	**0.80057**	0.29324
X5	0.11375	**0.98532**

X1	X2	X3	X4	X5
0.970320	0.965111	0.923528	0.726904	0.983796

X1-X4 load heavily onto factor one (X3 negatively), while X5 loads onto factor two. With regards to factor one, it follows that as the Commander's distance from both the forward line of own troops (X1) and the enemy (X2) increases, he becomes less active in the battle (indicated by a higher X4 number), and he gets closer to his maneuver unit's center of mass (X3). An evaluation of the loadings matrix allows the two retained factors to be characterized as follows:

<u>Factor</u>	<u>Name</u>	<u>Score</u>
One	Commander's Location	A low negative number indicates a Commander close to the front lines, and actively involved in the fight
Two	Commander's Survival	A high positive number indicates a Commander who

remains alive during the battle

Again, the lowest communality estimate is associated with the variable (X4) that was determined subjectively.

Focusing on the question of the effect the Commander's location has on unit mission success, a second factor analysis was conducted on only those variables that significantly contribute to the factor Commander's location (X1-X4). This was done in order to eliminate the noise the variable X5 imposes on the factor Commander's location. Again using Kaiser's criterion, one factor (eigenvalue of 3.5384) was retained, explaining 0.8846 of the total variance in the three original variables. Table 14 provides information on the retained factor (loadings vector, standardized scoring coefficients, and communality estimates), again termed as Commander's location.

Table 14. Commander's Location.

	Loadings	Standardized Coefficients
X1	0.98353	0.27796
X2	0.98127	0.27732
X3	-0.95184	-0.26900
X4	0.83797	0.23682

X1	X2	X3	X4
0.967334	0.962899	0.906008	0.702202

Note that there are slight changes in both the loading coefficients and the communality estimates. The interpretation of Commander location scores remain the same as the initial factor analysis.

Regression Analysis. This section of the analysis sought to fit a regression function that adequately fits the data. The independent variables used included the Commander's location factor (determined in the factor analysis above and from here on referred to as CL) and the variable Commander's Survivability (X5). An analysis of the correlation between these independent variables indicate a p, or correlation of 0.24686, not statistically significant at the 0.1000 level (pvalue = 0.18513). The dependent variable was the factor mission success (determined in the factor analysis above and from here on referred to as MS).

First Order Model. The first step of this analysis was to fit the first order regression model of the form:

$$MS = B_0 + B_1 (CL) + B_2 (X5) + e$$

SAS output of this regression analysis indicated the following results:

-The model's coefficient of determination (r^2) is 0.0337, with an adjusted $r^2 = -0.0378$.

-The F statistic, used to test the hypothesis $B_1 = B_2 = 0$, is 0.471. In this case, the resultant pvalue of 0.6293 indicates a large probability that we fail to reject the tested hypothesis. Thus, there is reasonable evidence to conclude that there is no linear association between the set of independent variables (CL and X5) and mission success.

-Separate hypothesis tests to determine if each individual parameter (B_i) is equal to zero, produce results similar to above. Specifically, we fail to reject the hypothesis that each parameter is equal to zero.

-Analysis of the residual plot and conducting a Wilk-Shapiro Goodness of Fit Test indicates that the error terms deviate from the assumption of normality (pvalue = 0.8227). These results indicate that the first order model was not appropriate and no relevant inferences can be drawn from it's parameters. Given this judgment, derivations of the first order model were investigated.

Polynomial Regression Model. The second step of this regression analysis was to fit the model:

$$MS = B_0 + B_1(CL) + B_2(X5) + B_3(CL)^2 + B_4(X5)^2 + B_5(CL)(X5) + e$$

SAS output of this regression analysis indicated the following results:

-The model's coefficient of determination (r^2) is 0.1686, with an adjusted r^2 = -0.0046. Comparing the results of these values to the first order model indicate a slight improvement.

-The F statistic, used to test the hypothesis $B_1 = B_2 = 0$, is 0.973. In this case, the resultant pvalue of 0.4538 indicates a large probability that we fail to reject the tested hypothesis. Thus, there is reasonable evidence to conclude that there is no linear association between the set of independent variables (CL, X5, and their associated second order terms) and mission success.

-Separate hypothesis tests to determine if each individual parameter (B_i) is equal to zero, produce results similar to above. Specifically, we fail to reject the hypothesis that each parameter is equal to zero. The coefficient B_3 is the closest to being statistically significant, with a pvalue of 0.2098.

-Analysis of the residual plot and conducting a Wilk-Shapiro Goodness of Fit Test indicates that the error terms deviate from the assumption of normality (pvalue = 0.88881).

Again, the conclusion drawn from this investigation is that the second order model is not appropriate, and thus, inferences drawn form the model parameters are not valid. The final model to be investigated was the log-linear regression model.

Log-Linear Regression Model. This step sought to fit the model:

$$MS = B_0 CL^{B1} X5^{B2}$$

If we take the log of each side, we can reduce this model into the linear equation:

$$\ln(MS) = \ln(B_0) + B_1 \ln(CL) + B_2 \ln(X5)$$

Evaluation of the SAS output provided the following results.

-The model's coefficient of determination (r^2) is 0.0072, with an adjusted $r^2 = -0.0664$. Comparing the results of these values to the first two models indicate this as the poorest of the three models.

-The F statistic, used to test the hypothesis $B_1 = B_2 = 0$, is 0.098. In this case, the resultant pvalue of 0.9078 indicates a large probability that we fail to reject the tested hypothesis. Thus, there is compelling evidence to conclude that there is no linear association between the set of independent variables (ln(CL),and ln(X5)) and ln(MS).

-Separate hypothesis tests to determine if each individual parameter (B_i) is equal to zero, produce results similar to above. Specifically, we fail to reject the hypothesis that each parameter is equal to zero. The coefficient $\ln(B_0)$ is the closest to being statistically significant, with a pvalue of 0.1698.

-Analysis of the residual plot and conducting a Wilk-Shapiro Goodness of Fit Test indicated that the error terms deviate from the assumption of normality (pvalue = 0.87180).

Conclusions drawn from the first two regression models, to a greater extent, also prove appropriate with the log-linear model.

Canonical Correlation Analysis. As a way of review, canonical correlation analysis seeks to determine the relationship between two sets of variables. In this case, we define the independent set of variables as X1-X5, and the dependent set of variables as Y1-Y4. In order to satisfy the model's assumptions of multivariate normality, each variable was normalized, using the formula:

$$NX_i = (X_i - X) / S_x$$

where:
NX_i is the normalized variable
X is the sample mean of the variable X_i
S_x is the sample standard deviation of the variable X_i

The resulting canonical correlation of the first canonical variate was 0.427872, explaining 0.4060 of the total variance in both the TF commander and MOE variable sets, relatively weak results. Testing the hypothesis that all of the canonical correlations are equal to zero, produces a test statistic value of 0.5804, with a resulting Pvalue of 0.9138. Thus, we can conclude with a high degree of certainty that the canonical variate is not statistically significant. Given these results, it would be inappropriate to draw any inferences from this analysis.

Descriminant Analysis. The final technique used to determine a relationship between the set of TF Commander variables and the set of MOE variables was descriminant analysis. Each battle was categorized as a victory, stalemate, or failure, based on the degree an attacking unit meets the success criterion in three areas (see ref. 2):

-Friendly forces remaining alive - 40% or higher.

-Enemy forces destroyed - 75% or higher.

-Terrain objective secured - yes or no.

Thus, for this study, battle success groups were defined as:

Failure: Did not achieve a success in any of the three (friendly forces, enemy forces, objective) criterion.

Stalemate: Achieved success in one or two of the three criterion.

Victory: Achieved success in all three criterion.

Given the above definitions, this investigation will first determine a discriminate function, test the validity of the function, and then, if valid, draw inferences from the function's coefficients. In order to satisfy the assumption of multivariate normality, each TF Commander variable was normalized.

The linear discriminate functions were determined using SAS (the program is contained in Appendix B) and an original set of 30 battles. Evaluation of the confusion matrix (Table 15) indicates a value of 0.3333 as an estimate of the apparent error rate. The technique of data splitting was also used to validate the function. Specifically, an additional 10 battles were used to determine the effectiveness of the function.

Table 15. Confusion Matrix.

Actual Group	Predicted Group Failure	Stalemate	Victory	Total
Failure	1	6	0	7
Stalemate	0	18	2	20
Victory	0	2	1	3

The result of evaluation of the determinate functions was also disappointing, as six of the ten battles were misclassified.

Thus, out of the entire set of 40 battles, the function had an apparent error rate of 0.4 (16 of 40). Given this outcome, it would be inappropriate to determine inferences on the relationship between the TF Commander variables and unit mission success using this discriminate function.

Investigation of the Entire Study Database

Results of the analysis conducted in part two proved to be inconclusive in determining a relationship between the TF Commander variables and the MOE variables. Thus, the investigation was expanded to include the entire set of independent variables (X1-X14). This section reviews the analytical results of part three of the methodology. Specifically, an analysis was conducted to determine the relationship between the set of TF Commander variables (X1-X5) and Battle Description variables (X6-X14), versus the MOE variables (Y1-Y4). As with part two, this section can be broken into four sections:

-A review of the results of the factor analysis conducted on the entire set of independent variables.

-A review of the aptness of regression models using the common factors determined in the factor analysis above.

-An explanation of the results of the canonical correlation analysis using the two sets of original variables.

-An evaluation of the appropriateness of the linear discriminate functions that seeks to determine unit mission success.

Factor Analysis. A factor analysis was conducted on the set of independent variables (X1-X14) for two purposes:

-To reduce the dimensionality of the data set from 14 to a more manageable number.

