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THESIS

DIRECT FIRE SYNCHRONIZATION

by

Robert W. Lamont

September 1992

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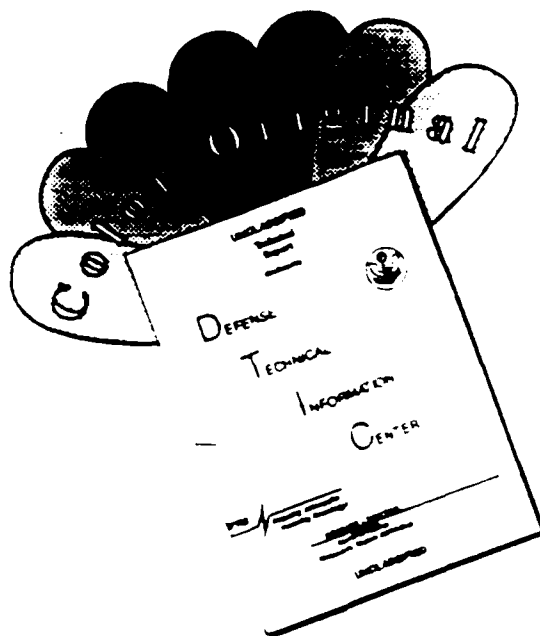
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Direct Fire Synchronization

by

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Submitted in partial fulfillment
of the requirements for the degree

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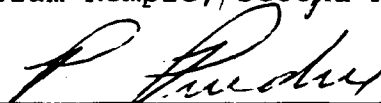   Robert W. Lamont

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ABSTRACT

This thesis analyzes defense in sector missions adapted from the National Training Center and conducted with the Janus(A) high resolution combat model to check for relationships which influence direct fire synchronization. This analysis should enhance the monitoring of unit performance in the area of concentration or massing of fires consistent with the commander's intent. The combat fighting vehicle, which combines the characteristics of mobility with high volumes of firepower, dominates the desert battlefield and is the focus of this study. Graphical methods and analytic techniques are developed to describe the battle in terms of direct fire synchronization and a mission measure of effectiveness (MOE). This research is being conducted under the U.S. Army's Battle Enhanced Analysis Methodologies (BEAM) study, which is developing objective doctrinal AirLand battle measures and visual displays to enhance training analysis. The thesis also describes the training environment of the NTC, defense in sector doctrine for both the U.S. Army and the U.S. Marine Corps with emphasis on asymmetries, and threat offensive doctrine.

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I. INTRODUCTION

A. BACKGROUND

The National Training Center (NTC) is located in the high desert of southern California. Since the establishment of the NTC, in June 1981, the center has been tasked with a twofold mission. First, the NTC is to provide visiting units with the most demanding training environment, short of war, that is consistent with safety limitations. This is accomplished with a dedicated opposing force (OPFOR) whose mission is to emulate soviet style tactics during free-play, force-on-force exercises. Second, data collected from these engagements by an extensive instrumentation array located on both combat forces and the surrounding terrain is to be used to assess unit organization, weapons systems, tactics, and doctrine.

In 1986 a Government Accounting Office (GAO) study stated that the full potential of the NTC had not been realized. It acknowledged that the first objective was being met, but illuminated some shortfalls with respect to the second. These included both an inability to use objective data for assessment of organizations and to obtain solutions to battlefield deficiencies. To help overcome these limitations the study called Battle Enhanced Analysis Methodologies (BEAM) was initiated at the U.S. Army's TRADOC Analysis Command-Monterey (TRAC-MTRY). [Ref 1:p. 2]

The goal of the BEAM program is to develop objective measures of AirLand Battle (ALB) doctrine tenets to resolve deficiencies in the data collection required at Combat Training Centers and improve identification of key performance

weaknesses in the use of tactical AirLand Battle doctrine. The four tenets of ALB doctrine are agility, initiative, depth, and synchronization. The measures developed by BEAM are envisioned as being graphical in nature, to be used in doctrinal training analysis during or after a combat simulation. The underlying concept is to show the warfighter how well the battle is going with respect to the ALB tenets. [Ref 1:p. 3]

The U.S. Army's Janus(A) combat model is a high resolution computer simulation that allows both interactive and systemic operations. Developed by researchers at the Combat Simulation Center, Livermore National Laboratory, Janus(A) is an event scheduling, stochastic model that defines weapon systems as entities. Each of these entities has its own characteristics that defines it within the combat model as a whole. This precise level of modelling allows such factors as weapon capabilities, ammunition and fuel status, and terrain effects, to be represented in a realistic manner. This high fidelity modelling allows Janus(A) to investigate the effects of new weapons and tactics to produce plausible results. [Ref. 2:p. 9]   Janus(A) is used extensively in this research to generate the data required to investigate the issue of direct fire synchronization.

B.   PURPOSE AND SCOPE

Analysis efforts in direct fire synchronization at the NTC have so far been subjective in nature. No formal study has been done on this subject. Observer-Controllers and analysts have recognized shortfalls in unit direct fire synchronization but quantitative analysis of "what happened" to support the study of these trends is

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lacking. [Ref. 18]   This thesis presents a quantitative analysis of direct fire synchronization based on Janus battles using an actual NTC scenario. The goal of this study is to quantify direct fire synchronization performance to assist the unit commander in determining if his forces are complying with his intent and vision of the battle.

The scope of this thesis is limited by the following constraints and assumptions:

o The Janus(A) combat model is representative of actual attrition and battlefield effects.

o Battles were conducted on desert terrain represented by the physical environment of the NTC's Siberia training area.

o The same defense in sector mission was used as the basis for all battles conducted in this research.

o Mechanized forces of both sides were operating consistent with the organization equipment mixes and doctrine employment schemes outlined in the second chapter.

The analysis procedure can easily be extended to other battles, missions, and forces but extrapolation of the analysis results outside the above constraints could lead to false conclusions.

C.   PROBLEM DESCRIPTION AND HYPOTHESIS

Two key problems must be addressed in this research. First, can direct fire synchronization be captured as envisioned by the BEAM project?   Second, what impact, if any, does varying the battlefield in time and space have on direct fire synchronization? The above questions provide the required structure to advance the hypothesis investigated in this thesis.

The following hypothesis will be tested for validity using data analysis: given a task force defense in sector mission conducted with the Janus(A) model under NTC conditions, there exists a relationship between the degree of direct fire synchronization and the mission's outcome. It is further hypothesized that this synchronization is best achieved when subordinate elements are positioned for mutual support and execution is decentralized consistent with the commander's intent. Such a relationship could lead to a quantified task force training standard, that is displayed graphically, for direct fire synchronization in the defense.

A two step approach is utilized to investigate the problems advanced in this study. First, a simulation and data analysis will be conducted to see which tactical parameters, when systematically varied in a scenario, influence the MOE. Parameters that appear to impact battle outcome will then be modelled in such a way that the warfighter will be able to change the input parameters based on his operational scheme. The second step of the study will utilize this model to build a display that graphically shows a unit their synchronization potential level or combat power. This display will include the human factors engineering required to provide relevant combat information to the warfighter.

II. TERRAIN AND OPPOSING DOCTRINES

A. TERRAIN

Because the NTC is used to establish the scenario under investigation, a knowledge of desert terrain and how it impacts the weapons systems of both sides is key to understanding the interactions between tactical parameters in the study. The following are the military aspects of terrain: observation and fields of fire, cover and concealment, obstacles, key terrain, and avenues of approach. Terrain analysis focuses on these factors [Ref 3:p. 4-9].

While observation involves target acquisition systems, both optical and electronic, this paper focuses on horizontal or point to point visibility described by a unit's field of fire. Overlapping these fields of fire is a prerequisite for the concentration of combat power and implies a potential for direct fire synchronization. Line-of-sight on the flat and open areas of the NTC is only interrupted on the slopes, which are cut with wadies formed from drainage patterns of the surrounding high ground. This results in many areas where a weapon's combat power, when positioned correctly, is largely limited only by the maximum range to which it can reach and the accuracy associated with that range. [Ref 4:p.2]

Concealment is protection from observation. Cover is protection from the effects of fire. [Ref 3:p. 4-9] Vegetation is a historical source of concealment for military operations. At the NTC, ground covering is extremely sparse. Available

vegetation is composed of eighty-five percent creosote brush scrub and fifteen percent joshua tree woodland shade scale scrub. Cover for vehicles is limited to wadies and the rolling nature of the valley floor or rock outcroppings. [Ref 4:p.1] The lack of cover and concealment emphasizes the importance of accurate long range fires. [Ref 5:p. 1-1]

Rapid change in elevation is the chief obstacle to mechanized movement at the NTC. The lack of precipitation, four inches on average per year, means there are no permanent water obstacles. [Ref 4:p. 2] Man-made obstacles include minefields and earthworks construction. Limitations on time, lift, and barrier material result in large areas of the battlefield being wide open to movement by mechanized forces. Such an environment is conducive to the concentration of combat power for both the attacker and defender.

Key terrain are those points on the battlefield that provide a marked tactical advantage to the side that controls them. The number of points that constitute key terrain in a desert environment are limited. Choke points or defiles between mountains and hills are areas through which enemy movement can be controlled. High ground has the potential to increase line-of-sight, and in turn, the combat power of units that occupy it. The value of terrain is more likely to be defined in terms of fighting positions for individual vehicles or small units rather than geographic formations on whose control would hinge a battle. [Ref 5:p. 5-1] The focus for desert warfare is the destruction of the enemy. To this end the value of direct fire synchronization takes on additional importance.

National Training Center (South)

N

Terrain

GO

SLOW GO

NO GO
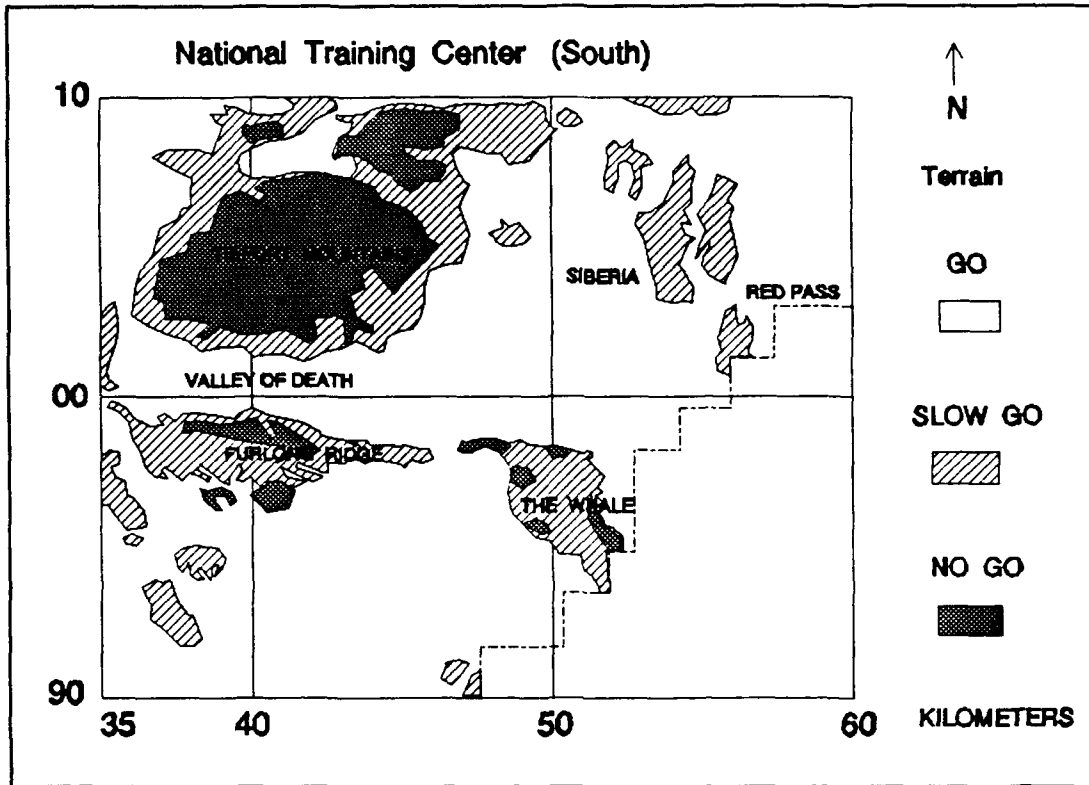
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Figure 1. Scenario Maneuver Areas

Lastly, avenues of approach at the NTC are formed by well defined corridors. They vary in size from a width of six to twelve kilometers and range in length from thirty to forty-two kilometers. The result is a maneuver area that supports the doctrinal styles of both U.S. and soviet-style forces. [Ref 4:p. 2]   Figure 1 shows the southern end of the NTC area where the scenario was conducted.

B.   THREAT OFFENSIVE DOCTRINE

The recent demise of the Soviet Union significantly reduces the likelihood of any direct conflict with them. However, the degree to which they have trained and equipped potential adversaries, notably in the oil rich deserts of the Persian Gulf,

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means soviet-style doctrine remains a threat. This section describes the soviet motorized rifle regiment's offensive doctrine, organization, and tactics used in the NTC scenario under investigation.

Threat forces view offensive operations as the basic form of combat action. Striking speed and force size are considered as the primary mechanisms by which the opponent will be overwhelmed. To implement this on the battlefield, soviet doctrine emphasizes the following operational concepts: rapid concentration and dispersal of combat power, using multiple axes of advance, hitting at weak points, and attacking deep. [Ref 6:p. 2-2] The organizational level at which these concepts are transferred into tactical reality is the motorized rifle regiment.

While the soviet motorized rifle regiment (MRR) is undergoing consistent change, Figure 2 outlines the basic composition of a typical MRR.

This force structure is representative of many of the formations that have been exported to the third world through the proliferation of soviet operational doctrine and of the OPFOR at the NTC. The MRR's principal combat power is located in the 130 Infantry Fighting Vehicles (BMPs) of the three motorized rifle battalions (MRBs), forty tanks, and twenty-four self-propelled howitzers. Tactical employment of these weapons are the means by which soviet operational concepts are achieved. [Ref 7:p. 163]

The following are the fundamentals of soviet tactical thought: aggressive reconnaissance, echelonment of forces, and adherence to march discipline. While reconnaissance is conducted at all levels, for the soviet ground commander division

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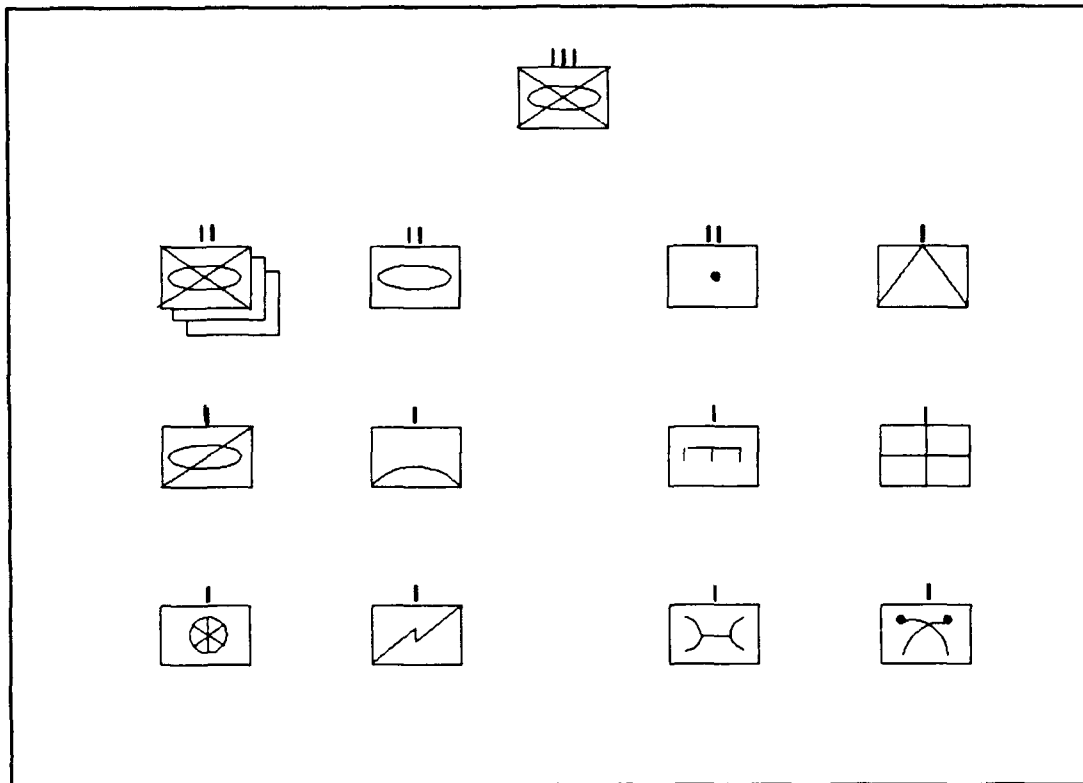
Figure 2. Motorized Rifle Regiment (MRR)

and regimental reconnaissance assets provide a direct means by which the battle is

influenced. A reconnaissance battalion precedes the Motorized Rifle Division by

fifty kilometers. They proceed on multiple routes and rely on stealth to collect

information on the enemy's dispositions. This intelligence forms a basis on which the

regiment can formulate its plan of attack. The regimental reconnaissance company

precedes the advance guard by twenty-five kilometers and uses similar techniques as

the divisional reconnaissance unit. They serve to confirm and update the battlefield

prior to contact with the main attack. [Ref 6:p. 2-4]

The concept of deploying units in echelons is key to soviet offensive tactics.

