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THESIS

HEAVY FORCE ANALYSIS OF JAVELIN

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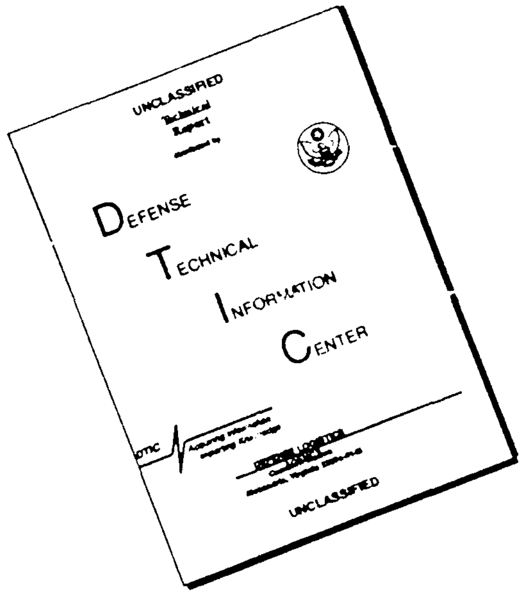

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HEAVY FORCE ANALYSIS OF JAVELIN

by

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ABSTRACT

Present mission requirements and increased weapons technology dictate that there is a need to replace the US Army Infantry's medium antiarmor Dragon weapon system. In lieu of the Dragon, the US Army is opting to field a new system called the Javelin Antitank Weapon System. This thesis explores the potential for the Javelin to enhance the operational effectiveness of the Mechanized Infantry assets of the US Army. This analysis includes the development of Mechanized Infantry scenarios which employ the Janus(A) high resolution combat model. These scenarios model force-on-force trials of mechanized versus fully modernized armor heavy threats in deliberate defense and movement to contact missions.

Results of the experimental data analysis indicate that the Javelin performs superior to the Dragon in terms of the mechanized force's range of antiarmor engagements, lethality, target stealing, and survivability. The findings to this thesis could benefit the US Army in force structure and antiarmor weapon requirements with the future fielding of the Javelin to Mechanized Infantry units.

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EXECUTIVE SUMMARY

Present mission requirements and increased weapons technology dictate that there is a need to replace the US Army Infantry's medium antiarmor Dragon weapon system. In lieu of the Dragon, the US Army is opting to field a new weapon called the Javelin Antitank Weapon System. Integrating the Javelin into the infantry's weapons inventory could be costly and unnecessary or it may be a beneficial and worthy combat multiplier. In the interest of evaluating the weapon, this thesis explores the potential for the Javelin to enhance the operational effectiveness of Mechanized Infantry assets of the US Army.

This analysis includes the development of Mechanized Infantry scenarios which employ the Janus(A) high resolution combat model. These scenarios represent force-on-force trails of mechanized infantry versus fully modernized armor heavy threats in deliberate defense and movement to contact missions. Each mission generates data output from multiple simulation runs with regard to four measures of effectiveness. These measures of effectiveness include the mechanized force's range of antiarmor engagements, force survivability, target stealing by antiarmor weapons, and lethality. Data analysis of the output using the Mann-Whitney Test is used to compare the operational effectiveness of the mechanized infantry with and without the Javelin.

Results of the experimental data analysis indicate that the Javelin performs superior to the Dragon across all four measures of effectiveness. These results support evidence that the Javelin equipped mechanized unit has the ability to kill enemy forces from greater distances and with greater lethality, while maintaining improved survivability. For the military commander, the contributions of the Javelin make it possible to improve heavy conventional forces.

Conclusive evidence suggests that the operational effectiveness of the Mechanized Infantry is significantly enhanced as a result of replacing the Dragon with the Javelin. The characteristics of the Javelin make it a favorable alternative for the Dragon. In this study, the Javelin proves to be a worthy combat multiplier to the Mechanized Infantry's arsenal.