-To eliminate the multicollinearity of the data set as exhibited in Table 8 (p. 74).

An initial factor analysis was conducted on all 14 independent variables. Evaluation of those eigenvalues greater than one (Kaiser's criterion) of the correlation matrix are contained in Table 16.

Table 16. Eigenvalues of the Independent Variable Matrix.

	Factor1	Factor2	Factor3	Factor4	Factor5
Eigenvalue	4.0261	2.2944	1.8027	1.5155	1.1731
Proportion of Total Variance	0.2876	0.1639	0.1288	0.1082	0.0838
Cumulative Variance	0.2876	0.4515	0.5802	0.6885	0.7723

The five retained factors explain 0.7723 of the total variance in the original data set.

A varimax orthogonal rotation was conducted on the five retained factors in order to achieve a simple structure (see p. 66). The subsequent factor loadings matrix and communality estimates are reflected in Table 17 (bold type indicates statistically significant loadings). As illustrated in the loadings matrix, we can determine the following significant relationships:

Factor	Original Variable
One	X1, X2, X3, and X4
Two	X9, and X10
Three	X11, and X12
Four	X7, X13, and X14
Five	X5, X6, and X8

As with the factor analysis conducted in part two, a second factor analysis was conducted in an attempt to reduce any variability induced by extraneous variables. Selection of the original variables to be included in the subsequent factor analysis included evaluating relatively high variable loadings on retained factors (0.8 or higher), and relatively high communality estimates (0.75 or higher). This selection criterion produced the following variables; X1, X2, X3, X4, X9, X10, X11, X12, and X13.

Table 17. Initial Independent Variable Loadings Matrix.

	Factor1	Factor2	Factor3	Factor4	Factor5
X1	**0.96404**	-0.03724	-0.13953	0.05561	-0.05532
X2	**0.95969**	-0.00110	-0.15496	0.06161	-0.03649
X3	**-0.92132**	0.00030	0.18399	-0.01197	0.13625
X4	**0.83913**	**-0.34539**	0.04528	-0.07846	0.12589
X5	**0.32517**	0.05155	0.14445	0.24104	**0.68428**
X6	0.16924	-0.17838	0.14720	-0.07024	**-0.68950**
X7	-0.06861	0.13473	0.05717	**-0.70763**	-0.17050
X8	**-0.44000**	**-0.31308**	-0.11112	-0.13246	**-0.60614**
X9	-0.26324	**0.84865**	0.10472	-0.03577	-0.04232
X10	0.01059	**0.90383**	0.02703	-0.01064	0.12151
X11	-0.10846	0.03026	**0.94783**	-0.08462	-0.06121
X12	-0.23562	0.12225	**0.90134**	0.06829	-0.04382
X13	-0.10153	0.02619	-0.04711	**0.86893**	-0.06592
X14	0.19382	**0.41849**	**0.30852**	**0.57896**	0.17081

X1	X2	X3	X4	X5	X6	X7
0.95637	0.95007	0.90139	0.84748	0.65559	0.56247	0.55310
X8	X9	X10	X11	X12	X13	X14
0.68891	0.80354	0.83263	0.92197	0.88945	0.77259	0.67225

A subsequent factor analysis was conducted using the nine variables identified above. An examination of the eigenvalues, the scree plot, and using Kaiser's criterion concludes that four factors should be retained. The four common factors explain 0.9169 of the total variance contained in the original nine variables. This high amount of total variance explained is also reflected in the uniformly high communality estimates, ranging from a low of 0.805412 (X4) to a high of 0.992964 (X13).

The resultant factor loadings matrix (significant loadings reflected in bold type), following varimax orthogonal rotation, is illustrated in Table 18. Given the variables that

Table 18. Independent Common Factors.

	Factor 1	Factor 2	Factor 3	Factor 4
X1	**0.97349**	-0.13982	-0.05511	0.01233
X2	**0.97506**	-0.14830	-0.01103	0.03945
X3	**-0.93951**	0.16910	-0.00703	0.04303
X4	**0.81407**	0.01002	**-0.35600**	-0.12592
X9	-0.23301	0.12558	**0.90070**	-0.00403
X10	0.03188	0.03078	**0.91029**	0.02042
X11	-0.09828	**0.95551**	0.02368	-0.14679
X12	-0.19931	**0.92956**	0.13345	0.12826
X13	-0.04188	-0.02070	0.01462	**0.99527**

significantly load on each of the four factors suggest the following classifications:

Factor	Name	Score
One	Commander's Location	A low negative number indicates a Commander close to the front lines, and actively involved in the fight
Two	Unit Experience	A high number indicates a unit experienced in NTC battle and the deliberate attack
Three	Equipment/Terrain	A high number indicates a unit equipped with the

		Army's newest equipment maneuvering in closed, compartmentalized terrain (This seems to reflect an effort on the O/C group to match equipment type to terrain)
Four	Unit Proficiency	A low number indicates a unit that has performed well during it's current rotation

Two points must be made at this point. First, the Commander's Location is very similar to the one developed in part two of this analysis. Secondly, the Equipment/Terrain factor does not seem to reflect any inherent common factor. Rather, it seems to possibly reflect an effort on the part of the O/C group to match the modernization of a unit's equipment to the terrain type. Additionally, the variable X4 (Commander's activity level) does significantly load on this factor but is not reflected in the naming of the factor. This seems to indicate the logical trend of the commander remaining farther back and less active in the battle as the terrain becomes more flat and open.

Regression Analysis. The method of conducting the regression analysis was similar to the methodology of part 2. Specifically, the first order model was fitted, and evaluated for aptness. Model validation was conducted by fitting the model based on the data of the first 30 battles, and then testing the model using the last 10 battles to determine if the actual scores were contained in the predicted confidence interval. If this evaluation proved the model to be inappropriate, derivations of the first order model were investigated.

First Order Model. Using the results of the factor analyis conducted above, the following first order model was fitted:

$$MS = B_0 + B_1 (CL) + B_2 (UE) + B_3 (ET) + B_4 (UP) + e$$

where:
- MS is Mission success
- CL is Commader's location
- UE is Unit experience level
- ET is Equipment/Terrain
- UP is Unit proficiency

SAS output of this regression analysis is contained in Table 19,

Table 19. First Order Model Results.

Analysis of Variance

Source	DF	Squares	Sum of Square	Mean F Value	Prob>F
Model	4	11.64212	2.91053	4.192	0.0098
Error	25	17.35788	0.69432		
C Total	29	29.00000			

Root MSE	0.83326	R-square	0.4015
Dep Mean	0.00000	Adj R-sq	0.3057
C.V.	3.6025439E19		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.000000187	0.15213098	0.000	1.0000
CL	1	-0.128806	0.15473183	-0.832	0.4130
UE	1	0.452739	0.15473163	2.926	0.0072
ET	1	-0.314375	0.15473174	-2.032	0.0529
UP	1	-0.284705	0.15473149	-1.840	0.0777

and indicates the following results:

-The model's coefficient of determination (r^2) is 0.4015, with an adjusted $r^2 = 0.3057$.

-The F statistic, used to test the hypothesis $B_1 = B_2 = B_3 = B_4 = 0$, is 0.0098. In this case, the resultant pvalue of 4.192 indicates a large probability that we reject the tested hypothesis. Thus, there is strong evidence to conclude that there is a linear association between the set of independent variables (CL, UE, ET, and UP) and mission success.

-Separate hypothesis tests to determine if each individual parameter (B_i) is equal to zero, concluded that the parameters B_0 and B_1 are not statistically significant at the 0.1000 level. Specifically, we fail to reject the hypothesis that these two parameters are equal to zero. The other three parameters are statistically significant.

-Analysis of the two residual plots (residuals vs predicted values and residuals vs time) and conducting a Wilk-Shapiro Goodness of Fit Test indicates that the error terms do not deviate from the assumption of normality (pvalue = 0.95237).

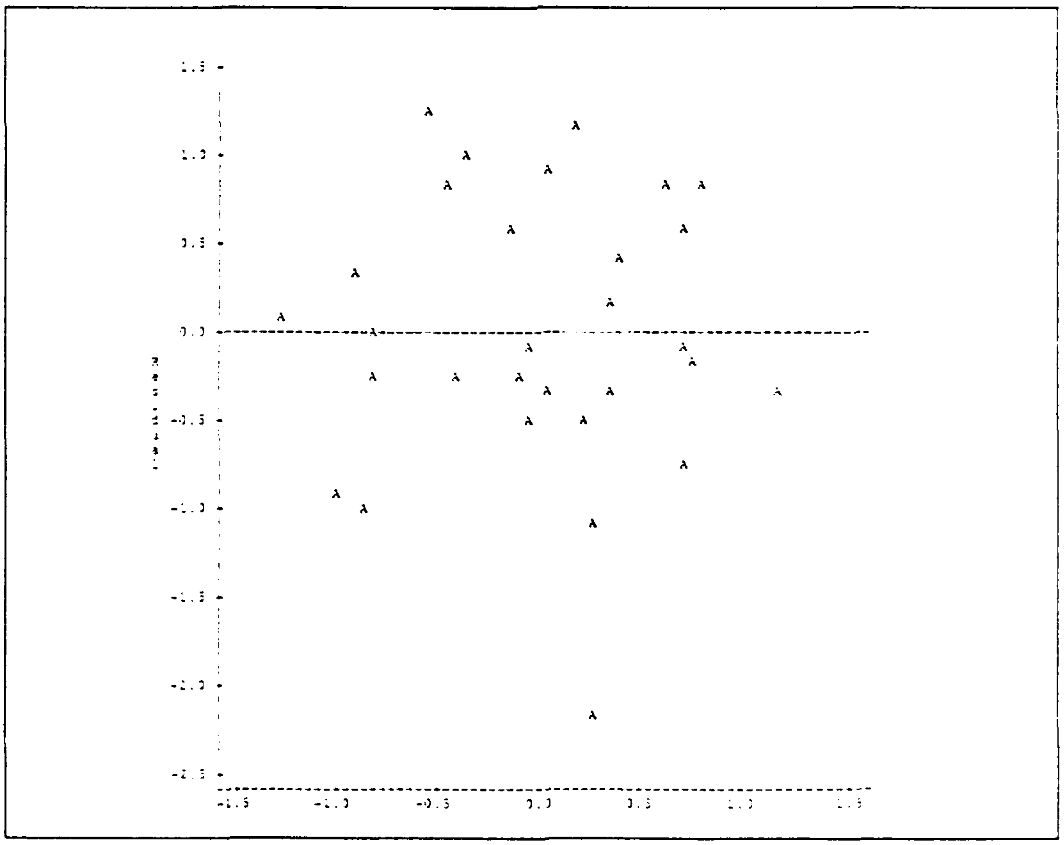

Figure 15. First Order Model Residual Plot.