Echelonment makes it possible to achieve numerical superiority without massing all

the required forces on line. The result is to reduce the vulnerability of the attacker from the effects of nuclear strikes and the improving accuracy of conventional weapons. The first echelon of an attacking unit is normally comprised of two of its component elements reinforced by strong attachments. These two elements then advance abreast to the regimental objective. [Ref 7:p. 24] This concept is illustrated in Figure 3.

The threat, or soviet style force, emphasizes pressuring the enemy by retaining contact with the maximum number of troops. Numerical superiority is counted on by tactical units to permit the second echelon to accomplish tasks that Western units
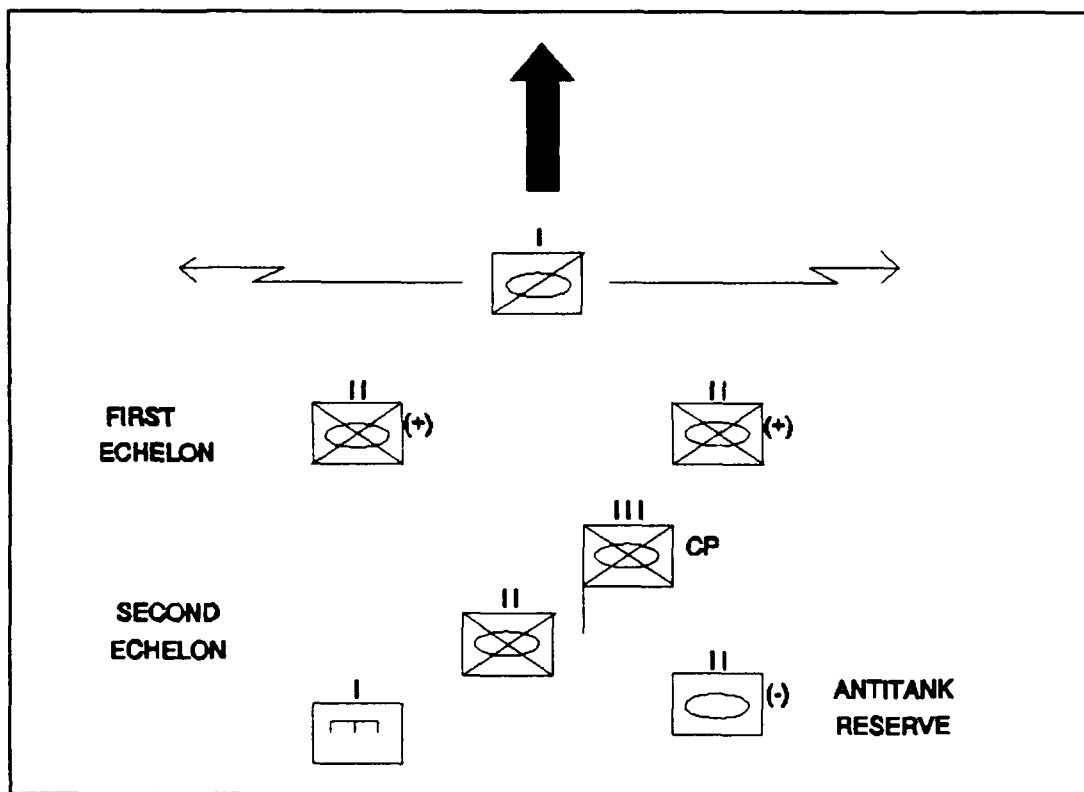

Figure 3. Echelon Attack Concept

would use their reserves for. In general, soviet doctrine uses small reserves whose focus is on anti-tank operations. [Ref 7:p. 24]

By combining the concepts of echelonment and attack frontage, the threat forces are able to achieve the correlation of forces that they view are required to win. A superiority of at least three to one in tanks, six to one in artillery, and four to one in motorized rifle strength is viewed as desirable for the attack. However, if the enemy can be neutralized with fire support, or surprised by maneuver, then these ratios can fall to the point where the threat is outnumbered by as much as three to one. [Ref 7:p. 24] This adds a degree of unpredictability to the threat operational scheme.

March formations and techniques provide the tactical glue by which the MRR commander fights his unit. The regiment is normally organized for the march by reinforcing three rifle battalions with a company from the tank battalion and forming a company size anti-tank reserve. These reinforced units then march along two routes echeloned as described above. The regiment will remain in march formation until forced to deploy laterally into prebattle formation. As the regiment continues to close on the enemy, the commander will elect to push through the opposition in prebattle formation to retain speed, or continue to deploy his unit into attack formation.

If the enemy situation is vague, the regimental commander will task his forward MRB to push forward security elements. This is accomplished by placing a reinforced company five to ten kilometers forward of the battalion. This company will act as a Forward Security Element (FSE). A Combat Reconnaissance Patrol (CRP),

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consisting of a reinforced platoon, is deployed approximately ten kilometers to the front of the FSE. This advanced guard will ensure favorable deployment of the main force once contact with the enemy is gained. [Ref 6:p. 2-4]

If threat reconnaissance elements are able to pin-point the enemy defenses, then the first element to strike the defensive line may be the forward detachment. The mission of the forward detachment is to disrupt the continuity of the defense. This is accomplished by seizing key terrain, a choke point or high ground, on which the defensive positions are situated. Another technique is for the forward detachment to pin elements of the defending force in place to allow the main body to concentrate on a smaller fraction of the defensive line. This concept hinges on the ability of long-range reconnaissance patrols to identify critical targets at which to strike. [Ref 7:p. 56.]

C.   FRIENDLY DEFENSIVE DOCTRINE

AirLand Battle Doctrine (ALB) articulates the Army's method of applying combat power to the battlefield. Combat power is generated by combining the following factors: maneuver, firepower, protection, and leadership. The first two factors are key to direct fire synchronization. [Ref. 3:p. 11]

Maneuver is the alignment of friendly forces which obtains a positional advantage over the enemy. During offensive operations, or while counter attacking in the defense, movement of ground units can be used to achieve positional advantage. However, friendly movement is not a prerequisite to maneuver. In the defense, if the enemy is drawn into a disadvantageous position where friendly fires

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are massed or his attack formation is disrupted, then maneuver is used as a defeat mechanism without ground movement. [Ref. 3:p. 12]

Firepower is the destructive force which is used in removing both the enemy's ability and will to fight. Maneuver can be facilitated when firepower is used to suppress the enemy's ability to counter friendly movement and thus insure a position of advantage is reached. Firepower may also be used independently of maneuver to destroy, delay, or disrupt uncommitted enemy forces. [Ref. 3:p. 12]

AirLand battle doctrine recognizes the following four basic tenets: initiative, agility, depth, and synchronization. The ability to successfully fight under this framework can determine battlefield success. Agility is the ability to act faster than the enemy. Initiative is seen as setting the terms of the battle. Depth is viewed as the extension of operations in space, time, and resources. Lastly, synchronization is the arrangement of battlefield activities in time, space, and purpose to produce maximum relative combat power at the decisive point. [Ref. 3:p. 15-17]

Synchronization includes concentration of forces and fires. The integration of firepower and maneuver is seen as a recurring theme in both Army and Marine Corps doctrinal literature. Such synchronization need not depend solely on the explicit coordination. The commander extends his span of control beyond the physical limitations of his communications architecture by insuring his subordinates understand the intent of his operational plans. In the chaos of battle, if communications fail and face-to-face coordination is impossible, such implicit coordination can provide the vehicle by which synchronization is achieved. [Ref. 3:p.

17] For direct fire forces to achieve concentration, their weapon systems must be able to overlap effective fires. Currently, the maximum range of gun and missile systems is about four kilometers. The width of a zone of attack for a MRR can extend from three to eight kilometers. [Ref. 9:p. 4-55] This means that for a battalion to mass sufficient numbers of antiarmor weapons to defeat a MRR, its defensive sector should not exceed a width that would prevent the concentration of direct fire. Based on these physical limitations of the weapon systems this would allow for a frontage of four to eight kilometers. Thus, it seems that the battalion provides the highest organizational level at which direct fire synchronization is achieved, and as such, is the focus of this study.

While pure battalion organizations are assigned tactical missions, the cross-attachment of subordinate elements between infantry and tank battalions is a fundamental concept that increases mission flexibility. The synergistic effects that result from combining the individual strengths and weaknesses of dissimilar units is one of the ways to increase combat power. The company is the lowest level at which cross-attachment occurs and once complete the resulting organization is referred to as a team. A battalion that is organized for a combat mission is called a task force.

Figure 4 outlines the task organization used by the friendly force in the historical NTC scenario. [Ref. 8:p.12] This organization remains constant during the course of this study. FM 71-123 Tactics, Techniques, and Procedures for Combined Arms Heavy Forces, outlines the doctrinal employment of this task force (TF) during the defense in sector (DIS) mission.

Tm Scout	Tm A	Tm F
Scout Plt	1/A Armor	1/A Mech
2 x Stinger	2/A Armor	3/A Mech
	2/A Mech	3/A Armor
	2/B Mech	Stinger
B Co	D Co(-)	TF Control
1/B Armor	2/D Armor	Hqs Tk Sec
2/B Armor	3/D Armor	A/--- Eng(-)
3/B Armor	1/E AT	1/A/--- Eng(-)
Stinger	Vul Plt (DS)	Hvy Mtr Plt

Figure 4. Blue Force Task Organization

The battalion commander develops his direct fire plan by determining likely platoon battle positions. Forces are placed on the battlefield to insure a good line-of-sight, lateral dispersion, cover and concealment, and mutual support between positions. Once these positions are identified, platoons are combined into company and team organizations to provide for the required command and control. [Ref. 9:p. 4-72]

Fire control is established over TF elements to insure the enemy is engaged on the best terms. Direct fires are oriented on target reference points (TRPs) and engagement areas (EAs) where the commander plans to destroy the enemy. Timing of the engagement can be either centralized or decentralized by using control

measures. Trigger lines allow subordinate elements to fire when the enemy reaches a set point on the battlefield. This means that weapons may start engaging at their maximum range and force the enemy to face concentric and ever-increasing volumes of fire. Another approach to fire control is to hold the opening of the engagement until numerous weapons can fire into the EA. The US Army prefers the technique that draws the enemy into an EA and masses fires simultaneously on him. [Ref. 9:p.4-73]

The Marine Corps on the other hand, when faced with a MRR sized threat, prefers to open the anti-armor battle at maximum range. This concept, which envisions long opening ranges for each class of anti-armor system, is called HAW-MAW-LAW. Each anti-armor weapon (AW) is broken down into a category based on range. Heavy AWs fire at long range, light AWs fire at short range, and medium AWs fill in between the heavy and light systems with some overlapping on each end of the spectrum. The intent of this tactic is to maximize the amount of time available to engage the enemy armor formation. [Ref. 6:p. 14]

III. THE EXPERIMENT

A. THE SCENARIO

The historical scenario being investigated for the purpose of studying direct fire synchronization is a defense in sector mission by an armor-heavy task force. The defensive concept divided the operation into two phases. Phase one is the counter-reconnaissance battle and phase two is the defense in sector. The task force commander's intent was to deceive the enemy as to the primary positions from which he would fight by conducting an aggressive counter-reconnaissance effort. [Ref. 8:p. 10] The goal of this part of the battle is to prevent the OPFOR from using a forward detachment to unhinge the defense by blinding his reconnaissance efforts. If successful it would deny the forward detachment an aiming point. The subsequent OPFOR operating scheme reveals the task force failed to prevent the enemy from finding an objective for the forward detachment.

Figure 5 shows the defender's dispositions for the second phase of the fight. In phase two of the defense the task force commander intended to destroy the enemy in EAs SHARK and PIRANHA. Tm A was to occupy battle position (BP) 22 and orient its fires into EA SHARK. B Co had the mission to occupy BP 24 and orient into EA PIRANHA. If the enemy attack developed in the south then B Co was to move to BP 34 and orient its fires on Red Pass. D Co(-) had the responsibility for occupying BP 25 and orienting its fires into EA Shark. Furthermore, they had an on-
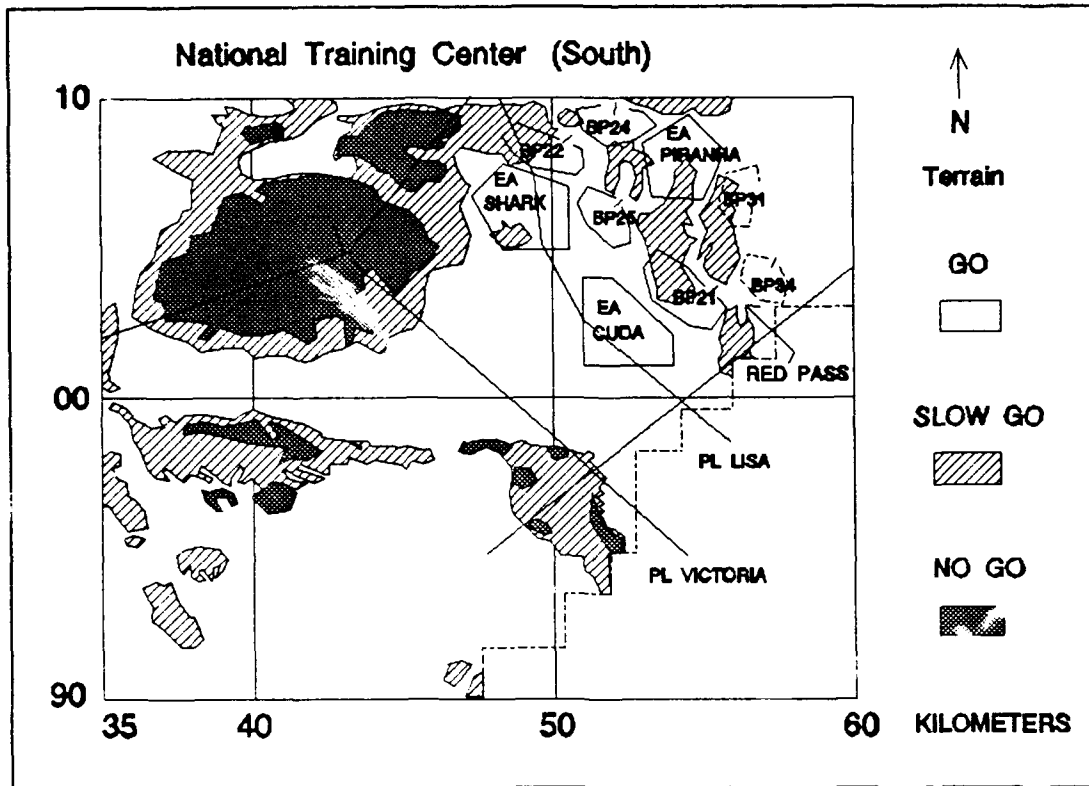
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Figure 5. Blue Force Defense in Sector Dispositions

order mission to redirect their fires into EA PIRANHA. Lastly, if the enemy pushed

through in the south Co D(-) was to reposition its vehicles to the firing line in the

vicinity of EA CUDA and engage the second echelon of the MRR. Tm F was to

occupy BP 21 and orient their fires on EA CUDA. If the enemy attacked in the

north then this team was to move to BP 31 and place its fires into EA PIRANHA.