I. INTRODUCTION

A. BACKGROUND

In recent years the United States Army has rigorously analyzed the events of a changing world order. With the Cold War years at an end, democratic nations around the world celebrate the freedom from the overbearing impasse of a superpower communist threat. Former Soviet nations have divided, changing their politics and their military structure only to make it more difficult for the United States to assess their intentions or hostilities. Moreover, the advances in technology among third world nations causes more concern each day as their potential for a mid-to-high intensity of war increases. As a result of the changing geo-political environment and the United States' own domestic political intolerance for current military end strengths, the US Army is transitioning from a forward deployed force to a smaller, more rapidly deployable force. This force will maintain the goal to assert an overwhelming, modernized advantage in strength and firepower in contingency operations when and wherever necessary.

Support for such a contingency force must be designed to provide critical weapon systems that provide higher force survivability and lethality. The Javelin Antitank Weapon System may provide such support. The Javelin currently is undergoing the Department of Defense's (DOD) acquisition process to enhance the robustness of Light Infantry forces. It is intended to be fielded by 1995 in order to replace its less effective predecessor, the Dragon [Ref. 1 and Ref. 2].

The availability of the Javelin raises a new issue to the Operational Test and Evaluation Command (OPTEC), United States Army Infantry School (USAIS), and Training and Doctrine Command (TRADOC). The question, "Should the Javelin also become part of the antiarmor arsenal of the Mechanized Infantry?" now must be considered.

B. LITERATURE REVIEW

As proponents for analysis of new weapon systems, TRADOC Analysis Center Research Activities at Monterey, California (TRAC-Monterey) is conducting model research in support of initial operational tests and evaluations (IOTE) conducted by OPTEC. TRAC-Monterey uses Janus(A), a high resolution combat model as its primary tool to conduct simulations research.

Masters thesis research [Ref. 3 and Ref. 4] involving simulations and military operational tests analyzing the Javelin versus Dragon indicate significant differences in specific measures of effectiveness and measures of performance. These models and tests were performed with modeling and field exercises with the Light Infantry. The methodologies and conclusions of these earlier works provide inordinate amounts of practical information that is pertinent to this study. In fact, the motivation of this thesis is that it is follow-on work to both Javelin: A Case Study in Model-Test-Model by Charles A. Pate (December 1992) and Javelin vs. Dragon II: A Comparative Analysis by Michael J. McGuire (September 1993).

The initial work by Pate [Ref. 3] addressing the Javelin weapon system and modeling on Janus(A) are the original efforts to begin Model-Test-Model research for an infantry antiarmor weapon system. The Model-Test-Model paradigm is a procedural analysis adopted by TRAC-Monterey and other test agencies to test, evaluate, and validate the effectiveness of new weapon systems. Pate's work in modeling the Javelin in Janus(A) involves four combat scenarios. Factors involved in these scenarios are modeled to represent the conditions of the initial operational tests that are conducted as part of the Model-Test-Model analysis.

For a vigorous analysis, Pate's work models scenarios with and without Mission Oriented Protective Posture (MOPP). Other considerations include size of friendly (blue) forces and opposing (red) forces. Pate varies the force strengths from a platoon conducting defensive missions to a company conducting offensive operations. Due to insufficient data for Javelin and Dragon night engagements at the time, all of Pate's work is limited to scenario modeling in day time conditions. The scenarios conducted were hasty defense in

MOPP-4, deliberate defense, deliberate attack, and movement to contact. The first two defensive missions employ a platoon size element (30 soldiers). The hasty defense mission is conducted in MOPP-4 for the purpose of simulating conditions in a nuclear, biological, or chemical (NBC) environment. A MOPP level of four in this case is factored into Janus(A) modeling to reduce the soldiers effectiveness as it would during the actual operational tests conducted by OPTEC. The remaining two offensive missions are conducted with a strength of a 90 soldier force, representative of a typical company size unit. These missions are modeled in an NBC free environment.

Opposing forces are typical in size for missions against blue forces. Hence, a company size mechanized unit consisting of eight BMPs and three T-72 tanks is paired against the blue force platoon. Likewise, a platoon size red force consisting of two BMPs and two T-72 tanks opposes the blue force company element. In all scenarios, the simulations are run until total annihilation of one force by the other or until the offensive unit gains its march objective.