Thus, the indicated first order model would be:

$$MS = 0.452739\ (UE) - 0.314375\ (ET) - 0.284705\ (UP) + e$$

where:
- MS is Mission success
- UE is Unit experience level
- ET is Equipment/Terrain
- UP is Unit proficiency

Conducting stepwise regression analysis supports the conclusion that this model is the best first order model for the data base.

Table 20 illustrates the results of the model's validation. Evaluating a confidence interval for each predicted value was done using the following formulation:

$$MS_{predict} \pm t(1-\alpha/2;\ n-p)\ S_{predict}$$

where:
- $MS_{predict}$ is the MS score predicted by the model
- $t(1-\alpha/2;\ n-p)$ is the student's t value at the point $1-\alpha/2$, n-p degrees of freedom
- $S_{predict}$ is the standard deviation of the predicted scores

As it is shown, eight of the ten actual Mission Success scores

Table 20. Predicted Score Confidence Intervals.

Actual Values for MS	Confidence Interval Upper Bound	Confidence Interval Lower Bound
0.0292*	-0.0242	-2.7656
-6.6371*	0.5628	-2.1786
0.6150	1.3221	-1.4193
-0.3682	1.9026	-0.8388
0.5765	0.7612	-1.9802
1.0337	2.1273	-0.6141
1.5016	1.7407	-1.0008
0.0175	0.8736	-1.8678
-0.7363	0.3639	-2.3776
0.4383	1.1322	-1.6092

* denotes a value outside the CI

fall within the prediction confidence interval (significance level of 0.1000). These results are in keeping with the model's relatively low coefficient of determination, but strong lack of fit test result.

First Order Derivations. In an attempt to find a model that would improve the fit of the study database, derivations of the first order model were investigated. The first model investigated was the second order polynomial regression model.

Results of the second order model are as follows:

-The model's coefficient of determination (r^2) is 0.5817, with an adjusted $r^2 = 0.1912$. Comparing the results of the adjusted r^2 values to the first order model (0.3057) indicate the first order model to be the better of the two.

-The F statistic, used to test the hypothesis $B_i = 0$, is 1.490. In this case, the resultant pvalue of 0.2264 indicates a strong probability that we fail to reject the tested hypothesis. Thus, there is compelling evidence to conclude that there is no linear association between the set of independent variables (CL, UE, ET, UP, and their associated second order terms) and mission success.

-Separate hypothesis tests to determine if each individual parameter (B_i) is equal to zero, produce results similar to above. Specifically, we fail to reject the hypothesis that each parameter is equal to zero. The coefficient associated with the term UP (Unit Proficiency) is the closest to being statistically significant, with a pvalue of 0.1063.

Evaluation of the log-linear model produced results that were significantly poorer than either the first or second order model ($r^2 = 0.0463$ and the f test pvalue of 0.6353). It appears, therefore, that the best normal error regression model is the first order model.

Canonical Correlation. This analysis sought to determine the relationship between two sets of variables. In this case, we define the independent set of variables as X1-X14, and the dependent set of variables as Y1-Y4. In order to satisfy the model's assumptions of multivariate normality, each variable was normalized, using the formula:

$$NX_i = (X_i - X) / S_x$$

where:

NX_i is the normalized variable
X is the sample mean of the variable X_i
S_x is the sample standard deviation of the variable X_i

The resulting canonical correlation of the first canonical variate was 0.890545, explaining 0.6192 of the total variance in both the independent and dependent variable sets. A ready example of this weak explanation of total variance is found in analyzing the scoring coefficients between the original normalized MOE variables (NY1-NY4) with their first canonical variate, shown in table 21. The first canonical variate has a

Figure 21. Canonical Coefficients for the MOE Variables.

	First Variate
NY1	0.0480
NY2	0.9608
NY3	0.1073
NY4	1.3697

a positive relationship with all of the original variables. Yet, in previous investigations (factor analysis on the MOE variables), and using intuition, there really is a negative correlation between the group of NY1-NY3 to NY4. Specifically, we would expect that as the values of percentage of friendly vehicles surviving (NY1), and the percentage of enemy vehicles destroyed (NY2) increase, the ratio of friendly vehicles destroyed to enemy vehicles destroyed (NY4) would decrease. This relationship is not reflected in Table 21.

Testing the hypothesis that all of the canonical correlations are equal to zero, produces a test statistic value of 1.1407, with a resulting Pvalue of 0.3206. Thus, the conclusion drawn is that the canonical variate is not statistically significant. Given these results, it would be inappropriate to draw any inferences from this analysis.

Discriminant Analysis. The final technique used to determine a relationship between the set of independent variables (X1-X14) and the set of dependent variables (Y1-Y4) was descriminant analysis. Again, each battle was categorized as a victory, stalemate, or failure, based on the degree of an attacking unit meets the success criterion in three areas (see ref. 2):

-Friendly forces remaining alive - 40% or higher.

-Enemy forces destroyed - 75% or higher.

-Terrain objective secured - yes or no.

Thus, for this study, battle success groups were defined as:

Failure: Did not achieve a success in any of the three (friendly forces, enemy forces, objective) criterion.

Stalemate: Achieved success in one or two of the three criterion.

Victory: Achieved success in all three criterion. Given the above definitions, this investigation first determined the discriminate functions, tested the validity of the functions, and then, if valid, drew inferences from the function's coefficients. In order to satisfy the assumption of multivariate normality, each independent variable was normalized.

The linear discriminate functions were determined using SAS (the program is contained in Appendix B) and an original set of 30 battles. Evaluation of the confusion matrix (Table 22) indicates a value of 0.1667 as an estimate of the apparent error rate. The technique of data splitting was also used to validate the function. Specifically, an additional 10 battles were used to determine the effectiveness of the function.

Table 22. Confusion Matrix.

Actual Group	Predicted Group			
	Failure	Stalemate	Victory	Total
Failure	4	3	0	7
Stalemate	2	18	0	20
Victory	0	0	3	3

The result of evaluation of the discriminate functions was inconclusive, as four of the ten battles were misclassified. Thus, out of the entire set of 40 battles, the function had an apparent error rate of 0.225 (9 of 40). Given this outcome, it would be inappropriate to determine inferences on the relationship between the independent variables and unit mission success using this discriminate function.

Variables Affecting TF Commander Survival

A descriminant analysis was conducted to determine those variables that significantly affect the survival of the TF Commander during the deliberate attack. The battles were divided into two groups; battles in which the Commander survived and battles in which the Commander's vehicle was 'killed'. Thus, the investigation first determined a discriminate function, tested the validity of the function, and then, if valid, drew inferences from the function's coefficients. In order to satisfy the assumption of multivariate normality, each predictor variable (X1-X4, X6-X14) was normalized.

SAS determined two quadratic discriminate functions (one for each group) using the first 30 battles in the study data base. Each function was of the form:

$$d_q^i = \text{constant}_i + \sum C_{ij} \, (NX_{ij})$$

where:
- i indicates the group
- j indicates the variable NX_j
- C_{ij} is the coefficient of the ith group and the jth variable

Group selection was simply determined by the group with the max d_q^i value.

Evaluation of the confusion matrix indicated that the functions correctly predicted the group for each one of the battles. Additionally, when the final 10 battles were evaluated (the validation technique of data splitting), the discriminate functions predicted all battles correctly. These results indicate that the discriminate functions accurately portray those variables that significantly affect TF Commander survival.

Table 23 illustrates the parameters of the two discriminate functions, along with a ranking of the difference in order of magnitude.

Table 23. Discriminate Function Parameters.

Variable	Died	Lived	Difference	Rank
Constant	-0.46532	-0.20930	-0.25602	12
NX1	0.34650	0.00291	0.34359	10
NX2	-0.00541	-0.01534	0.00993	14
NX3	-0.11364	0.61948	-0.73312	6
NX4	-1.14850	0.92260	-2.07110	1
NX6	0.20497	-0.09541	0.30038	11
NX7	-0.47070	0.09496	-0.56566	8
NX8	-0.73124	0.34053	-1.07177	4
NX9	-0.40198	0.32037	-0.72235	7
NX10	0.04660	-0.04757	0.09417	13
NX11	0.73835	-0.51524	1.25359	2
NX12	-0.71534	0.46846	-1.18380	3
NX13	-0.53750	0.25183	-0.78933	5
NX14	-0.30212	0.14987	-0.45199	9

Analysis of the results of this table indicates the following results. If the difference between the function parameters (Died - Lived) is negative, we can conclude that the smaller the variable value, the more chance the Commander has of surviving. Conversely, when the difference of the function parameters is positive, we can conclude that the larger the value of the variable, the more chance the Commander has of surviving. The variable with the most influence on Commander survival is X4 (Commander's activity level). Given the signs for each function, we can conclude that a negative number for NX4, or a Commander close to the front and involved in the fighting, is more apt to survive than a Commander farther away from the fight (a high positive number for NX4). The variable with the least effect on Commander's survival is NX2 (Commander's distance from the enemy).