[Ref. 8:p. 10] The task force commander's intent to destroy the enemy in the second

phase of the defense make this phase key in our analysis of direct fire

synchronization. This is due to the fact that the majority of the direct fire

engagements will occur during this part of the battle.

Figure 6 outlines the key elements of the OPFOR attack plan. The mission of the enemy MRR was to conduct an attack with the purpose of penetrating the forward blue positions, destroy the majority of his combat power, and retain sufficient OPFOR combat power for a follow-on attack. Their concept of operations was to pin the defending enemy in the vicinity of Red Pass with the forward detachment. The MRR main body would then attack the center of the defensive sector to open a hole for the second echelon. Lastly, the following echelon would push through the first echelon and continue moving to their final objective.
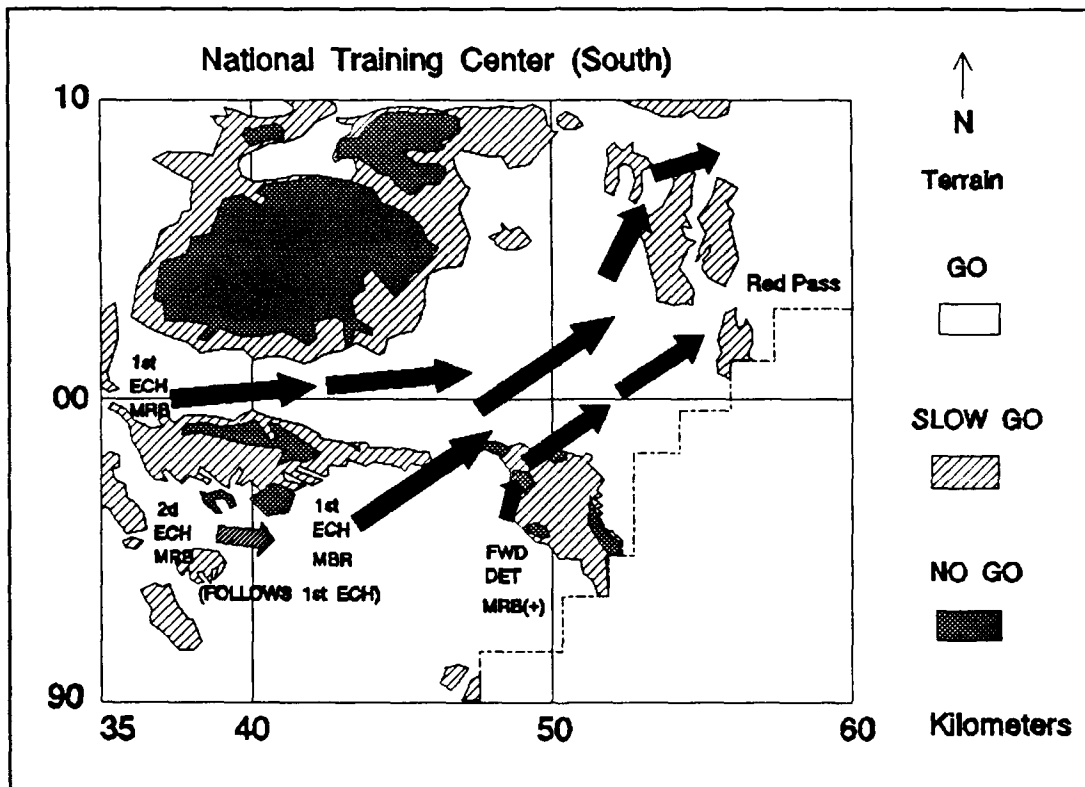

Figure 6. OPFOR Plan of Attack

B. TACTICAL PARAMETERS AND MEASURE OF EFFECTIVENESS

In 1914 F. W. Lanchester formulated two differential equation models for combat attrition under specific conditions. He contrasted a battlefield that was partitioned into a series of one-on-one duels with one in which firers could concentrate on surviving enemy from dispersed locations to generate a many-on-one scenario. The result of this effort was Lanchester's square law of combat which illustrates the advantage of concentrating combat power. [Ref. 10:p. 63] While these combat models are useful in the study of warfare at the aggregated level, and are imbedded in many low resolution simulations, they fail to capture the spatial aspects of the battalion level fight. Tactical parameters were selected to test the concept of concentration of force, and hence the influence of direct fire synchronization, in high resolution simulations where spatial aspects play a role in determining the battle outcome.

Timing the start of the engagement and vehicle positioning are the two key doctrinal factors for effective direct fire. Figure 7 outlines the experiment in matrix form.

Vehicle locations were first run from the historical scenario at the NTC. This became the baseline case against which other parameters could be tested. During these runs it was noted that the initial direct fire battles were conducted by the two companies in the southern half of the defensive sector. It was decided that changes in vehicle dispositions would be limited to these two companies. The goal was to limit changes in direct fire effectiveness to the actual influence of moving vehicle

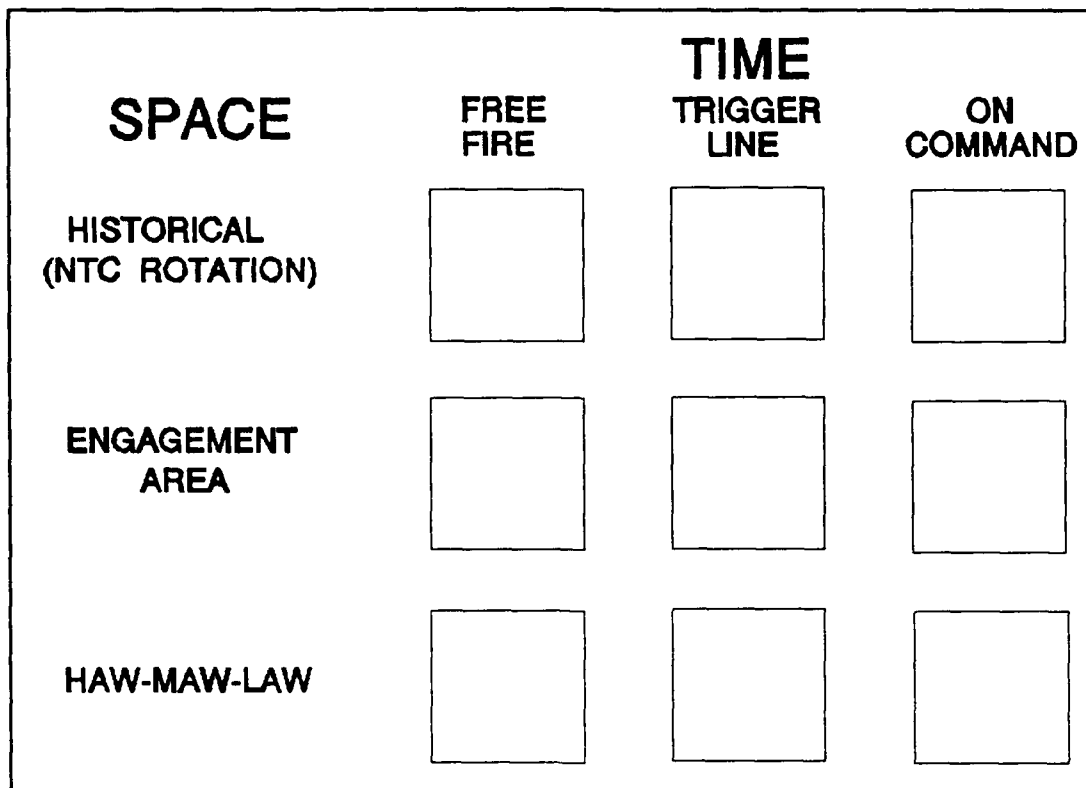| SPACE	TIME		
	FREE FIRE	TRIGGER LINE	ON COMMAND
HISTORICAL (NTC ROTATION)			
ENGAGEMENT AREA			
HAW-MAW-LAW			

Figure 7. Experiment Design

positions and adjusting the engagement timing. This was insured by keeping the localized force ratios constant in the area of first contact.

To further explore the spatial aspects of direct fire synchronization, Army and Marine Corps doctrinal positioning techniques were utilized. The southern two companies were repositioned to focus their direct fire weapons into EA CUDA. The result of this change was a concave alignment of combat fighting vehicles, relative to the OPFOR direction of attack, around the edge of EA CUDA. Lastly, the forces were repositioned in a linear fashion to support the maximum range engagement criteria of the Haw-Maw-Law approach.

Timing of the initial engagement was varied from no control through strict positive control by the battalion commander. The free fire runs allowed the defender to open fire when an enemy vehicle came within effective weapons range. The trigger line, used to evaluate the second timing approach, was Phase Line Lisa or any enemy vehicle that entered EA CUDA. This allowed the southern two companies to fire as independent elements when the situation permitted. Lastly, an on-command technique was tested to see the effects of starting an engagement only in self defense or when directed to do so by the battalion commander.

The tactical parameters for the OPFOR were held constant throughout the experiment. His movement and attack plan, as outlined in the previous section, did not change. His vehicles were kept in a free fire status and allowed to start an engagement at any time the defender was observed within effective range. Again the idea here was to limit the impact of factors outside the parameters under investigation.

To capture the results of each simulation run a measure of effectiveness (MOE) was developed to reflect the degree of direct fire synchronization. Changes in force levels on both sides provide a quantitative method for measuring direct fire synchronization. The more effectively that combat power is applied to the enemy the higher his losses will be. This destruction will in turn attenuate the effects of his direct fires and maximize the number of friendly forces that survive the battle.

The direct fire synchronization MOE is shown below.   It includes the quantifiable

$$BN/TFMOE=(\alpha)\%ENEMYKILLED+(1-\alpha)\%FRIENDLYSURVIVAL$$

mission objectives of enemy force destruction and friendly force survival. The percent

of enemy killed is the sum of the combat vehicles destroyed in the battle divided by

the total starting enemy strength. Friendly survival was found by subtracting the

number of friendly combat vehicles killed in the engagement from the starting total

and dividing by the initial number of combat vehicles. These two aspects can be

weighted by the commander using an α value between zero and one. During this

study, α was set at .5 to equally weight the two goals. [Ref. 11:p. 38]

If run as a "fight-to-the-finish", the attrition results from the scenario tend to

level out as both sides drive each others combat power down toward zero. This in

turn obscures the influence of the tactical parameters under investigation as other

factors, such as the counter-attacking force and non-combat elements, impact the

computation of the MOE. By tracking the temporal direct fire intensity, the battle

can be partitioned into periods of interest. The two key periods, from a direct fire

synchronization point of view, are the combat during the initial contact with the

forward detachment and main body of the MRR. These two key events are

conducted in succession and end at approximately 120 minutes into the Janus(A)

simulation. [Ref. 8:p. 45]   This point in the battle was selected to compute the MOE

for each run. Hence, by limiting the factors external to the experiment, to the

greatest extent that a controlled simulation would allow, the tactical parameters of

the study are reflected in the MOE and statistical techniques can be used to analyze

their influence on the battle outcome.

IV. STATISTICAL METHODOLOGY

A. STRATEGY AND APPROACH TO ANALYSIS

Each Janus(A) simulation run required three hours of run time for the battle to capture the events of interest. This placed a limit on the total number of runs that could be generated for this research. For each of the nine combinations of tactical parameters, five runs were conducted. The resulting killer-victim scoreboards provided the data to tally the MOEs for each experimental cell. They are shown below.

SPACE	TIME		
	FREE FIRE	TRIGGER LINE	ON COMMAND
HISTORICAL (NTC ROTATION)	.6512 .5304 .6527 .6996 .7038	.6539 .6598 .6112 .6277 .5829	.5086 .3701 .4982 .5236 .4751
ENGAGEMENT AREA	.8659 .8917 .8884 .7576 .8567	.8179 .8417 .7631 .7238 .8667	.5329 .7233 .5579 .7762 .6315
HAW-MAW-LAW	.8784 .8917 .8667 .8812 .8831	.8041 .5562 .8443 .8212 .8495	.6226 .6217 .5520 .6079 .5867

Figure 8. Janus(A) Simulation MOE Results

The MOE result from the actual battle data was .3799. Only one of the forty-five simulations runs was below the historical result. This may in part be due to differences in direct fire intensity attributable to human degradation during the battle. [Ref.8, p. 58]   In addition, the simulated battles were stopped after 120 minutes into the battle while the historical engagement was run as a fight to the finish; this increased time available for attrition may account for the lower MOE results during the rotation.

This data will form a basis to test the interaction of the tactical parameters utilizing analysis of variance (ANOVA) techniques. Because ANOVA methodology requires an underlying assumption of homogeneity of variance between cells, the variance of the output, as represented by the MOE, was investigated. Initially, the spread of the MOE was studied using box plots. This in turn was followed by Bartlett's test for homogeneity of variance. If the hypothesis underlying the ANOVA approach fails, then the data will be transformed in an attempt to establish the framework required by ANOVA techniques. Lastly, each of the tactical parameters will be developed to see which positively effect the MOE and if there is any interaction between the parameters of interest.