Each simulation run produces data output as required by the measures of effectiveness (MOEs). Pate derived these MOEs from the Critical Operational Issues and Criteria (COIC) developed at TEXCOM. The MOEs are categorized into three areas, engagement range, lethality, and survivability. Typically then the data requirements used for the MOEs are, respectively, average engagement range, number of kills/number of shots fired, and number of blue soldiers survinging/number of blue soldiers starting.

Pate applies several analytical tools including pairwise comparisons of MOEs and One Way Analysis of Variance (ANOVA). It is important to note that in each case, hypothesis testing in ANOVA assumes normality. When testing proves no evidence of normality, Pate uses the Kruskal-Wallis One Way Analysis by Ranks test as a nonparametric technique for analyzing the collected data. This final approach provides a less powerful test but still offers a robust analysis.

The findings in Pate's work concludes that in all scenarios, the analytical methods support the alternative hypothesis, H_a, that the mean MOE of Dragon does not equal the mean MOE for Javelin. Accordingly, the MOEs for the Javelin equipped force proves to be statistically different and better than the Dragon equipped force up to a five percent level of significance [Ref. 3].

Trends to be considered in Pate's analysis become evident in the analysis of the lethality MOE. While the range of percentages for Javelin's lethality dominated that of the Dragon's, in offensive operations these ranges for both weapon systems were lower than their respective measures of lethality in the defense missions. This can be accounted for by the fact that in defensive operations, by doctrine, antiarmor weapon systems are employed in such a manner as to take full advantage of their engagement ranges. This most desirable tactic is not always possible in an often unpredictable offensive type mission.

McGuire [Ref. 4] extends Pate's work on modeling and analyzing the Javelin versus Dragon in Janus(A). Using a similar approach, McGuire investigates six scenarios. These scenarios are divided into three defensive and three offensive missions. In addition, with new night time data, factors are systematically varied to represent the conditions for both day and night operations. Operations considered in his study are the deliberate day and night defense, hasty day and night ambush, and finally, deliberate day and night attacks. Each scenario is simulated in an NBC free environment. McGuire mentions no reason for excluding NBC conditions. At the time however, an assumption may have been drawn from Pate's conclusions that regardless of NBC conditions, Javelin equipped scenarios are significantly different then the alternatively equipped Dragon scenarios.

The size of blue and red forces are identical to Pate's scenarios with regards to mission types. As an exception, McGuire adds attack helicopters to red forces and two tubularly launched, optically tracked, wire guided (TOW) antiarmor missiles to blue forces as a supplemental weapon system to each deliberate defense mission and the hasty night ambush. During each run, the TOW missiles engage and destroy the attack helicopters. Due to the unrealistic result, it is determined that helicopters should not be used in any scenarios involving TOW missiles.

The design of McGuire's experiment, a completely randomized block design, is treated simply as a completely randomized design. For each scenario three trained army officers are used to run the simulations. The assumption McGuire makes is that the individuals cause no blocking effects on the analysis. Given that, McGuire varies the scenarios by the six levels of missions and by two levels of weapon types, Javelin and Dragon.

McGuire's results in pairwise comparisons of MOE data are similar to Pate's findings. Likewise, the MOE data requirements are categorized in the areas of range, lethality, and survivability. Failing normality, the ANOVA approach similarly proves fruitless for McGuire as did the Shipiro-Wilkes tests and Kolmogorov-Smirnov test for typical hypothesis testing. Realizing the nonparametric structure of the data, McGuire analyzes the MOEs using the Mann Whitney test. McGuire also concludes that for most scenarios there is a significant difference shown between

Javelin and Dragon. Under the category for lethality, McGuire discovers that the most meaningful MOEs are loss exchange ratios (LERs), force exchange ratios (FERs), and the ratio of threat vehicles killed by Dragon or Javelin divided by the total number of shots by Dragon or Javelin. In any case, the conclusive analysis indicates that for these three MOEs, the Javelin proves significantly different than the Dragon in lethality. There is however one exception to this result for MOEs, LER and FER, in the deliberate day attack scenario. McGuire offers several reasons. First, the support by fire position for both the Javelin and Dragon are within 1000 meters of the objective. This short distance fails to provide a standoff distance safely away from red force engagements. Secondly, the terrain in the Janus(A) database may influence the operators to assess that there is less cover and concealment than there is actually on the corresponding piece of terrain at Fort Hunter Liggett, thus, providing an unexpected longer survivability time for both weapons and allowing more time to inflict heavier losses to the red forces.