VII. Conclusions and Recommendations

Introduction

The U.S. Army's manual on military leadership, FM 22-100, defines military leadership as "a process by which a soldier influences others to accomplish the mission" (10:44). This process, by it's nature, is a distinctly human operation. Given the limitations of currently available data, this study did not attempt to resolve all issues related to the human factors of combat leadership. Rather, the central question of this research was to determine the effect of the Commander's battle positioning on unit combat performance. This chapter will present inferences and conclusions drawn from the analytical results described in the previous chapter. Finally, recommendations will be made concerning improvements in data collection at the NTC, and will identify further research ideas on the broad topic of leadership's effect in combat.

Study Conclusions

Under the general investigation of determining the effect of the Commander's battle positioning on unit combat performance, this study sought to answer specific questions. As a way of review, these questions focused on determining the following relationships:

-Is there a relationship between a Commander's location in combat and his unit's effectiveness?

-Can a Commander's contribution to the battle be quantified through knowledge of his location, and survival during the battle?

-What is the relationship between a Commander's location and his survival?

-Is there an "optimal" location with respect to the above mentioned concerns?

The following paragraphs will reply to these specific questions, and highlight other inferences that can be drawn from the study results.

<u>The Commander and Unit Effectiveness</u>. Results of this analysis indicated no direct relationship could be identified between the location of the TF Commander and unit combat performance. This conclusion is based on the results of 40 battles investigated.

A correlation analysis between the TF Commander variables and the MOE variables (Table 6, page 72) indicated no relationship could be found between any of the individual variables. Secondly, the results of the regression model, using the factor "Commander's location" and the variable X5 (Commander's survival), indicated no linear relationship between those variables and the factor Mission success (see pages 82-85). This would seem to lead to the conclusion that neither the Commander's location, or his survival during the battle, affect his unit's combat performance. In fact, the regression model that best fits the study database did not include the factor "Commander's location" as a regressor (see pages 92-95).

Attempts to determine a relationship between Commander's location and Mission success using canonical correlation analysis and discriminant analysis led to the same conclusions. Based on this study, it was impossible to identify any quantitative effect that the Commander's location had on unit combat performance. Similarly, it was equally impossible to determine an optimal location for the Commander to enhance unit combat performance. Before commenting on the results of analyzing the Commander's location effects on his survival, however, some inferences can be drawn on other factors that seem to affect unit combat performance. The best regression model, cited in the paragraph above, was of the form:

$$MS = 0.452739\ (UE) - 0.314375\ (ET) - 0.284705\ (UP) + e$$

where:
MS is Mission success
UE is Unit experience level
ET is Equipment/Terrain
UP is Unit proficiency

Remembering that if a high positive score for the factor MS indicates a unit that achieved successful results in it's attack, then the analysis of the regression coefficients indicates that the factor UE (Unit experience) had the most effect on MS (Mission success). Given the positive sign of the coefficient, this result indicates that a unit achieves a higher level of mission success when the unit encounters the battle later in it's rotation, and after conducting prior deliberate attacks it before it performs this tested mission. One explanation of this phenomena seems intuitive, the more practiced the unit is in conducting battles at the NTC, especially deliberate attacks, the better the unit performs this mission. Another inference, less readily apparent, deals with the cohesion of the unit. Many military historians (Marshall, Henderson, LaPorte, and others) believe that a unit's combat performance is predicated on the cohesiveness of the unit. Henderson (ref. 22), along with the Army's manual on leadership (FM 22-100), contend that unit cohesion is enhanced when distractions to the unit's mission are minimized. It is interesting to note that the farther along a unit is in it's rotation, the farther removed it is from the distractions of garrison operations (family responsibilities, administrative requirements, building maintenance, etc).

The factor ET (Equipment/Terrain) also had a relatively strong effect on MS (Mission success). Given the negative sign of the coefficient, this result would indicate a unit achieves a higher level of mission success due to smaller values of ET. Reviewing the variables that significantly load on the factor ET, we can make the following conclusions:

-Mission success is enhanced by small values for X9 (Terrain characterization). This indicates that open, flat terrain is more conducive to attack success. This conclusion may be a result of improved target acquisition on the attacking forces part due to the openness of the terrain.

- Older equipment (M60 tank, M113 APC) in units tended to enhance mission success. Although this conclusion seems counter-intuitive, one explanation of this phenomena may be that the enhanced speed and mobility of the newer equipment (M1 tank, M2 IFV) increases the tempo of the attack to the point that units are committed against defender strengths before they can react. It is important to realize that the battles analyzed in this study occurred during the period 1987-1989, when some units were still relatively inexperienced in the employment of the newer series of vehicles.

The final factor affecting mission success was UP (Unit proficiency). The negative sign of the coefficient is entirely consistent with the reality that high values for UP indicate units that have performed poorly during their rotation.

Survival of the TF Commander. Intuition would indicate that the Commander's location would greatly influence his likelihood of being engaged and destroyed in battle, i.e., the closer he positions himself forward in the battle, the higher the probability that he would be killed. Results of the study's analysis, however, demonstrate that the TF Commander's location does not significantly influence his survivability. This conclusion is based on the outcome of two separate investigations.

First, a correlation analysis of the TF Commander variables indicated relatively weak correlations between the Commander's survival variable (X5) and the Commander's location variables (X1-X3) (see page 72). This relationship was manifested in the factor analysis conducted on the entire set of TF Commander variables (see pages 79-82). This analysis produced two independent common factors, Commander's location and Commander's survival. Examination of the resulting loadings matrix (Table 13, page 80) leads to the conclusion that the variables that describe the Commander's location (X1-X3) do not significantly load on the factor Commander's survival, and thus do not significantly affect this factor.

Secondly, the discriminant analysis conducted on the original variables concerning TF Commander survival also produced interesting results (see pages 99-101). The variable that seemed to have the most effect on whether the Commander survived the battle was X4 (Commander's activity level). Evaluation of the discriminate functions lead to the conclusion that the smaller the value for X4, the higher the chance is that the Commander survives. Low values for X4 indicate a Commander close to the front of his formation, actively involved in the fight.

This result, however, seems to contradict with the evaluation of the function coefficients of the Commander distance variables (X1-X3) (see Table 23, page 100). Interpretation of the discriminate functions conclude that the greater the distance the Commander is from both the front line of his own troops (X1) and the forward enemy vehicle in the main defensive belt (X2), and the closer he is to the unit's center of mass (X3), the greater his chance of survival. It must be noted, however, that the magnitude of these variables' effect is much less than the effect attributed to X4. This incongruence may lead to the questionable conclusion that the Commander's survival is enhanced by being forward in his formation, but not too far forward. The nebulous nature of this inference, however, and the small magnitude of location variables' effect, indicate that the proficiency of the unit (X13), the experience level of the unit (X11 and X12), have a far greater effect on Commander's survival.

Recommendations

As was forcasted in the introduction to this chapter, the following recommendations can be divided into two broad categories:

-Improvements in the data collection process at the NTC, and;

-Further research topics related to this study.

NTC Data Collection. Most historians agree that combat is an extremely human experience. "Despite the increasing complexity and sophistication of our weapons and equipment, our most perplexing problems are human rather than technical in nature" (33:7-1). Unfortunately, the current NTC database has little information concerning the human factors that could influence leadership, and unit combat performance. It must be understood that the number of these human factors are nearly limitless, such as motivation, fatigue, pressure, and quality of leadership. Thus, the following paragraphs will focus on improvements in data collection related to this specific study.

Data Collection Prior to the Unit's Rotation. As discussed in Chapter II, a commander's effect on unit combat performance is directly related to the effectiveness of his leadership techniques. Additionally, unit combat performance, especially at the lowest levels (section, squad, and platoon), depends greatly on the cohesiveness of the unit. Indications of the status of these leader factors, could be obtained in the form of surveys or questionnaires, completed during the equipment draw phase of a unit's rotation.

An example of such a survey would include, but not be limited to, the following questions.

I. Information on the TF Commander.

a. How long has the he been in his position?

b. How many previous rotations has he had to the NTC and in what positions?

c. Does he have any previous combat experience?

d. What is the level of his military schooling?

e. What are his perceptions on his unit's discipline, cohesion, and level of training?

II. Information on the Subordinate Chain of Command. Questions similar to the ones in part I above should be directed tc critical members of the chain of command, such as:

a. TF Executive Officer.

b. TF Operations Officer.

c. TF Command Sergeant Major.

d. Company Commanders.

e. Platoon Leaders.

f. Platoon Sergeants.

g. Tank Commanders and Squad Leaders.

III. A random survey of the soldiers in the unit.

a. What is his position?

b. How long has he been in his unit, and position?

c. What are his perceptions on his unit's discipline, cohesion, and level of training?

d. What are his perceptions of the leaders of his unit? Specifically, their technical and tactical proficiency, their ability to care for the soldier's needs, etc?

Data Collection During Force-on-Force Battles. Despite being the most instrumented training environment in the world, there are distinct limitations to the NTC data collection process during the actual force-on-force battles. Those limitations that directly affected this study are detailed in Chapter IV, and will not be reexamined here. Rather, this section will focus on two recommendations that would improve the type of information available to the analyst researching combat leadership.