B.   HOMOGENEITY OF VARIANCE

Figure 9 shows a box plot for each of the experimental cells outlined in chapter three. Each box plot is a visual representation of some statistical attributes of the data, collected during the simulation, as described by the MOE. The length of the box from end to end is the distance between the first and third quartiles or
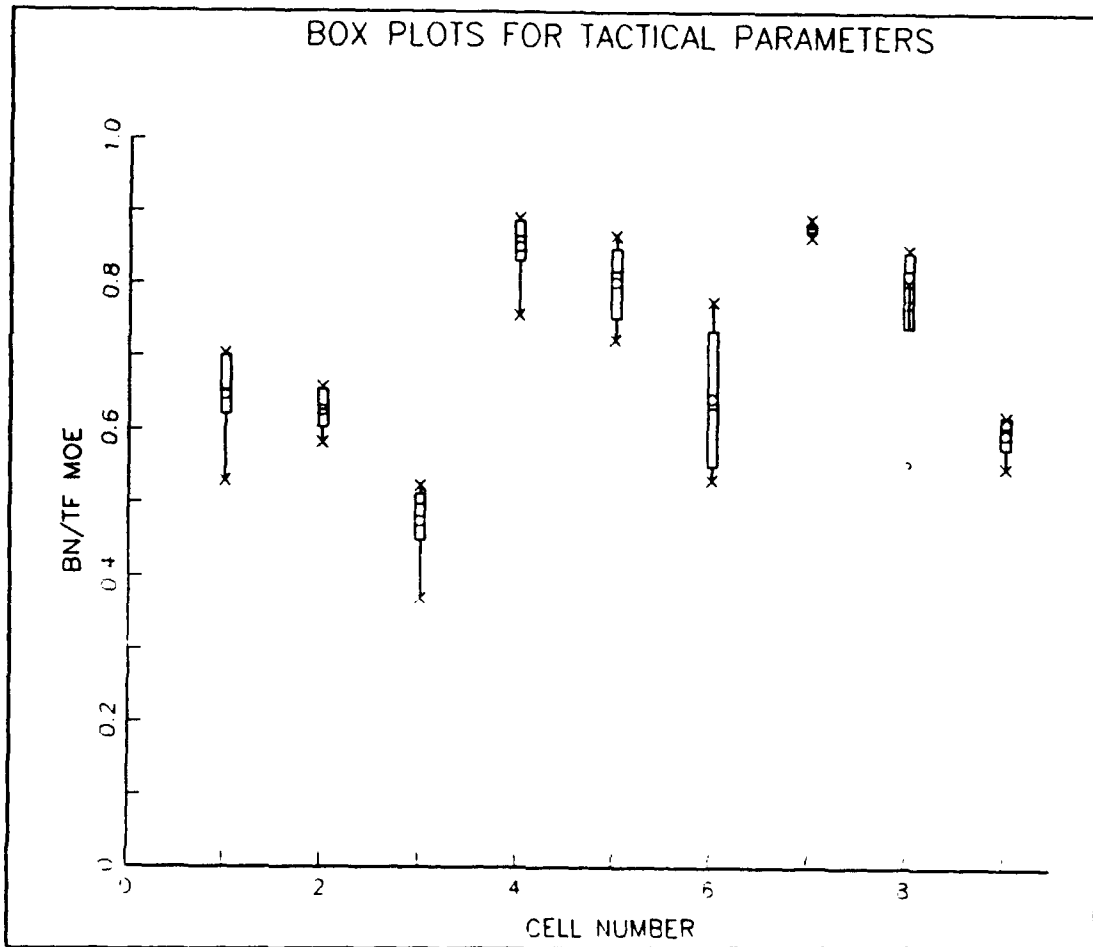
Figure 9. Experimental Cells Box Plots

interquartile range (IQR). The line through the box is the median and the circle within the box is the mean. The Xs above and below the box mark the points at which the adjacent values fall. These points extend as far as 1.5 IQRs beyond the range of the box and must end at a data observation. This explains the folding back effect of cell 8 which is unduly influenced by the single outlier. This point can be seen as the circle below the box plot. [Ref. 17, p. 53.] One drawback to the graphical representation is that only the final outcomes are communicated. Sensitivity to sample size of five observations in the above statistics, is masked in the display.

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The assumption of homogeneity of variance appears to be doubtful when the length of the box plot in cell six is contrasted with that of cell seven. If these two cells are dropped from the analysis, the remaining box plots appear to be roughly similar in size. This suggests a more precise technique be employed to test the hypothesis of equal variance.

Bartlett's test for homogeneity of variance was utilized on the experimental MOE results. This test uses a Chi-Square value, with eight degrees of freedom (number of cells less one). The significance level was set at $\alpha = .05$. [Ref. 12, p. 249] The result of this test was rejection of the hypothesis of equal variance. This rejection led to attempts to transform the data to see if the variance could be stabilized.

DATA/ Transforms	DoF	Chi-Sq Value Bartlett's Test *	Chi-Sq Value Acceptance	Outcome
Original	8	25.56	15.50	Reject
Arcsin	8	23.50	15.50	Reject
SqRoot	8	26.46	15.50	Reject
Log	8	28.40	15.50	Reject
Data less Cells 6 & 7.	6	11.45	12.59	Fail to Reject

Ho: Equal Variance

* Less correction factor.

TABLE 1. BARTLETT'S TEST SUMMARY

The MOE employed must lie between zero and one. The usual transformations for this type of data, to stabilize the variance, include arcsin, square root, and log. First, the arcsin transformation was conducted and while it lowered the χ^2 statistic from 25.56, with the original values, to 23.5 it fell well short of the acceptance level of fifteen. The square root transformation raised the χ^2 value to 26.46. Lastly, the log transform resulted in a χ^2 statistic of 28.4 and Bartlett's test again rejected the hypothesis that the variance was the same across the experimental cells. The attempts to transform the data are summarized in Table 1. Thus, it appears that ANOVA techniques may be used to gain some insights into trends between parameters but the associated statistical confidence limits that these procedures normally provide may not be valid.

The large variability in cell six may partly be explained by the combination of tactical parameters that this cell represents. This cell combines the highest volume of initial direct fire, as represented by the mass achieved with the engagement area technique, with the strictest method of control. The "on command" tactical parameter required that units on a hold fire status be allowed to fire for self defense or when it was deemed that orders from the battalion commander to initiate the engagement were received at the company level. This required manual input from the experiment controller. Human induced judgmental decisions may have increased the variability of these MOE results. Conversely, the very small variance of cell seven is explained by the complete lack of human interaction.
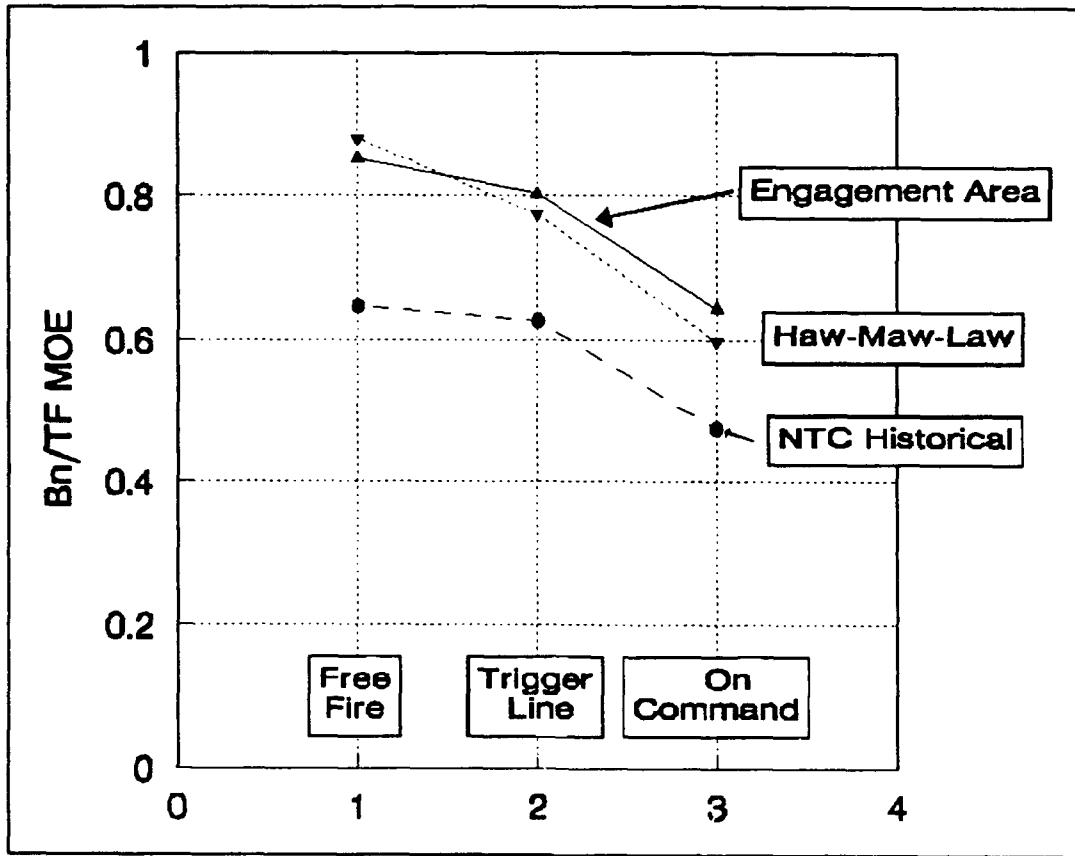
Figure 10. ANOVA Summary of MOE Results

Removing the human element from the process, when coupled with the Haw-Maw-Law positioning scheme, maximized the time available for each weapon system to engage with direct fire.

C. DATA ANALYSIS

The results of an analysis of variance for the experimental MOE are summarized in Table 2. An important development from the ANOVA table is the apparent low level of interaction between the time and space parameters. This is demonstrated graphically in Figure 10. The top two tactical test results tend to parallel the historical scenario which indicates no interaction.

ANALYSIS OF VARIANCE (MOE RESULTS)

SOURCE	DF	SS	MS	F Ratio
Time	2	.3916	.1958	40.79
Space	2	.3094	.1547	32.23
Interaction	4	.0170	.0042	
Error	36	.1729	.0048	
Total	44	.8910		

TABLE 2. ANOVA RESULTS

When analyzing the MOE results in Figure 10 the experimental results seem to indicate that the free fire command and control technique is superior when coupled with any of the positioning schemes. Furthermore, when the free fire technique is not used the engagement area positioning scheme is the preferred approach. Combining the free fire command and control approach with the Haw-Maw-Law positioning scheme is the dominant tactical approach in the experiment. This is evident from Figure 9 as this cell's box plot has the highest MOE value coupled with the least apparent variance.

It should be noted that in the scenario under investigation the actions of the threat were held constant. The Marine Air Ground Task Force Antiarmor operations

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manual (FMFM 2-12) warns that a chief drawback of the Haw-Maw-Law positioning scheme is that early engagements at long range may reveal the defender's operating methodology before his full firepower weight can be brought to bear on the attacker. [Ref. 6, p. 3-13] The MOE from our experiment does not capture any penalty against the defender if he fires early. The visual model of direct fire synchronization needs to incorporate the aspect of firepower density over both space and time.

The last aspect of our statistical analysis is to see if the tactical parameters make a difference that is statistically significant. The strategy will be to use box plots to explore the hypothesis that the parameters have no impact and the medians are equal. Notched box plots can provide a hypothesis test that is sensitive to the number of observations in the experiment. The following formula was used to establish the ends of the notches.

$$Median \pm 1.57 \times (IQR/\sqrt{n})$$

When comparing cell 6 with cell 7, the notched regions were bounded by (.48, .77) and (.87, .89) respectively and failed to overlap. This provides strong evidence that the difference in medians is attributed to the tactical parameters and not random fluctuations of the data. [Ref. 14:p. 62.]

Since the data set failed to conform to the constraint of equal variance required of classical statistical methodology, a nonparametric approach was also used. The MOE outcomes were ranked and an analysis of variance was performed. The results paralleled the earlier ANOVA findings. Table 3 outlines the results from this methodology. The P value for the interaction effects was .1889 and the alternative

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ANALYSIS OF VARIANCE (NONPARAMETRIC)

SOURCE	DF	SS	MS	F Ratio
Time	2	3493.4	1746.7	28.83
Space	2	2358.5	1179.3	42.70
Interaction	4	266.1	66.5	
Error	36	1470.9	40.9	
Total	44	7589.0		

TABLE 3. NONPARAMETRIC ANOVA RESULTS

hypothesis of no interaction was accepted. The zero P values for both the space and timing factors indicated that they are significant and should again be included in our model of direct fire synchronization.

Finally, the issue of which combinations of tactical parameters are statistically superior must be investigated. The strategy was to use a nonparametric approach in pair-wise analysis of the data from experimental cells. The Krusal-Wallis test was selected to check the null hypothesis that the resulting means were equal between cells. A confidence level of α = .05 was utilized throughout this procedure. If this hypothesis is rejected then the level of battlefield performance attributed to these

tactical techniques can be quantified and insight gained as to which operational approach is preferred.

First, the NTC historical positioning scheme was contrasted with the engagement area and Haw-Maw-Law approach. In each test the result was found significant. Either of the doctrinal positioning concepts would have been preferred to those of the historical scenario. This finding suggests that the battalion under investigation would benefit from increased training on the doctrinal employment of their weapon systems. Execution of current tactical methodology would have improved the performance, as defined by the MOE, of the blue force in the NTC scenario.

The engagement area technique was contrasted with the Haw-Maw-Law positioning scheme for each of the command and control procedures. Across the board, no statistical difference in mean MOE performance was detected between the two positioning approaches. Given a simulation in which the threat force scheme of maneuver remains unchanged, the engagement area approach of massing fires for a shorter duration of time was found indistinguishable from the more linear Haw-Maw-Law technique that maximized the time available to employ antitank weapons.

Next, the influence of the various command and control approaches was investigated. In all cases the on-command technique, in which the battalion commander retained strict positive control over the direct fires of the task force, was found to be statistically different from the two decentralized methods. The lower mean MOE associated with this command and control technique suggests that it is

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the least preferred approach for initiating a direct fire engagement. For the engagement area positioning scheme no difference in mean MOE performance was detected when the free fire approach was contrasted with using a trigger line to start the battle. Conversely, with the Haw-Maw-Law tactic the free fire method statistically out performed the trigger line approach.

Thus, our nonparametric analysis has resulted in the identification of three dominant tactical approaches for this scenario. If an engagement area is utilized then either the free fire or trigger line command and control approaches seem to yield good results. On the other hand, if a Haw-Maw-Law tactic is employed then it should be coupled with a free fire command and control technique. This insight supports the original hypothesis of this study that the MOE for direct fire synchronization is maximized when execution is decentralized consistent with the commander's intent.

V. THE MODEL

A. DEVELOPMENT

The main focus of the BEAM project is to produce diagnostic displays that are meaningful to the warfighter. The approach to this problem will be to represent the time and space parameters of synchronization in a graphical display. This display must be ergonomically friendly to the warfighter and require minimal additional training to interpret. A combat potential surface, which models the killing characteristics of the armored fighting vehicles under investigation, can be utilized to show the warfighter areas where the prerequisites of direct fire synchronization have been achieved. This will demand that vehicle combat power is quantified.

Since this display is envisioned as a training tool, intended for inclusion in exercise after-action reviews, it will be a widely disseminated product. This will require the classified probabilities of hit, for various weapon systems, not be utilized in model development. An alternative modelling technique is introduced to insure the combat potential surface is realistic and unclassified.