McGuire addresses survivability using two measures of effectiveness, unit survivability and weapon survivability for both Dragon and Javelin. Unit survivability measures how many blue soldiers survived relative to how many began the battle. Likewise, weapon survivability for Dragon and

Javelin measures the number of respective gunners surviving relative to their starting number. McGuire's results concur with Pate's with regard to the two missions: movement to contact (resulting into a hasty day ambush in McGuire's work) and the deliberate defense. These mission pairs show significant differences between Javelin and Dragon. On the other hand, McGuire's deliberate day attack mission indicates no differences between either weapon system and in essence contradicts Pate's results for the same mission type. Similar reasons to explain this phenomena are characterized by those noted earlier for the discrepancies in the LER and FER results. The rational for the outcome is an observed inverse relationship between survivability and unit loss.

McGuire and Pate made an important contribution to the IOTE of the Javelin weapon system at Fort Hunter Liggett in early Spring of 1994. Their findings aided in streamlining the design of the operational tests conducted as part of the Model-Test-Model research of the Javelin weapon system. The recommendations from both studies indicate that different pairs of missions of the same nature, offensive or defensive, need not necessarily be performed so that operational tests can be tapered to make efficient use of resources and still provide sufficient amounts of real data. Knowledge of these particularly redundant scenarios helps omit them from any follow-on operational tests. This conserves precious resources and attempts to avoid conducting statistically unproductive field tests. [Ref. 4]

C. PROBLEM STATEMENT

Successful operational and live fire tests have proven the Javelin superior to the Dragon. Unfortunately, limited resources have restricted operational testing of light or dismounted infantry forces scenarios. The Army needs to know if the Javelin should be fielded in mechanized units. The mechanized units today maintain a robust inventory of millions of dollars worth of extremely technical equipment. New and advanced weapon systems also come with a high price tag therefore, the cost of the system must be weighed against its contributions to operational effectiveness. As a proposal, modeling and simulations will be used to address this question as the Army has allotted no resources for additional operational tests and evaluations involving heavy forces scenarios.

D. SCOPE

As resources continue to diminish, acquisition of advanced weapon systems like the Javelin will become increasingly more difficult if not impossible without prior analysis of each new system's developmental and operational performances. Integrating the Javelin into the infantry's weapons inventory could be costly and unnecessary or it may be a beneficial and worthy combat multiplier. The scope of this thesis is to further explore the utility of the Javelin for the Army in the interest of potentially fielding the weapon system to the Mechanized Infantry.

This thesis investigates the contributions of the Javelin for the Mechanized Infantry using modeling in Janus(A) to determine if the system proves to enhance combat operational effectiveness. The scenarios used in Janus(A) reflect combat operations developed by applying current tactics and doctrine for the light (dismounted) and mechanized infantry platoon/company size forces. Operations selected for study in the Janus(A) mechanized scenarios are based on input from prior research and requirements for analysis by the host agency, TRAC-Monterey. Additionally, these scenarios are analyzed in terms of measures of effectiveness selected by the author and TRAC-Monterey. Graphical and statistical data analysis is applied to determine the operational effectiveness of the mechanized infantry in cases modeled with and without the Javelin as a replacement for the Dragon in the antiarmor role. The results from this analysis will directly aid in the decision of where to field the Javelin for the future, smaller, and more elite US Army.

II. EQUIPMENT AND SCENARIO DESCRIPTIONS

This chapter serves to describe the differences in weapon systems, friendly and enemy forces, and their capabilities as they impact upon the mechanized infantry unit. Moreover, the employment of the Dragon and Javelin is discussed as appropriate to each type of scenario, be it offensive or defensive. These descriptions provide a basic knowledge from which to understand how mechanized infantry fight. Gaining an understanding of these tactics makes it clearer on how to implement the systems into Janus(A) modeling. Furthermore, a sound knowledge of equipment and tactics aids in comparing and contrasting the systems in question. This understanding helps establish and validate meaningful results of the MOEs in the design of the experiment.