Attributing Lethality Below the TF Level. Henderson contends that leadership has it's greatest effect at the lowest levels of a unit's organization (squad, platoon, and company) (22:11-12). However, the current database is unable to assess one measure of unit proficiency, namely the number of enemy combat vehicles, and personnel killed, below the TF level. In order to attribute lethality at the individual weapon system level, improvements must be made to the Paired Event Table (PET) of the digital database. Remember that only 20-30 % of the current firing events (near misses, hits, and kills) can be paired between a firing weapon system and target.

One such method of improving the PET would follow the methodology described in Figure 16 below.

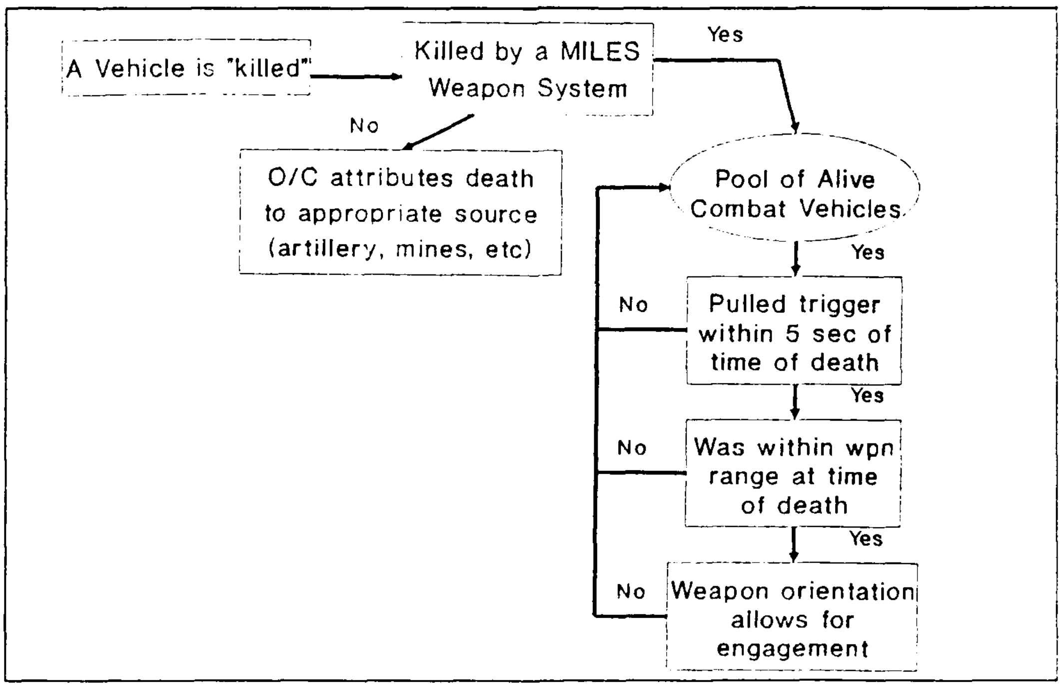

Figure 16. Improved PET Methodology.

Determining weapon system orientation would be the only step of this methodology that is not possible with the current level of instrumentation. This problem could be solved by attaching sensors to each end of the weapon system, and monitoring this information by the same method that vehicle locations are determined.

Monitoring the Leader's Actions During Battle. Information on the actions (or thoughts) of the TF Commander, or for that matter any other leader, was limited and mostly speculative during these battles. Thus, this research was restricted in it's ability to assess the amount of time a leader spends "fighting" his unit, as opposed to fighting his own combat vehicle.

Currently, Observer/Controllers (O/C) are too busy adjudicating battle results to closely observe and capture the mental and physical activities of each leader. One recommendation to collect this information in a tank unit would be to attach a video camera on the leader's vehicle and an audio hookup to his vehicle's intercom system. This would allow for a detailed analysis of what the leader did, his communications to his tank crew, and his radio transmissions during the battle. A similar setup for an infantry leader, however, would not be appropriate, as many times the infantry leader fights the battle dismounted from his combat vehicle. Collection of this information in an infantry unit would require an observer to move with the leader, possibly inducing bias in this report. Detailed information of this nature would allow the analyst to to determine the relationship between those tasks that the Commander focuses his attentions, and his proximity to the point of attack. A first cut on specific Commander activity phases would include, but not be limited to:

-Planning.

-Monitoring the battle.

-Issuing orders to subordinates.

-Receiving orders / reporting to higher headquarters.

-Maneuvering own vehicle.

-Engaging enemy with own vehicle's weapon system.

Further Research Topics. During the conduct of this research, numerous topics of additional research interest became apparent. Certain topics have already been alluded to in discussions concerning implementing recommendations in improving data collection at the NTC. The following section details further topics that appear promising.

During the initial stages of this study, attempts were made to include Observer/Controller (O/C) evaluations of the unit's performance in the eight Battlefield Operating Systems (BOS), contained in Section III of the Take Home Packages (see p. 43). Problems were encountered, however, in translating the subjective comments from the O/Cs to a rating system that allows for ease of numerical evaluation. Study may reveal interesting relationships between performance in these eight BOS, and the locations of not only the Commander and his command group (normally consisting of Fire Support Officer, the Forward Air Controller, and the Battalion Operations Officer), but also the Battalion Tactical Operations Center (TOC), and the Battalion Administrative Logistics Center (ALOC).

While the NTC database proved inconclusive in determining the effect a TF Commander's battle positioning has on his unit's combat performance this, however, is not the only Combat Training Center (CTC) upon which to conduct studies. Infantry forces conduct training in low to mid-level intensity combat at the Joint Readiness Training Center (JRTC), Fort Chaffee, AK and the Combat Maneuver Training Center (CMTC), Hohenfels, FRG allows for mounted, mid-level intensity combat training. Although these areas lack some of the instrumentation of the NTC, a similar attempt at isolating a commander's effect on combat performance may be conducted using information collected from these two sites. In fact, the focus of training at these two sites are more at the Company and platoon, allowing for investigations at levels lower than Battalion/Task Force.

This research limited itself to analyzing TF deliberate attacks. A related topic of research would be determining the effect of a Commander's battle positioning to his unit's performance in other combat operations, such as defensive operations, and movement to contacts.

Observation of over 40 TF deliberate attacks using the GNATT playback program seemed to indicate the trend that unit's that maintained their momentum of attack acheived a greater level of success than units that seemed to stop during the attack phase of the operation. This observed trend may reinforce the importance of the AirLand Battle tenet of initiative. Described by the Army's manual on Operations (FM 100-5), "initiative implies never allowing the enemy to recover from the initial shock of the attack" (14:15). It is important to note, however, that this inference is based only observations of the battle playbacks, and is not supported by any type of analytical results. Research on this topic may yield interesting outcomes.

A final set of research topics is predicated on improving the NTC's ability to attribute lethality at the lowest possible level (individual weapon system). If this were possible, research similar to this study could focus on the squad, platoon, and company level. Historical study on the dynamics of combat leadership seems to indicate that a leader has his most direct effect on unit performance at the lowest levels of the organization.

Determining lethality at the weapon system level allows for eventual access to a number of other interesting topics of study. Military historians have noted that the majority of combat kills recorded by a certain unit can normally be attributed to a few "hunter-killers" in the unit, while other soldiers barely fire their weapons. Future analysts would be able to define the "killers" of the NTC battlefield, analyzing the factors (human, environmental, etc.) that produce the hunter-killers (and the no fire soldiers) of the NTC battlefield.

Summary

The purpose of this research was to assess to what extent the location of the TF Commander impacts on the outcome of battle during daytime deliberate attacks at the National Training Center. Results of this analysis neither proved or disproved that the Commander's position had an effect on unit combat performance. The information contained in the NTC data base, located at the ARI-POM Archives, was unable to resolve this issue of Commander's positioning during battle. It is important, therefore, to correctly identify appropriate conclusions given this result.

The relatively low coefficient of determination of the best mathematical model predicting unit success (p. 94) indicates the complexity of combat. Numerous factors that affect unit combat performance, not addressed in this study, are obviously missing from this model. What was determined was that the more experience a unit had in the mock battles of NTC, and specifically the more experience it had in conducting deliberate attacks, the better chance it had of achieving success. Past and current reflections on combat insist that the human element, such as unit cohesion and leadership, have an effect on battle outcome. Thus, it would be appropriate to assume this study failed to capture certain elements of leadership beyond

Commander's positioning that directly influence performance.

An interesting outcome of this study was the counter-intuitive result that the mortality of the TF Commander had nothing to do with the outcome of these battle. One must be cautious not to apply this result to leaders at all levels. The effect of losing a leader at a lower level of command, given the personal contact that a squad or platoon sergeant have with their soldiers, may dramatically affect battle outcome. Additionally, it may be improper to draw the same lack of effect conclusions on the antiseptic NTC battlefield and apply that to a real combat situation.

This study can not properly conclude that the Commander's location in combat has no effect on unit combat performance. Factors that may interact with where the Commander positions himself in battle, such as his level of command (TF, Company, Platoon, Squad, etc.), the accuracy of information he receives from his subordinates, and the effe~tiveness of his leadership, were not measured in this study. Rather, in the limited scenario of daytime deliberate attacks conducted in the training environment of the NTC, the effect of the TF Commander's location (as it was measured in this study) on the TF's success was not statistically significant.

Appendix A: Ingress Database Query Commands

Introduction

The digital database located at the Archives, ARI-POM, provided much of the raw information used in this study. Information was obtained from the Ingress database using four basic query commands:

- Player ID: Identifies the friendly players involved in the battle, their logical player number (lpn), and their weapon system.
- Battle Deaths: Identifies the time a vehicle "dies" on the battlefield.
- Locations at CT: Identifies the locations of friendly combat vehicles at a specified time.
- Commander's Location: Identifies the TF Commander's location throughout the battle.

These four basic queries are listed below.