B. VEHICLE OPERATIONAL LETHALITY INDEX

Because the majority of the MRR's combat power is located in the armored fighting vehicles which are embedded in its organization, the antiarmor lethality of the U.S. Task Force is key to halting their attack. The two main platforms which influence the battle are the M-1 Abrams tank and the M-2 Bradley Infantry Fighting

Vehicle. The principle antiarmor weapons on these vehicles are: 120mm tank main gun, TOW missile, and 25mm Chain Gun. The factors that may influence the combat potential of these weapon systems are outlined in Figure 11.[Ref. 13:p. 83]
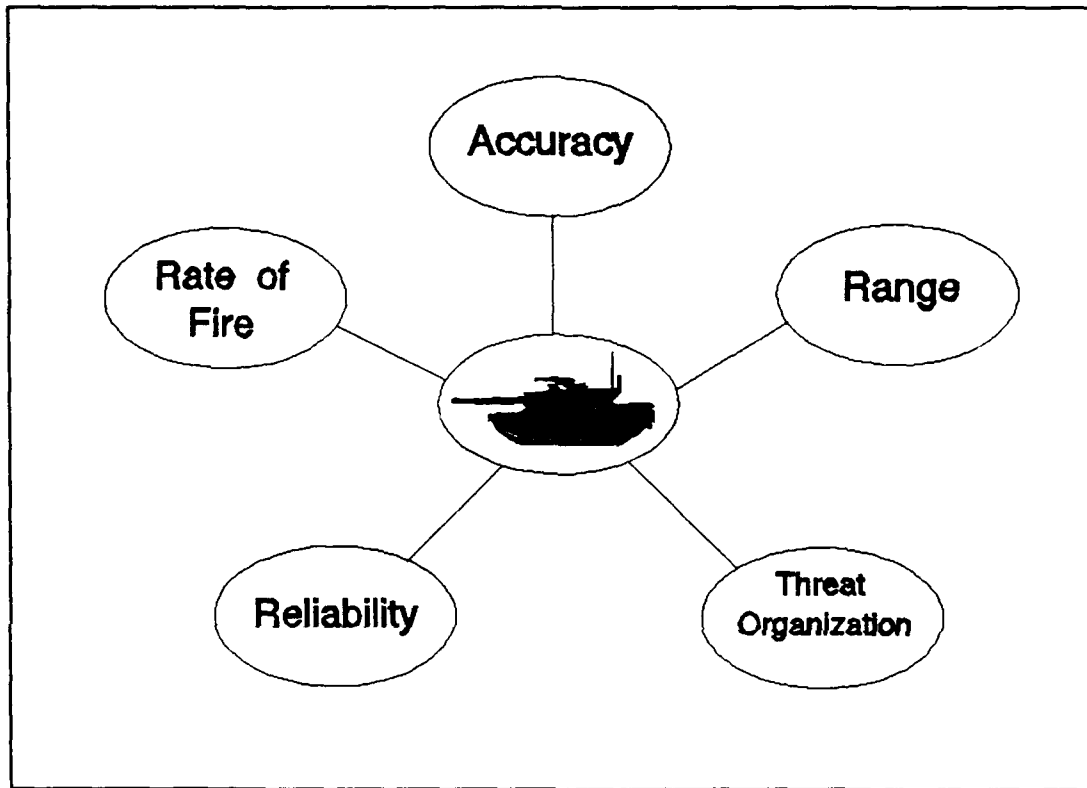

Figure 11. Operational Lethality Index Factors

An Operational Lethality Index (OLI) for each vehicle will be developed to model it's ability to inflict damage. The OLI will reflect the expected number of vehicle kills from our antiarmor weapons in a one minute period. This method will serve to add the time parameter to the combat potential surface.

The strategy to develop the OLI is to explore the factors in Figure 11. Reliability of the weapon system is a constant and will influence the number of rounds fired. Because it is a constant the net effect on our combat potential surface

would be to lower it by a uniform height. Given our small time interval of one minute the likelihood of failure is very small and this aspect of the model will not be developed further. Apart from reliability, the armament of tanks and APCs have distinctive characteristics.

When modelling the traits of combat fighting vehicles the asymmetries of guns versus missiles must be included. Figure 12 outlines the general concept of the gun-missile paradox. Characteristics of both guns and missiles will influence the combat potential surface.
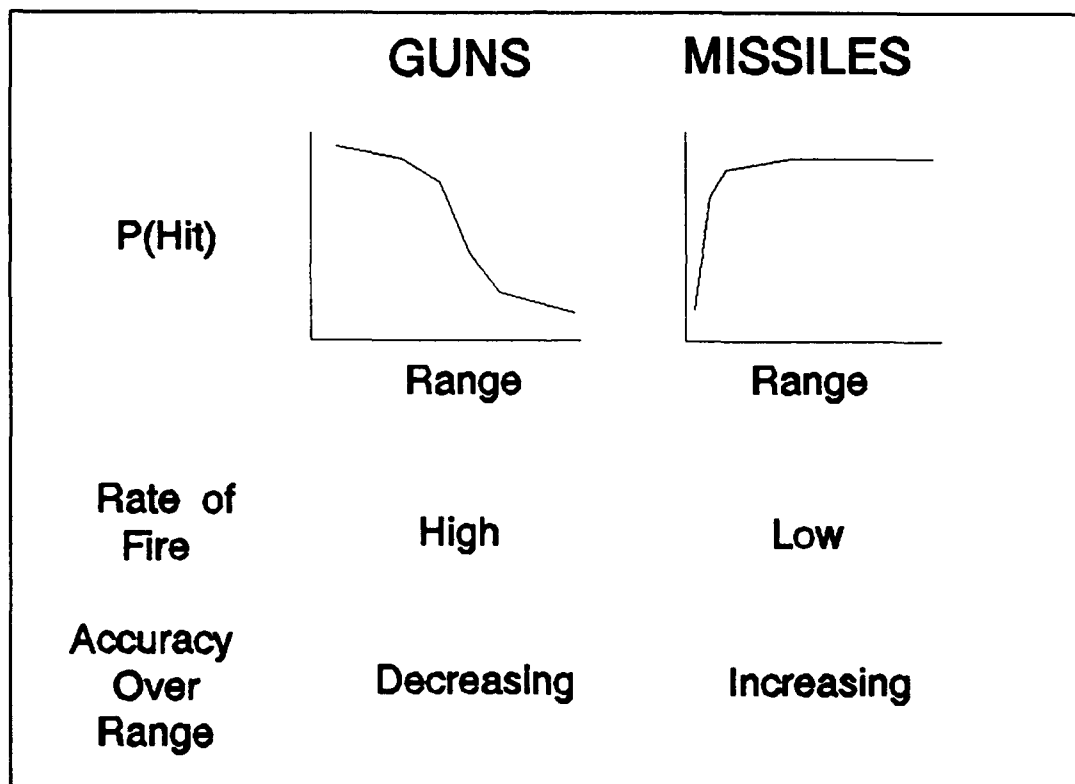

	GUNS	MISSILES
P(Hit)	Range	Range
Rate of Fire	High	Low
Accuracy Over Range	Decreasing	Increasing

Figure 12. Gun-Missile Paradox

The number of rounds that a tank can fire at an armored target in one minute interval is fairly constant. This is driven by the fact that the main gun is used to destroy vehicles with either light or heavy armor. By changing ammunition types the tank may use its main fire control system in each of the engagements. The physical characteristics of these 120mm rounds are so similar that their handling time in battle is basically the same. The tank rate of fire is set at three rounds per minute, accounting for reload time, the interval of time for dust to settle between rounds, and gunner lay adjustments. These conditions do not hold for the APC.

Both the M-2 Bradley and the BMP-2 are equipped with a dual main armament. Each APC carries a heavy anti-tank missile and a rapid fire cannon. This combination produces the ability to kill both heavily and lightly armored vehicles but at different rates, with the two different weapons. This makes the employment times of each weapon dependent on the types of targets on the battlefield. It is assumed that each gunner will use anti-tank (AT) missiles when firing at tanks and reserve his cannon fire for APCs. This aspect of the model is captured in threat organization (T/O) factors that are used to adjust the lethality of APCs.

The following example is used to explain the concept of the T/O factors. Figure 13 is the micro battlefield for this discussion. Both heavy and light armored targets approach a Bradley platoon in the defense. The type of target density will determine, in an aggregated sense, the amount of lethality the platoon collectively discharges from its two weapon systems. Since two of the ten attackers are tanks, the TOW missile will add twenty percent of its lethality to the combat potential surface.
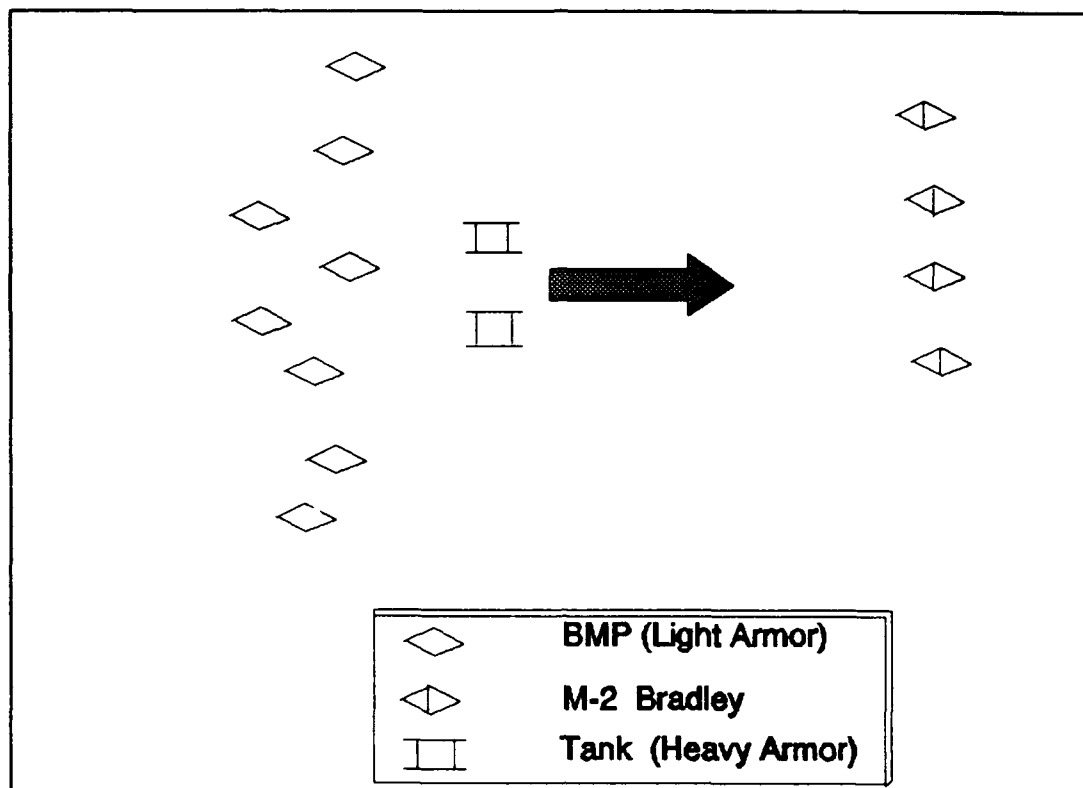
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Figure 13. Threat Organizational Factors Example

The other eighty percent of the Bradley's lethality will be delivered by their chain guns. This procedure precludes double counting of expected kills in the one minute time interval by preventing an APC from simultaneously adding both tow and chain gun lethality for the full period.

For the model these T/O factors were found by dividing the number of tanks in the MRR by the total combat fighting vehicles in the regiment. This yielded a fraction of .29 for the contribution of TOW lethality to the combat potential surface. AT missiles were given a rate of fire of one per minute which accounted for the time required during firing, tracking, and reloading.

A similar approach was used with the chain gun. If a Bradley was not firing at a tank, then the chain gun would add seventy-one percent of its lethality to the combat potential surface. Because the chain gun produces less of a dust signature when firing than a tank, its rate of fire will tend to be higher. This accounted for the ability of the chain gun to rapidly re-engage a target and apply burst-on-target techniques to walk rounds onto the enemy. Each APC was considered able to deliver four bursts per minute of well aimed fire with their chain gun.

The range and accuracy factors of the vehicle's weapon systems combine to form the probability that a target is hit and killed. This is explained as the probability of a kill given a hit times the probability of a hit. A kill is defined as sufficient damage to remove a vehicle from further influencing the battle at hand. Since we have assumed gunners will use the correct type of ammunition against the target, the likelihood of a kill given a hit is essentially one. This conclusion rests on the fact that, while a vehicle may survive a hit, damage to the combat subsystems of fire control and boresighting, communications, and the track mobility mechanisms will render it not repairable before the battle will end. This result allows the model to focus on the probability of a hit to capture the factors of accuracy and range. Because probability of hit data is restricted another approach was required to model this aspect of the OLI.

Seth Bonder proposed one method for attenuating Lanchester attrition coefficients over range using the formula below:

$$a(r)=a_o \times (1-(r/Rmax))^\mu$$

with a(r) being the Lanchester coefficient for the current range r. [Ref. 10:p. 5-6] a_0 is the maximum value of the attrition coefficient at point blank range. The part of the equation in parenthesis and raised to the power μ accounts for the range effects and serves as an unclassified probability of a hit in the model. Rmax is the maximum employment range of the weapon system. μ is used as a shaping constant to fit the probability of a hit curve to the characteristics of each main armament. This method is currently used in the VECTOR series of combat models. [Ref. 10:p. 91.]

The end points of each curve are based on the technical characteristics of the weapon. The shaping coefficient is then fit to the range at which the probability of a hit is fifty percent, information which is available in unclassified form. For gun weapon systems this approach worked well to capture the effects of decreasing probability of a hit over range. Figure 14 portrays this approach for the M-1 tank.

Missile systems required a modification to the Seth Bonder equation. When a gunner fires a missile, the back blast and violent launch of the projectile briefly interrupt the tracking process. This period of gunner dazzle lasts approximately one to two seconds. During this time, the missile is traveling down range at two hundred meters per second. When the effects described above are combined with the warhead's sixty-five meter arming distance, the result is a dead zone around the
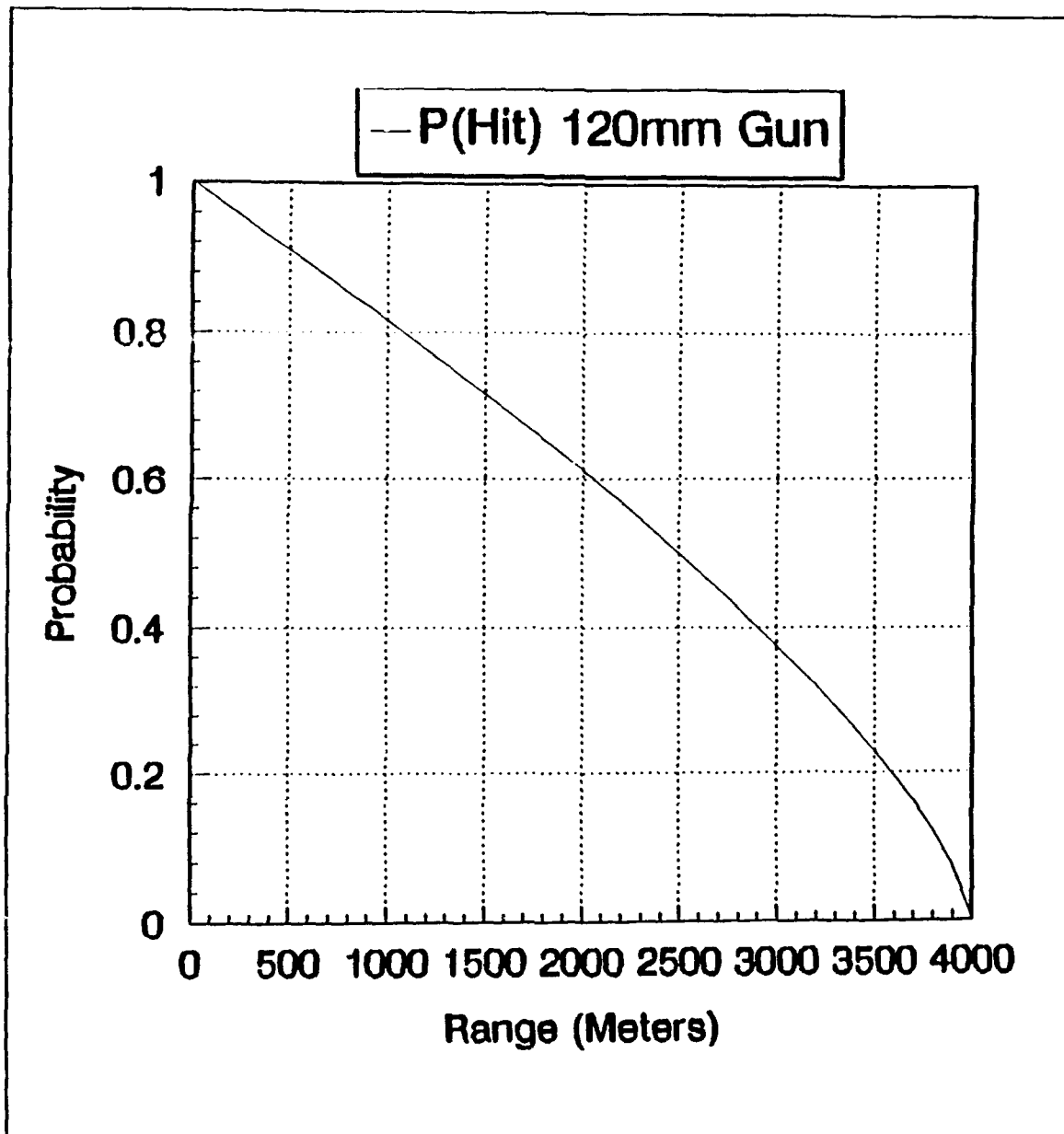
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Figure 14. M-1 Tank P(Hit) Curve

point of missile launch. This effect disappears as the missile moves away from the gunner and normal tracking is resumed. To capture these battlefield effects, the following change was made to the Seth Bonder equation:

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$$a(r)=a_o-a_o\times(1-(r/Rmax))^\mu.$$

The hit probability curve for the TOW missile is shown in Figure 15, with a_o = .9.

The final operational lethality index is:

$$OLI=(RoF)\times P(Hit)\times(T/O).$$

This value is summed for all combat vehicles that have line-of-sight to a given location on the ground to define the combat potential surface. As the height of the combat potential surface increases so does the ability of the task force to synchronize their fires. Whether this combat potential is realized or not may depend on factors external to this study.

C. THE DISPLAY

The use of visual displays to present statistical information is not new. The eye-brain system is the most sophisticated information processor ever developed, and through graphical presentation we can gain insight into the structure being studied. Large volumes of information can be conveyed with graphs since the eye-brain system can summarize information quickly and extract the key features. [Ref. 14:p. 1] The visual display technique is an effective method for communicating the patterns and relationships inherent in the spacial aspects of direct fire synchronization.

Since the BEAM project is geared to providing the warfighter with a usable product, it is the warfighter who became the focus of our visual display design. Effective visual displays have the following properties: visibility, distinguishability, and interpretability. Visibility means insuring all critical elements are seen.
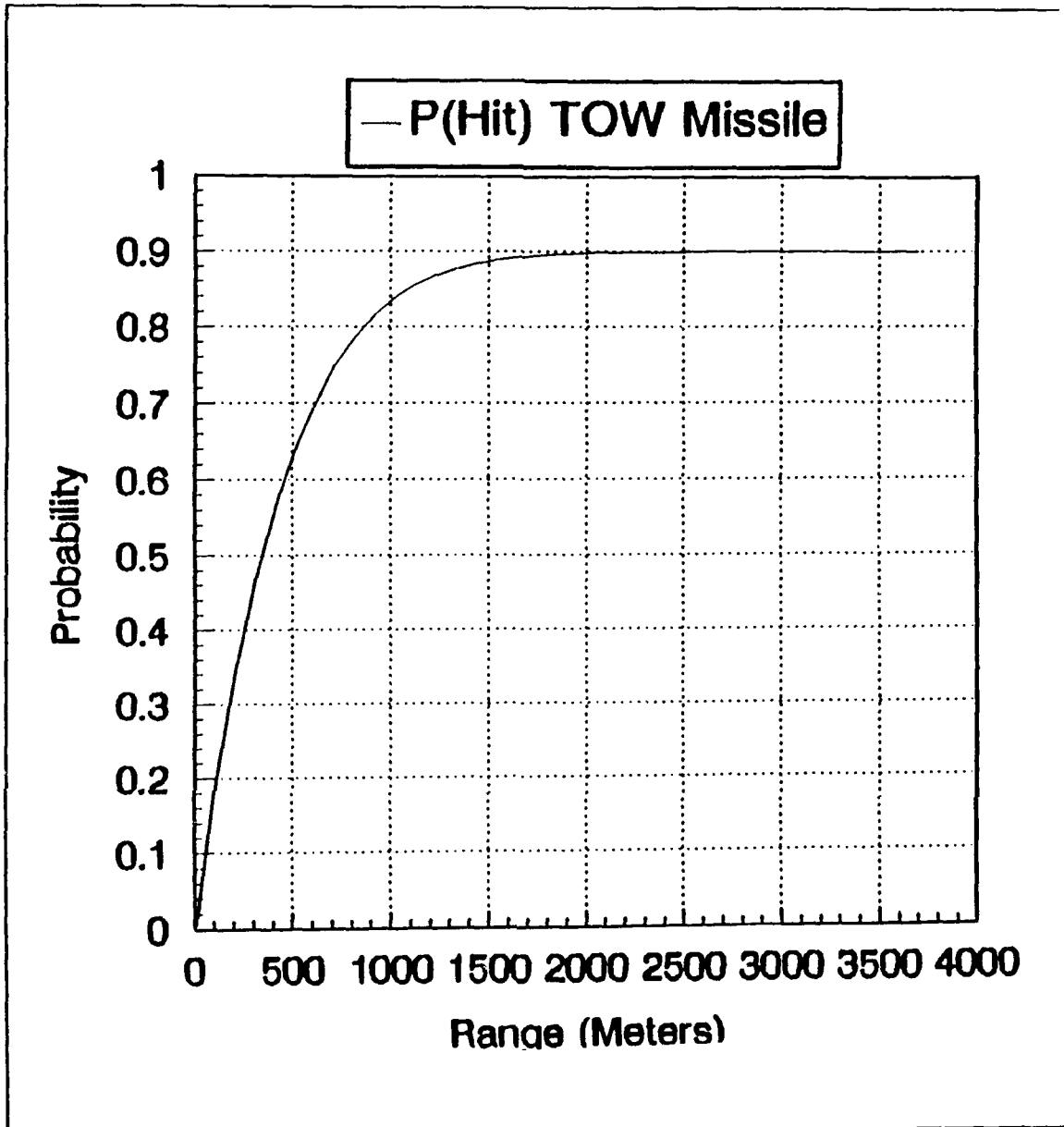
44

Figure 15. TOW Missile P(Hit) Curve

Distinguishability provides that all elements of the display can be separated. Interpretability means the parts and symbols of the display can be understood. [Ref. 15:p. 205] Interpretability is enhanced when information is placed in a frame of reference familiar to the user.

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The frame of reference which is most accepted to communicate information about military operations is the map. All warfighters receive map training during their entry level programs and are comfortable with this medium. A map of the area of operations, overlaid with a grid system of measurement, will provide the backdrop to the display. This will provide the warfighter directly with the range parameter developed in the model. The time parameter will be introduced by taking "snap-shots" of the battlefield during the engagement. The battle can then be animated at different points in time to depict direct fire synchronization. The third aspect that the visual display must show is the height of the combat potential surface.

The general concept for displaying the combat potential surface is illustrated in the two pictures of Figure 16. The picture on the left shows the three dimensional nature of the combat potential surface. This surface is based on combining vehicle position, the OLI, and line-of-sight (LOS) considerations. The resulting formula for the Z axis is:

$$Z = \sum_{units} OLI(x,y) \times LOS(x,y).$$

LOS serves as an indicator variable to turn on and off combat power based on whether or not a vehicle can engage a specific point. The picture on the right shows the combat potential surface presented in contour form. The small circle is the top, or high value of combat power, which radiates downward over range. This display will be come the visual medium for communicating the model output with regards to combat potential or direct fire synchronization.
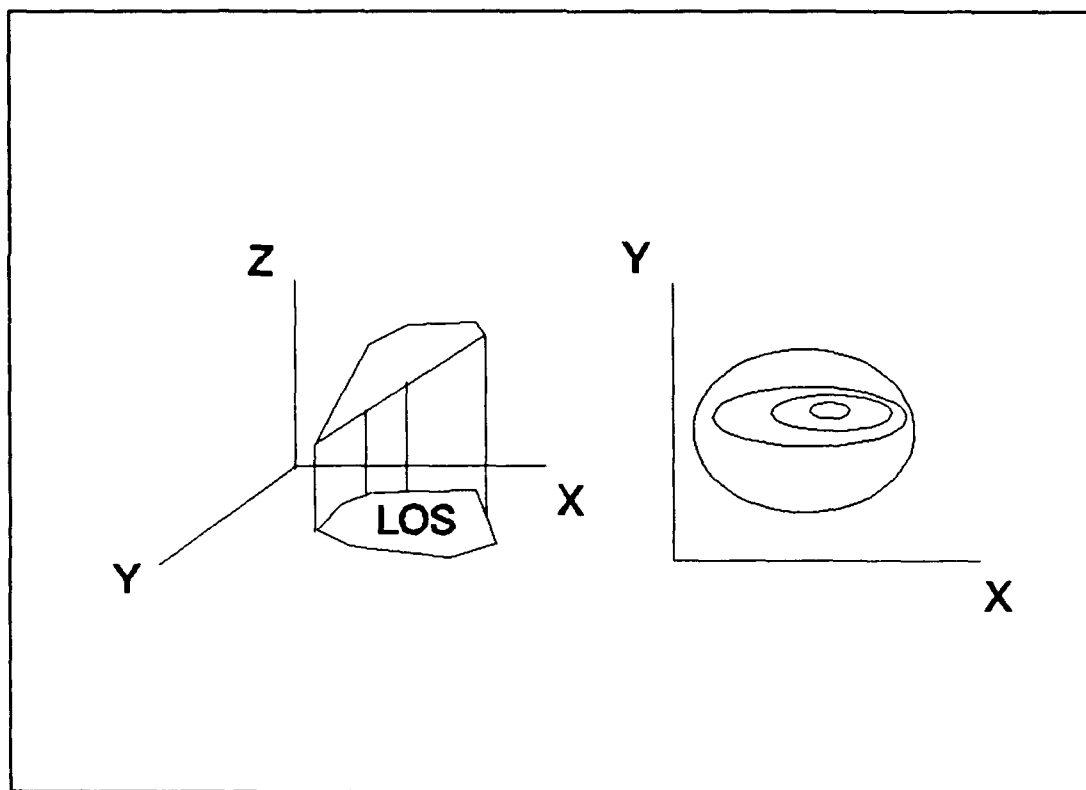
Figure 16. Combat Potential Surface Concept

The information presentation technique of small multiples uses a single display format and updates the data for repeated images. Since the map will remain the same over the period of animation a similar approach may be utilized. Once the warfighter has decoded the initial data design, he will only have to adjust his perception to the changes in the combat potential surface to comprehend his current level of direct fire synchronization. The use of small multiples works as an efficient summary of data by providing the decision maker with complementary variations of the major substantive theme. [Ref. 16:p. 30]

The problem that the display must overcome is translating the three dimensional combat potential surface onto a two dimensional presentation media.
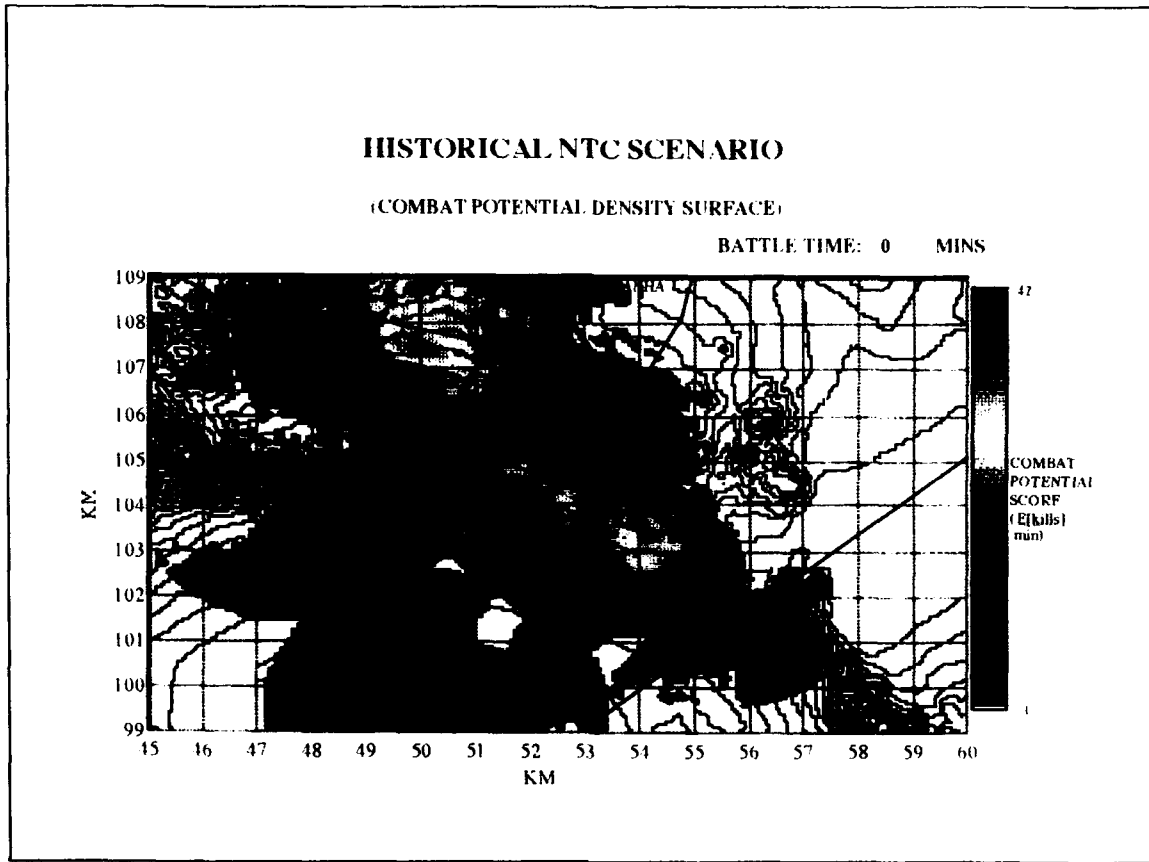
HISTORICAL NTC SCENARIO

(COMBAT POTENTIAL DENSITY SURFACE)

BATTLE TIME: 0 MINS

Figure 17. Historical Scenario at Start

Color can be an important channel for conveying information. It has been shown that the use of color in a display can reduce visual search time by fifty to seventy percent and increase accuracy at the same time. [Ref. 16:p. 216] The presentation problem is overcome by contouring the combat potential surface based on a color scheme. The warfighter's familiarity with elevation contours on a map provides a starting point for this approach. Theories of vision show that the human cognitive processing gives considerable and decisive weight to contour information. [Ref. 16:p. 94] Lastly, a familiar frame of reference was used to color code the contours. Red is used to show hot areas with a large volume of direct fire. Conversely, blue represented the

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cool areas where combat potential is low. Green and yellow are used as transitional links between these two extremes.

The assignment of color to the combat potential surface was tied to the synchronization requirement for the battalion. The task force is attempting to overlap the killing potential of the subordinate company/teams. If the commander is successful in his positioning scheme then the effective combat power of two teams will range the same area where he intends to destroy the enemy. For this study, effective combat power is defined as half of the total expected kills that a company potentially could inflict in a one minute period. This resulted in an upper bound on the coloring scheme of forty-two. The red and yellow areas show battlefield locations where the expected killing potential of two companies are massed. The blue and green areas represent points where the battalion can inflict damage on the enemy, but only one company's killing potential is present. This implies that the prerequisite conditions for direct fire synchronization have not been established at the battalion level.