Database Queries

Player ID.

```
range of p is psit
retrieve (p.all)
where p.side = "B"
```

Battle Deaths.

```
range of p is psut
retrieve (p.time, p.lpn, p.pstat)
where p.side = "B"
and p.side = "O"
```

Locations at CT.

```
range of p is psit
range of g is gplt
retrieve (g.pllpn, g.x, g.y)
```

```
where p.lpn = g.pllpn
and p.side = "B"
and g.time = "26 Feb 87 10:00:57"
```

Commander's Location.

```
range of p is gplt
retrieve (p.all)
where p.pllpn="275"
```

Note: Lpn 275 in this case refers to the TF Commander.

Appendix B: SAS Programs

```
options linesize=78;

/*   The purpose of this SAS program is to answer solve part 1
     (p. 64) of the methodology.  Specifically, this program
     will:
          a.  Input the initial 30 battle database contained in
     the SAS data file 'first.sas'.
          b.  Develop a correlation matrix between:
               1)  The Commander variables (X1-X5) and the MOE
     variables (Y1-Y4).
               2)  The Battle Description variables (X6-X14) and
     the MOE variables (Y1-Y4).
               3)  All of the independent variables (X1-X14).
          c.  Plot each one of the Commander variables (X1-X14)
     against the dependent, or MOE variables (Y1-Y4).

Input of the 'first.sas' data file into the SAS working file
'WORK.INITIAL'.
*/

data initial;
     input x1-x14 y1-y4;
     %include first;

/*
Developing a correlation matrix between the Commander variables
and the MOE variables.
*/

proc corr;
     var x1-x5 y1-y4;

/*
Developing a correlation matrix between the Battle Description
Variables and the MOE variables.
*/

proc corr;
     var x6-x14 y1-y4;

/*
Developing a correlation matrix between the independent
variables. */

proc corr;
     var x1-x14;
```

```
/*
Plotting the Commander variables versus the dependent variables.
*/

proc plot;
     plot y1*x1;
     plot y1*x2;
     plot y1*x3;
     plot y1*x4;
     plot y1*x5;
     plot y2*x1;
     plot y2*x2;
     plot y2*x3;
     plot y2*x4;
     plot y2*x5;
     plot y3*x1;
     plot y3*x2;
     plot y3*x3;
     plot y3*x4;
     plot y3*x5;
     plot y4*x1;
     plot y4*x2;
     plot y4*x3;
     plot y4*x4;
     plot y4*x5;

run;

/*   Part 2.a. requires this SAS program to determine the common
     factors for both the MOE variables (Y1-Y4), and the
     Commander variables (X1-X5).  Specifically, this program
     will:
          a.  Input the initial 30 battle database contained in
     the SAS data file 'first.sas'.
          b.  Conduct an initial factor analysis on both the MOE
     variables and the Commander variables to determine:
               1)  The common factors underlying the observable
     variables.
               2)  Those variables with the highest loadings on
     those common factors that are relevant to this study (i.e.
     commander's location and unit success).
          c.  Conduct a subsequent factor analysis using the
     variables determined in part b.2) above.
          d.  Print the results of the subsequent factor scores.


Input of the 'first.sas' data file into the SAS working file
'WORK.PART2'.
*/

data part2;
```

```
     input x1-x14 y1-y4;
     %include first;

/*
Conduct the initial factor analysis on the MOE variables and the
Commander variables.
*/

proc factor method=principal scree mineigen=1 rotate=varimax;
     var y1-y4;

proc factor method=principal scree mineigen=.9 rotate=varimax;
     var x1-x5;

/*
Conduct a subsequent factor analysis on only selected MOE and
Commander variables.
*/

proc factor out=factory method=principal mineigen=1
rotate=varimax;
     var y2 y3 y4;

proc factor out=factorx method=principal mineigen=1
rotate=varimax;
     var x1-x4;

/*
Print out the factor scores from the subsequent factor analysis.
*/

proc print data=factory;
     var factor1;

proc print data=factorx;
     var x5 factor1;

run;

/*
     Part 2b.  The purpose of this SAS program is to determine a
     linear regression model that adequately describes the
     relationship between the independent variables Commander's
     Location (fx), Commander's Survival (x5), and the dependent
     variable Unit Success (fy).  To achieve this objective, this
     program follows the following sequence.
          a.  Input the data set 'factor' and determine the
     following variables:

               nx5:   Normalized Commander Survival variable.
               fx2:   Squared Commander's Location variable.
               nx52:  Squared Normalized Commander Survival
```

```
                     variable.
              fxnx5: Interaction term.
              lfy:   Log of the Mission Success variable.
              lfx:   Log of the Commander's Location variable.
              lnx5:  Log of the Normalized Commander Survival
                     variable.

          b.  Fit the first order model and evaluate the model
     aptness.
          c.  Fit the second order polynomial model and evaluate
     the model aptness.
          d.  Fit the log-linear model and determine model
     aptness.

Input the data set.
*/

data part2b;
     nx5=(x5-0.8568)/0.2317;
     fx2=fx*fx;
     nx52=nx5*xn5;
     fxnx5=fx*nx5;
     lfy=log(2.0+fy);
     lfx=log(2.0+fx);
     lnx5=log(3.0+nx5);
     input fx x5 fy;
     %include factor;

/*
Fit the first order model and determine model aptness.
*/

proc reg;
     model fy=fx nx5;
     output out=aptness p=fyhat r=fyresid;

proc print data=aptness;
     var fy fyhat fyresid;

proc plot data=aptness;
     plot fyresid*fyhat / vref=0;

proc univariate data=aptness normal noprint;
     output out=normck n=samsize normal=pvalue;

proc print data=normck;

/*
Fit the second order model and determine model aptness.
*/

proc reg data=part2b;
```

```
     model fy=fx nx5 fx2 nx52 fxnx5;
     output out=aptness p=fyhat r=fyresid;

proc print data=aptness;
     var fy fyhat fyresid;

proc plot data=aptness;
     plot fyresid*fyhat / vref=0;

proc univariate data=aptness normal noprint;
     output out=normck n=samsize normal=pvalue;

proc print data=normck;

/*
Fit the log-linear model and determine model aptness.
*/

proc reg data=part2b;
     model lfy=lfx lnx5;
     output out=aptness p=lfyhat r=lfyresid;

proc print data=aptness;
     var lfy lfyhat lfyresid;

proc plot data=aptness;
     plot lfyresid*lfyhat / vref=0;

proc univariate data=aptness normal noprint;
     output out=normck n=samsize normal=pvalue;

proc print data=normck;

run;

/*   Part 2c.  This SAS program evaluates the canonical
     correlation variates of the independent normalized Commander
     Variables (nx1-nx5) and the normalized Measures of
     Effectiveness (ny1-ny4).  In sequence, this program:
               a.  Input the data set and then normalize the
     variables to ensure the data set meets the assumption of
     multivariate normality.
               b.  Conduct a canonical correlation analysis using
     the SAS procedure 'proc cancorr'.

Input the data set and normalize each variable.
*/

data part2c;
     input x1-x14 y1-y4;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
```

```
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     ny1=((y1-0.4076)/0.1173);
     ny2=((y2-0.5378)/0.2385);
     ny3=((y3-0.3000)/0.4661);
     ny4=((y4-3.2162)/2.0710);
     %include first;

/*
Conduct a canonical correlation of the normalized variables.
*/

proc cancorr vname='Normalized Commander Variables'
     wname='Measures of effectiveness';
     var nx1 nx2 nx3 nx4 nx5:
     with ny1 ny2 ny3 ny4;

run;

/*   Part 2d.  The purpose of this program is to conduct a
     discriminate analysis using the normalized Commander
     variables (nx1-nx5) and the success groupings described in
     the methodology.  Specifically, this program:
               a.  Inputs the data set and normalizes the
     Commander variables.
               b.  Determines the discriminate function and
     validates the function.

Input the data set and normalize the Commander variables.
*/

data original;
     input x1-x5 success_no @@;
     if suc_no=1 then success='Failure  ';
     if suc_no=2 then success='Stalemate';
     if suc_no=3 then success='Victory  ';
     drop suc_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     %include first1;

/*
Conduct the descriminant analysis using 'proc descrim'.
*/

proc discrim out=info pool=test pcorr list;
     class success;
     var nx1-nx5;
```

```
     priors proportional;

/*
Input the second data set using 10 additional battles.
*/

data check;
     input x1-x5 success_no @@;
     if suc_no=1 then success='Failure  ';
     if suc_no=2 then success='Stalemate';
     if suc_no=3 then success='Victory  ';
     drop suc_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     %include second3;

/*
Validate the discriminate function using the second data set
'WORK.CHECK'.
*/

proc discrim data=info testdata=check testlist;
     testclass success;
     var nx1-nx5;

run;

/*   Part 3.a-b. requires this SAS program to determine the
     common factors for the entire set of independent variables
     (X1-X14).  These common factors will then be used as the
     independent variables (the factor 'Mission Success',
     determined in part 2.a. previously, will be used as the
     dependent variable) in conducting a regression analysis.
          a.  Input the initial 30 battle database contained in
     the SAS data file 'first.sas'.
          b.  Conduct an initial factor analysis on the
     independent variables to determine:
               1)  The common factors underlying the observable
     variables.
               2)  Those variables with the highest loadings on
     those common factors that meet the meinegen criteria
     (eigenvalue greater than or equal to one).
          c.  Conduct a subsequent factor analysis using the
     variables determined in part b.2) above.
          d.  Print the results of the subsequent factor scores.
          e.  Fit the first order regression model and determine
     model aptness.
          f.  Fit the polynomial regression model and determine
     model aptness.
```