The final key component of the display is the operational overlay of the battalion's defensive plan. This uses common military symbols, found in the doctrinal literature, to visually show the commander's intent of how the battle will be conducted. The contours of the combat potential surface will show if direct fires were allocated within EAs according to the battalion commander's plan. This display can serve as a key tool in the after-action review process to help commanders, at all levels, visualize how well their elements performed direct fire synchronization.
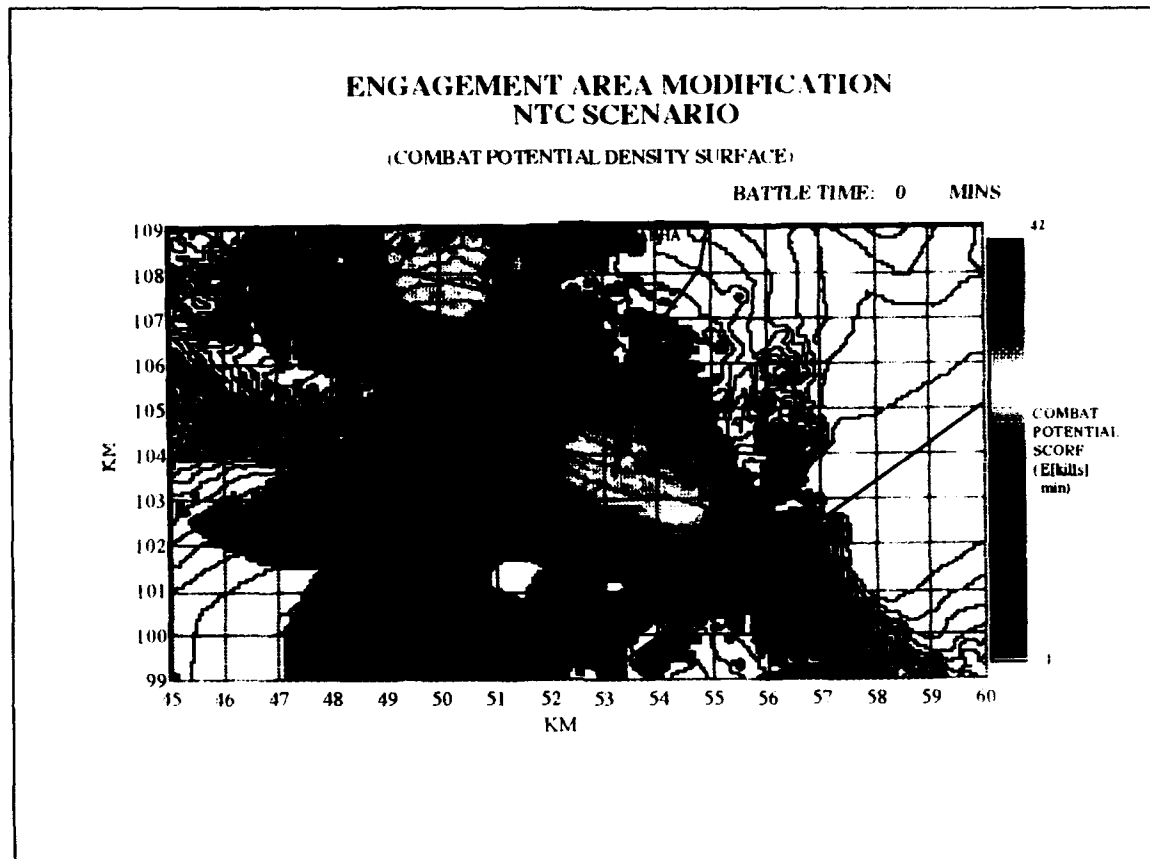
Figure 18. Engagement Area Positioning Scheme at Start

Figure 17 is an example display based on the initial positions of the NTC

historical scenario. It shows that the task force had massed some fires in EA Shark

and to a lesser extent overlapped a few areas in EA Cuda. When this is contrasted

with the engagement area dispositions, Figure 18, it is seen that the repositioning of

vehicles can greatly increase the combat potential in EA Cuda. The nature of the

Haw-Maw-Law approach is captured in Figure 19. While some massing of fires is

achieved in EA Cuda, the increased width of the green band running across the

battlefield is representative of the piecewise linearization of combat power associated

with this technique. While these diagrams show some minor differences in the

HAW-MAW-LAW MODIFICATION
NTC SCENARIO

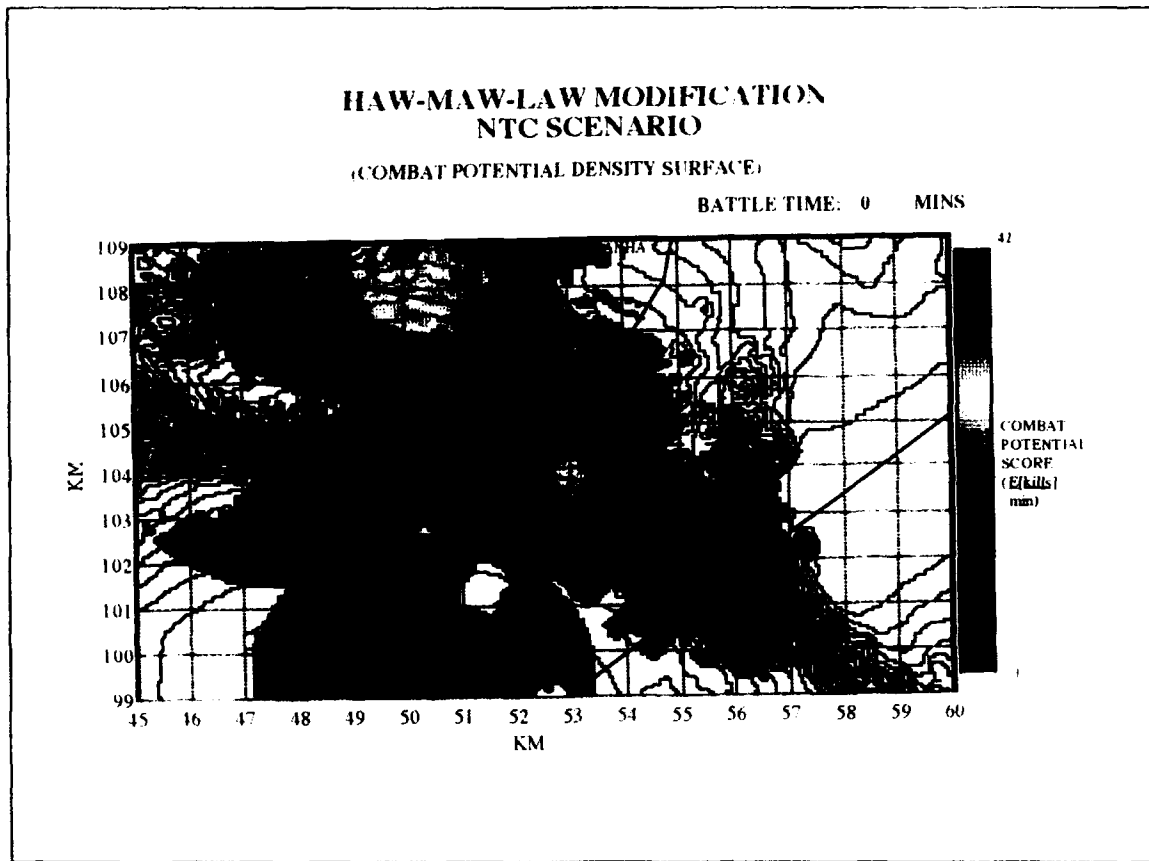(COMBAT POTENTIAL DENSITY SURFACE)

BATTLE TIME: 0   MINS

Figure 19. Haw-Maw-Law Approach at Start

relative synchronization of fires they do not appear to account for the statistically

different MOE results noted in Chapter IV.

The increment was updated for these three cases to 120 minutes into the battle.

Figure 20 now shows the combat potential status under the historical positioning

scheme. Nowhere on the battlefield are the fires of two companies overlapping. In

the center of the task force holes have been opened by the OPFOR first echelon.

These are shown as white areas on the north side of EA Cuda. At this point in the
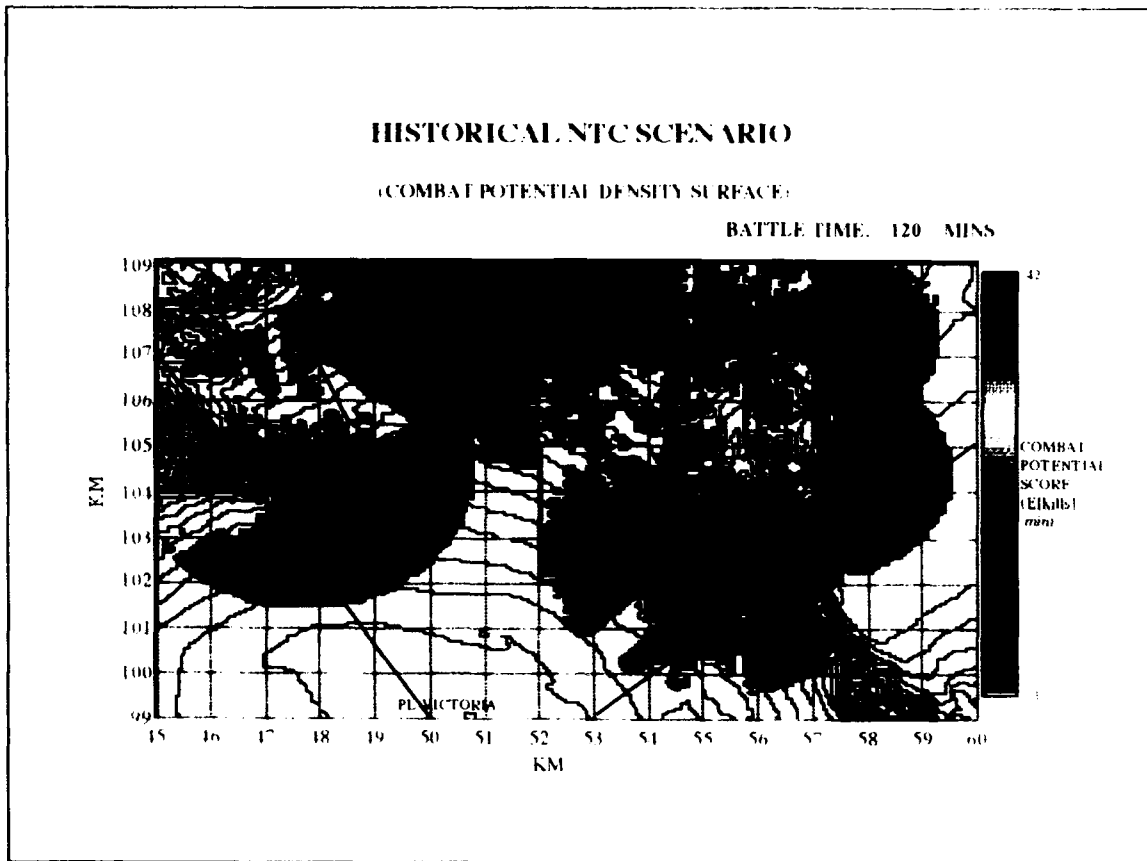
Figure 20. Historical Scenario at 120 minutes

engagement the enemy has destroyed the counter-reconnaissance forces from the southern end of the sector and is well on his way to passing the second echelon through the defense.

Contrast this situation with the engagement area positioning scheme, in Figure 21, at 120 minutes into the battle. In this case the synchronization in EA Cuda has been maintained as indicated by the bright band running through its center. Depth has been added behind EA Cuda as forces repositioned from EA Shark. While the enemy has been able to roll back counter-reconnaissance forces as before, he was unable to force his way across EA Cuda.
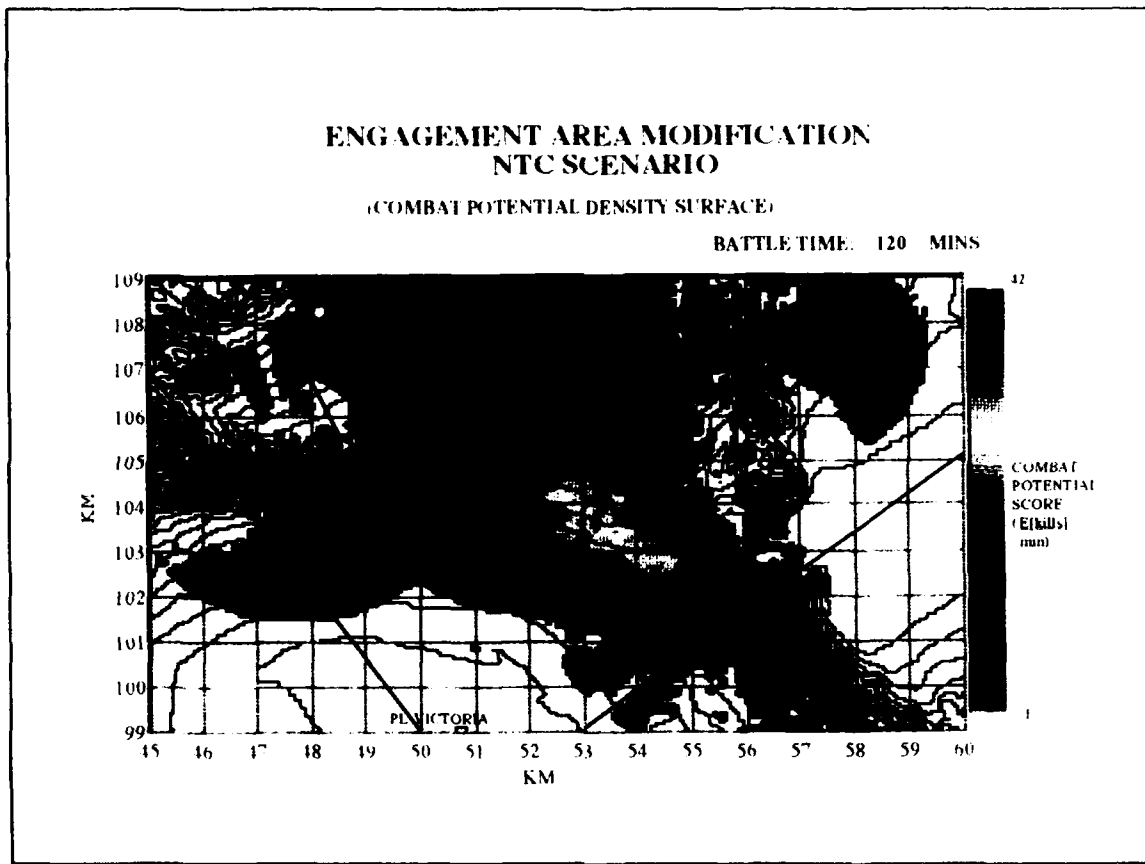
Figure 21. Engagement Area Scenario at 120 minutes

Lastly, Figure 22 shows the end game position for the Haw-Maw-Law approach.