g. Fit the log-linear model and determine model aptness.

```
Input of the 'first.sas' data file into the SAS working file
'WORK.PART3A'.
*/

data part3a;
     input x1-x14 fy;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     nx6=((x6-48.3333)/31.213);
     nx7=((x7-1.5333)/0.8193);
     nx8=((x8-2.2333)/0.5683);
     nx9=((x9-1.7333)/0.7849);
     nx10=((x10-1.8000)/0.6644);
     nx11=((x11-0.6161)/0.2617);
     nx12=((x12-1.6333)/0.7649);
     nx13=((x13-1.3504)/0.7024);
     nx14=((x14-11206)/10847);
     %include factor2;

/*
Conduct the initial factor analysis on the independent variables.
*/

proc factor method=principal scree mineigen=1 rotate=varimax;
     var x1-x14;

/*
Conduct a subsequent factor analysis on only selected independent
variables.
*/

proc factor out=part3b method=principal n=4 rotate=varimax;
     var x1-x4 x9-x13;

/*
Print out the factor scores from the subsequent factor analysis.
*/

proc print data=part3b;
     var factor1-factor4 nx5-nx8 nx14 fy;

/*
Fit the first order multiple regression model.
*/
```

```
proc reg;
     model fy=factor1-factor4;
     output out=aptness p=fyhat r=fyresid;

proc print data=aptness;
     var fy fyhat fyresid;

proc plot data=aptness;
     plot fyresid*fyhat / vref=0;

proc univariate data=aptness normal noprint;
     output out=normck n=samsize mean=mean std=s normal=pvalue;

proc print data=normck;

proc rsreg data=part2b out=aptness;
     model fy=fx nx5 / lackfit noopt residual;
run;

/*   Part 3d.  The purpose of this program is to conduct a
     descriminate analysis using the normalized Independent
     variables (nx1-nx14) and the success groupings described in
     the methodology.  Specifically, this program:
               a.  Inputs the data set and normalizes the
     Independent variables.
               b.  Determines the descriminate function and
     validates the function.

Input the data set and normalize the Independent variables.
*/

data original;
     input x1-x14 suc_no @@;
     if suc_no=1 then success='Failure  ';
     if suc_no=2 then success='Stalemate';
     if suc_no=3 then success='Victory  ';
     drop suc_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     nx6=((x6-48.3333)/31.213);
     nx7=((x7-1.5333)/0.8193);
     nx8=((x8-2.2333)/0.5683);
     nx9=((x9-1.7333)/0.7849);
     nx10=((x10-1.8000)/0.6644);
     nx11=((x11-0.6161)/0.2617);
     nx12=((x12-1.6333)/0.7649);
     nx13=((x13-1.3504)/0.7024);
     nx14=((x14-11206)/10847);
     %include first2;
```

```
/*
Conduct a descriminate analysis using 'proc descrim'.
*/

proc discrim out=info pool=test pcorr list;
     class success;
     var nx1-nx14;
     priors proportional;

/*
Validate the descriminate function using 10 additional battles.
*/

data check;
     input x1-x14 suc_no @@;
     if suc_no=1 then success='Failure  ';
     if suc_no=2 then success='Stalemate';
     if suc_no=3 then success='Victory  ';
     drop suc_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-0.8568)/0.2317);
     nx6=((x6-48.3333)/31.213);
     nx7=((x7-1.5333)/0.8193);
     nx8=((x8-2.2333)/0.5683);
     nx9=((x9-1.7333)/0.7849);
     nx10=((x10-1.8000)/0.6644);
     nx11=((x11-0.6161)/0.2617);
     nx12=((x12-1.6333)/0.7649);
     nx13=((x13-1.3504)/0.7024);
     nx14=((x14-11206)/10847);
     %include second1;

proc discrim data=info testdata=check testlist;
     testclass success;
     var nx1-nx14;

run;

/*   Part 4.  The purpose of this SAS program is to conduct a
     descriminant analysis on the original 30 battle data set to
     determine those variables that most affect commander
     survival.  Specifically, this program will:
               a.  Input the initial 30 battle data set and
     normalize the input variables.
               b.  Conduct a descriminant analysis using the SAS
     procedure 'proc descrim' based on the two groupings:
                         0 - Commander died.
                         1 - Commander lived.
```

c. Validate the descriminate function using a data base with 10 additional battles.

```
Input the initial 30 battle data set and normalize the input
variables.
*/

data part4;
     input x1-x13 sur_no @@;
     if sur_no=0 then survive='Died    ';
     if sur_no=1 then survive='Lived   ';
     drop sur_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-48.3333)/31.213);
     nx6=((x6-1.5333)/0.8193);
     nx7=((x7-2.2333)/0.5683);
     nx8=((x8-1.7333)/0.7849);
     nx9=((x9-1.8000)/0.6644);
     nx10=((x10-0.6161)/0.2617);
     nx11=((x11-1.6333)/0.7649);
     nx12=((x12-1.3504)/0.7024);
     nx13=((x13-11206)/10847);
     %include first3;

/*
Conduct a descriminate analysis on the initial data set.
*/

proc discrim out=info pool=test pcorr list;
     class survive;
     var nx1-nx13;
     priors proportional;

/*
Validate the descriminate function using 10 additional battles.
*/

data check;
     input x1-x13 sur_no @@;
     if sur_no=0 then survive='Died    ';
     if sur_no=1 then survive='Lived   ';
     drop sur_no;
     nx1=((x1-5463)/6124);
     nx2=((x2-5637)/6064);
     nx3=((x3-529.6333)/6339);
     nx4=((x4-3)/1.3131);
     nx5=((x5-48.3333)/31.213);
     nx6=((x6-1.5333)/0.8193);
     nx7=((x7-2.2333)/0.5683);
```

```
     nx8=((x8-1.7333)/0.7849);
     nx9=((x9-1.8000)/0.6644);
     nx10=((x10-0.6161)/0.2617);
     nx11=((x11-1.6333)/0.7649);
     nx12=((x12-1.3504)/0.7024);
     nx13=((x13-11206)/10847);
     %include second2;

proc discrim data=info testdata=check testlist;
     testclass survive;
     var nx1=nx13;

run;
```

Appendix C: Study Database

1. The following table provides a description of each variable.

Variable	Description
TF Commander Variables	
X1	Commander's distance from forward line of own troops.
X2	Commander's distance from forward enemy in main defensive belt.
X3	Commander's distance from unit center mass.
X4	Commander's activity level.
X5	Commander's survivability.
Battle Description Variables	
X6	Enemy strength.
X7	Terrain observation and fields of fire.
X8	Terrain cover and concealment.
X9	Terrain type.
X10	Equipment type.
X11	Unit rotation experience.
X12	Deliberate attack experience.
X13	Unit proficiency,
X14	Unit mass.
Measures of Effectiveness Variables	
Y1	Friendly forces.
Y2	Enemy forces.
Y3	Terrain objective.
Y4	Loss exchange ratio.

2. The study database is contained on the next page. Note that the gap between the first 30 battles and the last 10 battles indicate the groupings if data splitting was used for verification, otherwise, the entire set was used for analysis.

Table of Values

[illegible]	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Y1	Y2	Y3	Y4
[illegible]	364	617	6574	1	1	19	1	2	2	2	0.6	2	3.9	29948	0.53571	0.47368	0	4.33333
[illegible]	4277	4961	5646	3	1	19	1	3	1	1	0.16666	1	3	15159	0.44047	0.47368	0	5.22222
[illegible]	11713	11362	-7505	5	1	67	1	2	1	1	0.33333	1	2.38271	5224	0.41	0.36158	1	0.92187
[illegible]	8705	7713	-4565	4	1	24	2	2	2	2	0.33333	1	0.83858	1940	0.45263	0.45833	0	4.72727
[illegible]	3012	3055	396	5	1	22	1	3	1	1	0.5	1	0.81021	15270	0.41758	0.90909	1	2.65
[illegible]	1178	2575	4044	2	0.4812	19	1	2	2	2	0.33333	1	1.13148	4662	0.47706	0.89473	0	3.35294
[illegible]	9590	11110	-4602	5	1	39	1	1	2	3	0.33333	1	1.46806	11765	0.32673	0.30769	0	5.66666
[illegible]	13317	14194	-9659	4	0.87421	43	1	2	1	1	0.66666	2	1.46808	2544	0.56603	0.27906	0	3.83333
[illegible]	2142	777	9526	5	0.91093	38	1	1	2	3	0.6	1	1.49160	49153	0.425	0.15789	0	7.66666
[illegible]	2692	2775	5062	3	1	20	2	3	1	2	0.5	1	1.18340	5651	0.55	0.5	0	4.5
[illegible]	5926	1494	463	2	0.60367	51	1	2	1	1	0.66666	2	0.96825	9090	0.55445	0.82352	1	1.07142
[illegible]	7984	1339	3737	3	0.50476	43	1	2	1	1	1	2	0.86005	5705	0.35789	0.93023	0	1.525
[illegible]	5702	5647	2669	5	1	42	1	3	1	2	1	2	1.03963	2785	0.51111	0.92857	1	1.12820
[illegible]	719	1277	4509	2	0.85185	34	1	2	3	2	0.5	1	0.96086	3974	0.48930	0.52941	1	2.66666
[illegible]	4326	4327	4043	3	0.41667	55	3	2	1	1	0.5	1	0.64261	4352	0.28395	0.54545	1	1.93333
[illegible]	1070	2639	4661	3	1	30	1	2	2	2	0.83333	3	2.27464	8141	0.33333	0.5	0	2.93333
[illegible]	691	1768	2830	1	1	40	1	3	4	3	1	3	1.59064	25330	0.60550	0.725	0	1.48275
[illegible]	3369	3331	763	2	1	38	1	3	2	1	0.33333	1	0.79702	3530	0.36448	0.57894	0	3.09090
[illegible]	1776	1628	1359	3	0.45133	103	3	2	2	2	0.8	2	1.13973	6471	0.56122	0.63106	0	0.66153
[illegible]	700	1492	3144	2	1	48	3	2	2	2	0.66666	1	0.86930	3803	0.17167	0.60416	1	1.82758
[illegible]	7553	7546	-636	3	1	64	3	2	2	2	0.33333	1	1.20425	9022	0.34965	0.23437	0	4.6
[illegible]	277	343	1971	1	0.22549	71	2	2	2	2	0.66666	2	1.36016	5539	0.45346	0.33802	0	1.95833
[illegible]	1013	1032	7796	3	1	70	3	2	3	2	1	3	0.82156	11885	0.31147	0.38571	1	1.55555
[illegible]	1610	1253	5786	2	1	69	2	2	2	2	1	3	1.31620	13407	0.45454	0.43478	0	1.6
[illegible]	170	75	5000	1	0.57647	54	1	3	3	3	0.33333	1	1.28125	1432	0.43119	0.14814	0	7.75
[illegible]	832	1023	5879	2	1	36	1	2	2	2	1	3	1.281.5	34154	0.33720	0.81578	1	1.83870
[illegible]	16677	17096	-8114	5	0.8156	70	1	2	1	1	1	2	1.19063	10568	0.23913	0.8	0	1.25
[illegible]	1645	1746	2089	3	1	43	1	2	1	1	0.5	1	1.22457	8136	0.35130	0.16279	0	8
[illegible]	3514	3692	3141	4	1	27	3	3	1	2	0.5	2	0.75257	7167	0.30769	0.70370	0	3.31578
[illegible]	2335	2968	7429	3	1	40	1	3	1	2	0.5	1	1.30416	20164	0.12658	0.5	0	3.45
[illegible]	3863	4226	6574	2	1	25	3	1	2	1	1	1	2.51282	7124	0.35714	0.72	0	3.5
[illegible]	6994	6949	-4777	4	1	28	1	2	3	1	0.4	1	2.34862	2547	0.39563	0.07142	0	19
[illegible]	9443	6972	10596	3	1	66	2	3	2	3	0.83333	2	1.06482	20152	0.46666	0.74242	0	0.97959
[illegible]	7622	[illegible]	[illegible]	4	0.31667	47	2	2	2	1	0.8	1	1.05492	2601	0.44705	0.38297	0	[illegible]
[illegible]	311	[illegible]	[illegible]	1	1	28	2	2	2	3	0.33333	1	0.75257	10147	0.46606	0.85714	0	2.08333
[illegible]	1456	1450	6917	2	0.49763	28	2	2	2	1	0.83333	3	1.58791	39738	0.33734	0.75	1	2.61904
[illegible]	1313	1036	4659	3	1	65	2	2	2	1	0.66666	2	1.58791	12427	0.45763	0.6	1	0.86538
[illegible]	962	1148	1802	1	0.44571	54	3	4	3	3	0.66666	2	1.46606	12178	0.35135	0.5	0	1.77777
[illegible]	22648	22371	-17595	5	1	58	3	1	2	3	0.5	1	1.01766	9095	0.15169	[illegible]	0	[illegible]
[illegible]	16167	16029	-12117	5	1	60	2	2	2	1	0.6	1	1.45236	13603	0.42990	0.7	0	[illegible]

Bibliography

1. Anderson, MAJ Jeffrey W. "The Warrior Spirit," Military Review 53:73-81 (July 1987).

2. BDM Corporation/Army Research Institute Report BDM/ARI-TR-0016-87. A Unit Effectiveness Measurement System at the National Training Center. By James T. Root, and Ray A. Zimmerman, 15 August 1988.

3. Catton, Bruce. Terrible Swift Sword. New York: Washington Square Press, 1963.

4. Chipman, Donald D. "Clausewitz and the Concept of Command Leadership," Military Review 54:27-39 (August 1987).

5. Clark, Colonel Wesley K. "Penetration - Brigade Task Force in the Attack," Military Review 68:38-48 (October 1988).

6. Clausewitz, Karl Von. On War. Editors Michael Howard and Peter Paret. Princeton, N.J.: Princeton University Press, 1976.

7. Department of the Army. Army Regulation 350-50, Combat Training Center Program. Washington, D.C.: 27 May 1988.

8. Department of the Army. "ARI-CTC Archive and Research Center Workshop Notebook." Combined Arms Training Activity, Center for Army Lessons Learned, Fort Leavenworth, KS, September 1990.

9. Department of the Army. Field Circular 101-1, Organizational and Tactical Reference Data for the Army in the Field. Fort Leavenworth, KS: 1984.

10. Department of the Army. Field Manual 22-100, Military Leadership. Washington, D.C.: August 1983.

11. Department of the Army. Field Manual 71-2, The Tank and Mechanized Infantry Battalion Task Force. Washington, D.C.: September 1988.

12. Department of the Army. Field Manual 100-2-1, Soviet Army Operations and Tactics. Washington, D.C.: July 1984.

13. Department of the Army. Field Manual 100-2-3, Soviet Army Troops, Organization, and Equipment. Washington, D.C.: July 1984.

14. Department of the Army. Field Manual 100-5, Operations. Washington, D.C.: April 1986.

15. Department of the Army. Lessons Learned, Vol 88-1. Combined Arms Training Activity, Center for Army Lessons Learned, Fort Leavenworth, KS, 31 January 1988.

16. Department of the Army. Training Circular 25-6, Training With MILES. Washington, D.C.: 30 September 1982.

17. Dillon, William R. and Matthew Goldstein. Multivariate Analysis: Methods and Applications. John Wiley and Sons: New York, 1984.

18. Dryer, CPT David A. An Analysis of Ground Maneuver Concentration During NTC Deliberate Attack Missions and its Influence on Mission Effectiveness. MS thesis, Naval Postgraduate School, Monterey, CA, September 1989.

19. Freeman, Douglas Southall. Lee's Lieutenants Vol. 2: Cedar Mountain to Chancellorsville. New York: Charles Scribner's Sons, 1944.

20. Gause, General Alfred. "Command Techniques Employed by Field Marshall Rommel in Africa," Armor: 62:140-146 (July-August 1958).

21. Hall, George M. "The Faces of Leadership," Army 39:38-49 (June 1989).

22. Henderson, William D. Cohesion: The Human Element in Combat. Washington, D.C.: National Defense University Press, 1985.

23. LaPorte, Leon J. Leadership Succession in the Military. U.S. Army War College. Carlisle Barracks, PA, March 1989.

24. Lempke, Duane A. "Ridgway's Leadership Legacy," Military Review 68:69-75 (November 1988).

25. Marshall, Colonel S.L.A. Men Against Fire: The Problem of Battle Command in Future War. Gloucester, Mass: Peter Smith, 1978.

26. National Training Center, Lessons Learned, Commander's Memoradum, Fort Irwin, CA, 20 November 1985.

27. Neter, John, William Wasserman, and Michael H. Kutner. Applied Linear Statistical Models. Second Edition. Irwin: Homewood, Illinois, 1985.

28. Newell, LTC Clayton R. "Fog and Friction: Challenges to Command and Control," Military Review 54:18-26 (August 1987).

29. Parker, Major Michael L. Battalion/Task Force Command and Control -- Are We Using the "Big Four" Effectively? School of Advanced Military Studies, U.S. Army Command and General Staff College. Fort Leavenworth, KS, November 1988.

30. Roberts, Wesley K. "Razor's Edge of Leadership - Battlefield Leaders for the 21st Century," Military Review 68:2-16 (November 1988).

31. SAS Institute Inc. SAS User's Guide: Statistics, Ver. 5. SAS Institute Inc.: Cary, NC, 1985.

32. Semmes, General Harry H. "General George S. Patton, Jr's Psychology of Leadership," Armor Vol. LXIV:93-109 (May-June, 1955).

33. U.S. Army Armor School. FKSM 17-10-3, Leadership Handbook for the Armor Leader. Fort Knox, KY, January 1986.

34. U.S. Army Training and Doctrine Command. TRADOC Pamphlet 525-2: Tactical Command and Control. Fort Leavenworth, KS, June 1986.

35. U.S. Military Academy. "Leadership in Combat: An Historical Appraisal." Unpublished report. Department of History, USMA, West Point, NY, 1984.

36. Willbanks, Major James H. Airland Battle Tactical Command and Control: Reducing the Need to Communicate Electronically in the Command and Control of Combat Operations at the Tactical level. MA thesis, U.S. Army Command and General Staff College, Fort Leavenworth, KS, May 1984 (AD-B090 215).

Vita

Captain Thomas I. Pratt was born on 4 March 1960 in Wheeling, West Virginia. He graduated from North Allegheny High School in Wexford, Pennsylvania in 1978 and attended the U.S. Military Academy, graduating with a Bachelor of Science in Engineering (concentration: International Relations) in May 1982. Upon graduation, he received a Regular Army Commission, Armor Branch, and served his first tour of duty with the 3rd Infantry Division, Schweinfurt, FRG. While with the 2nd Battalion, 64th Armor Regiment, he served as a Tank Platoon Leader, Mortar Platoon Leader, and Battalion S-3 Air. His second tour of duty was with the 4th Infantry Division, Fort Carson, CO, where he served as the Commander of HHC, 1st Battalion, 8th Infantry Regiment and the Commander of C Company, 2nd Battalion, 77th Armor Regiment. Some of his observations on operations at the NTC are based on first person experience during rotations with both HHC, 1-8 Infantry and C Co., 2-77 Armor. He entered the School of Engineering, Air Force Institute of Technology in August, 1989.

[redacted]