While the level of direct fire massing in EA Cuda is somewhat less than the

engagement area scheme, the two figures look very similar. This was reinforced by

the statistical analysis in chapter four that could not differentiate the MOE results

for these two tactical approaches. Since the starting points showed the Haw-Maw-

Law tactic as having a lower combat potential then the engagement area technique,

how can the two tactical approaches finish with similar results? The answer is with

the different command and control approaches used. Since the free fire technique

was coupled with the Haw-Maw-Law approach, this resulted in a lower level of
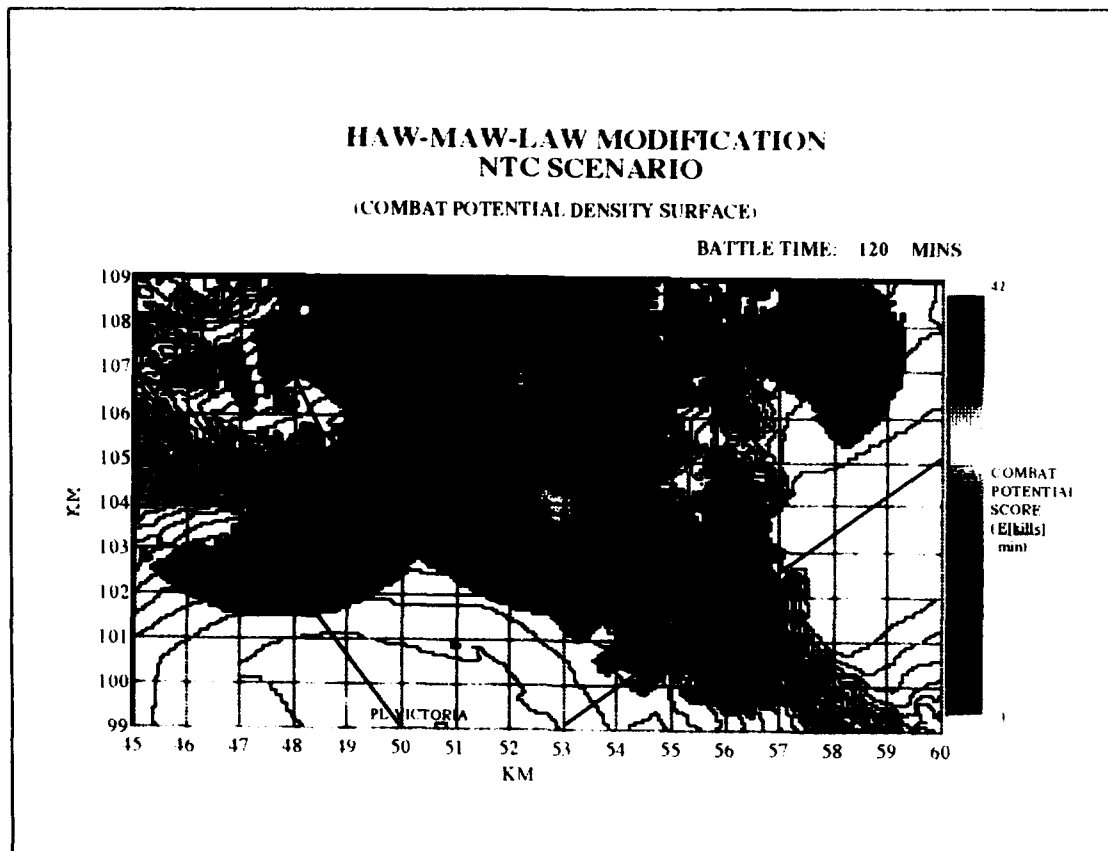
Figure 22. Haw-Maw-Law Scenario at 120 minutes

combat power applied against the enemy for a longer period of time. Conversely, the use of a trigger line with the engagement area provided a high volume of fire, but it was delivered for a shorter duration. The net result was very similar outcomes.

D. MODEL ANALYSIS

The last aspect of this thesis asks the question, does the model provide any insights into the tactical parameters? The command and control parameters have investigated the effects of opening the engagement at various ranges based on the degree to which the control of direct fires were centralized. Before opening fire, as the distance to the enemy decreases the probability of a hit will increase. Once the

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battle is joined, the dynamics of the engagement will rapidly alter the static dispositions on which the defense is established. The key point to discover then, is at what opening range is the OLI value maximized?

For gun based systems this is a classical optimization problem of trading time for the engagement versus an improving chance of hitting the enemy as he approaches. It is assumed that due to enemy tactical counter actions, such as shifting the direction of the attack, suppressing the defense with artillery fire, or any other measures consistent with his doctrine, the P(Hit) will stop increasing once the battle
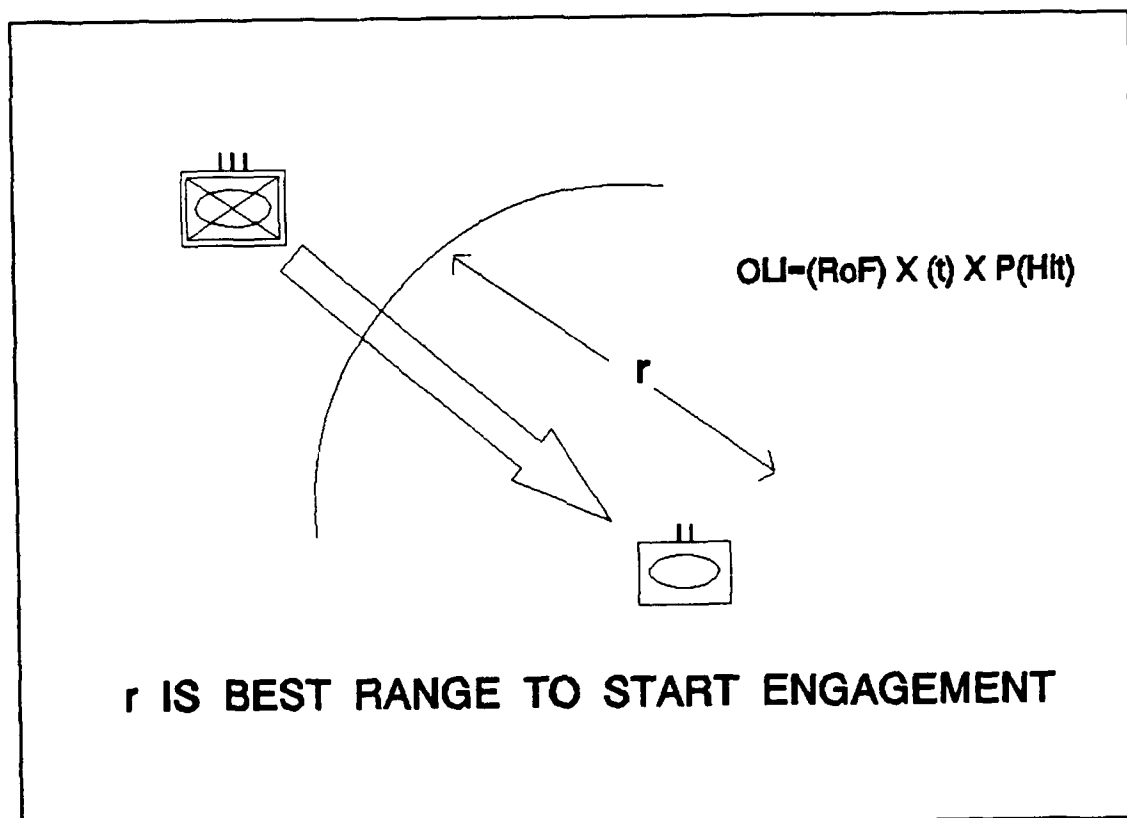

OLI=(RoF) X (t) X P(Hit)

r IS BEST RANGE TO START ENGAGEMENT

Figure 23. Optimum Opening Range Problem

is joined. For the purpose of this analysis it is assumed that the P(hit) remains fixed at the initial firing value. This model captures the active nature of the enemy which was not investigated in the simulation scenario.

If the OLI is expanded beyond the one minute interval and the threat organization factors are discounted as weapon system specific, then the resulting formula is:

$$OLI = (Rof) \times (t) \times P(Hit).$$

Time and current target range are the two variables in this scheme. To simplify the process, time available for the engagement is expressed as the opening range divided by the rate of enemy advance (RoA). The result of this substitution is:

$$OLI = (Rof) \times (\frac{r}{RoA}) \times (1 - \frac{r}{Rmax})^{\mu}.$$

Figure 24 is a graph of this function over opening range and shows the nature of the OLI for an engagement under these conditions.

To find the optimal range at which to start the engagement we set the first derivative to zero and solved. It can be shown that this results in the following expression,

$$r = \frac{Rmax}{(1+\mu)} \quad .$$

These results yielded optimal opening ranges for the two gun based weapon systems. For the missile based systems this analysis was simplified by the fact the these functions are monotonically increasing in form. Their maximum will occur at
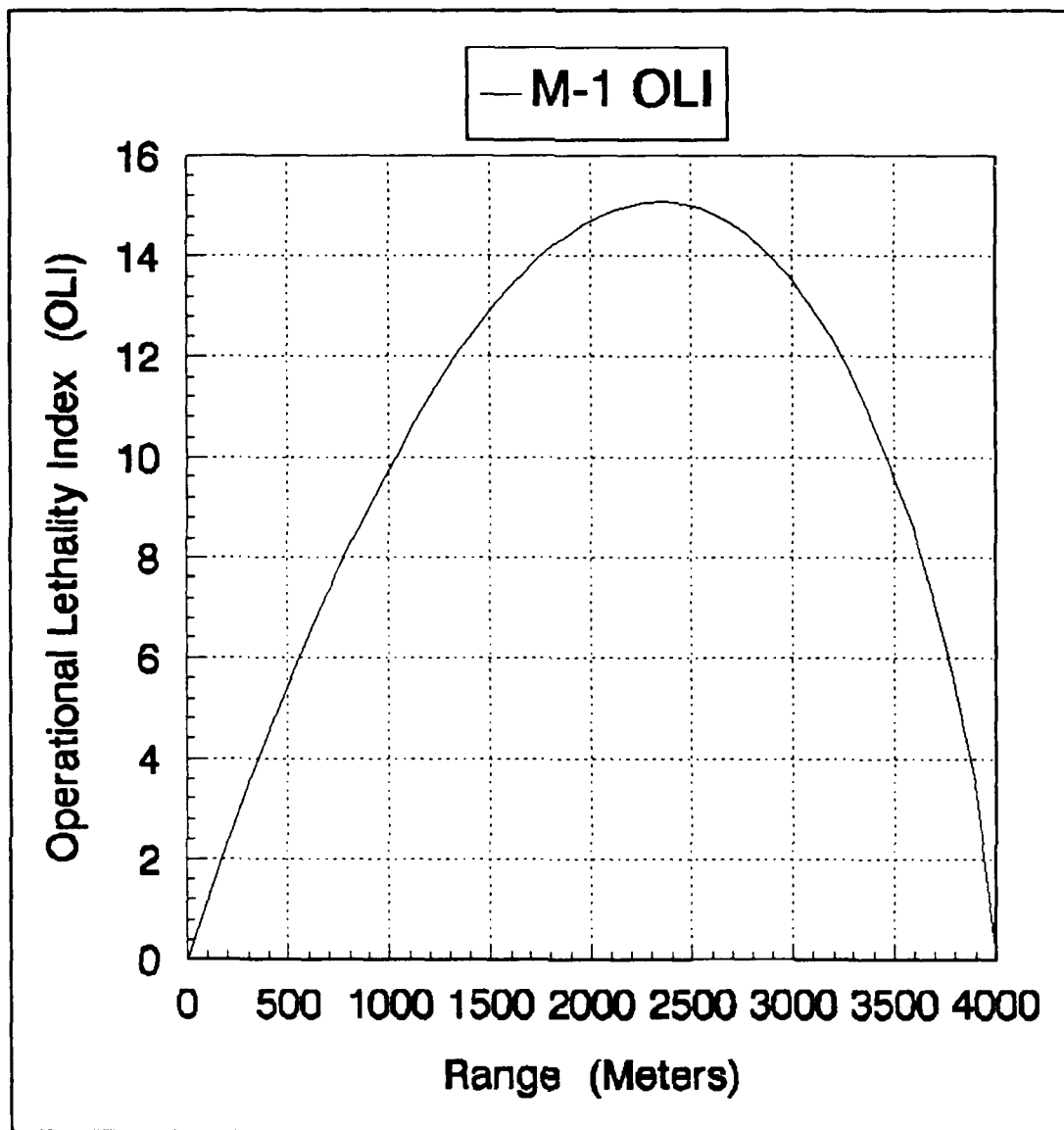
Figure 24. Operational Lethality Index (OLI)

the non-zero end point or in this case the weapons maximum range. Table 4 summarizes the results of this analysis.

This appears to clarify the statistical outcomes in chapter four. Recall, the free fire command and control methodology when paired with either the engagement area or Haw-Maw-Law positioning schemes and the engagement area combined with the trigger line were not statistically different. Opening ranges for gun based systems

WEAPON SYSTEM		OPENING RANGE
	120mm GUN	2343
	25mm GUN	1590
	TOW MISSILE	3750

TABLE 4. OPENING RANGE SUMMARY

tend to be less than their maximum, thus discounting the use of free fire command and control methodology. Furthermore, the range disparity between missile based systems and their gun counterparts demand non-linear emplacement for maximum direct fire volley intensity at the point of first contact. This result tends to nullify the strengths of the Haw-Maw-Law approach.

Thus, the engagement area positioning scheme, augmented with the trigger line command and control technique seems to offer a superior tactical approach for defense in sector missions. The high levels of initial direct fire, when coupled with the minimum reaction time afforded the enemy, result in a tactical alignment in which the direct fires of each weapon system can be optimized through

synchronization. This was demonstrated in the graphical displays associated with the

BEAM project.

VI. CONCLUSIONS

A. FINDINGS

The following hypothesis was tested for validity. Direct fire synchronization in the defense is best achieved when subordinate elements are positioned for mutual support and execution is decentralized consistent with the commander's intent. Statistical analysis of simulation results, as measured by the battalion/task force MOE, confirmed the hypothesis.

The best tactical approach for the defense in sector mission is to combine the engagement area positioning scheme with the trigger line execution methodology. If the enemy is faced with constrained freedom of action, then the Haw-Maw-Law approach holds some promise when coupled with the free fire technique. The ability of the enemy to shift his point of attack following initial contact will help determine whether intensity of the opening fires should be traded for increased engagement time.

Capturing the influence of direct fire synchronization as envisioned by the BEAM project does indeed appear possible. The combat potential surface provides the warfighter with a familiar visual reference through which to objectively explore his tactical dispositions. The commander can track the concentrations of his combat power relative to the operational graphics to see how well subordinate units are complying with his intent. This should provide for centralized planning and

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decentralized execution. These two components are key to battlefield synchronization.

As an after action review tool, the combat potential surface holds great promise. Since the potential of the battalion can be tracked before the start of the engagement, locating battlefield shortfalls beyond the scope of tactical dispositions is now possible in an objective manner. For example, if the OPFOR is able to push through an area where direct fires have been massed then the problem can be traced to lack of gunnery technique or failure in boresighting vice inadequate vehicle positioning.

B. RECOMMENDATIONS

The Combat Potential Surface should be included in the instrumental upgrade of the NTC's data collection and processing equipment. The format, speed, exportability of this display make it well suited to the future training process of Army battalions during defense in sector missions. This display has further potential to be incorporated at Army schools that use Janus(A) in their instruction.

C. FOLLOW-ON RESEARCH

While the Combat Potential Surface has done a good job at capturing vehicle mounted anti-tank weapon systems the dismounted side of task force operations has not been modelled. Further efforts could include adding infantry weapons such as the Dragon or other hand held weapons to the display. Furthermore, a display that focused on the dismounted aspects of the battle could provide insights into the

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combat conducted in the non-armor fight. This display would show the combat potential of infantry weapons in closed terrain.

Lastly, weapons still in development could be added to the display once their operating parameters had been determined. This would allow for the visualization of the battlefield contribution of systems like the Hyper-velocity Anti-Tank Missile. Various tactical approaches could be modelled to gain insight as to the effect of different weapon parameters and their input to combat potential.

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