A. ANTIARMOR WEAPON SYSTEMS

1. Dragon

The Dragon is the primary antiarmor weapon system for the dismounted element of the mechanized platoon and company. The major components of the weapon are the day sight, attachable thermal night sight, and a single missile. Although the day and night sights are reusable, the cost for each Dragon missile is an estimated $25,000 dollars. The combined weight of the system is approximately 55 pounds.

Although it is manportable, the bulky size and weight of the Dragon make maneuvers and speed of movement difficult.

To fire the Dragon, the gunner steadies his aim using the bipod stand and firm ground. When engaged, the gunner ensures that the missile has a direct line-of-fire to reach its target. Figure 1 shows the Dragon gunner in the sitting firing position.

Figure 1. Dragon gunner employed in firing position.

The Dragon engages light skinned and heavy armored vehicles up to a range of 1000 meters. Most enemy weapon systems of machine-gun caliber and higher are more than capable of engaging and returning fire to the Dragon gunner at these distances. As a result, employing the Dragon potentially exposes the gunner to threatening enemy fires because of its lack of standoff in range. Additionally, the muzzle flash and smoke from the missile's launch compromises the location and inevitably the survivability of the Dragon gunner. [Ref. 5]

Range standoff is not the only shortfall of the Dragon system. The Dragon is a command-linked wire guided missile with a relatively slow velocity. As a consequence, the gunner may remain exposed for as much as 10 to 12 seconds because of the extensive tracking time of the missile until target impact.

2. Javelin

The Javelin Antitank Weapon System is also a manportable system. It has been suggested to replace, one-for-one, the Dragon in the antiarmor role for dismounted infantry. The Javelin is designed to weigh five to six pounds less than the Dragon, but it too is large and difficult to carry in the field. The system includes two major components: a reusable command and launch unit (CLU) and the warhead itself which is a missile packaged in a sealed tube. Although currently not in full scale production, the Javelin missile itself costs an estimated $100,000 dollars, approximately four times that of the Dragon. The CLU has an integrated day/night sight which provides target acquisition even in adverse weather conditions. As an added benefit, the CLU may also be used independently as another means of target acquisition on the battlefield. The Javelin has an increased engagement range of 2000 meters and a detection range out to 4500 meters. Technically and tactically, the key advantage of the Javelin is its fire-and-forget capability. This allows the gunner to quickly locate the target, lock on the missile, engage and seek cover immediately upon missile launch. Another feature of the Javelin is the gunner's selection of modes of target engagement. The two modes of fire are top attack mode, which shoots a high trajectory, and a flat trajectory or direct line of sight fire mode. The gunner selects the top attack mode to engage enemy tanks and vehicles at greater distances. This allows for the missile to impact the top of the target vehicle where it is less heavily armored and more vulnerable to catastrophic kills. When overhead cover obstructs the indirect flight path of the missile, the gunner selects the direct fire mode. Figure 2 illustrates the Javelin ready to fire in the top attack mode from a kneeling position. Also, the Javelin uses a soft launch feature which allows it to be fired from enclosures and covered fighting positions and helps reduce the launch signature of the gunner. [Ref. 6]

3. Bradley Fighting Vehicle (BFV)

The BFV came to the Mechanized Infantry out of necessity. The advances in technology developing the M1A1 Abram Tank left the Mechanized Infantry behind in firepower and speed. The effect made it difficult for the Infantry to provide mutual combined arms support on the battlefield. The BFV closes this gap, giving the Infantry the tools to succeed in their mission to close with and destroy the enemy in a combined arms battle.

Figure 2. From [Ref. 2], Javelin gunner in open position.

The BFV has the capacity to carry a nine man squad within excellent armor protection. Three crew members operate the vehicle and its mounted armament. The fire team (dismounted) element rides in the rear troop compartment and is able to mount or dismount the vehicle through the ramp access door or when the ramp is down. Figure 3 illustrates the ramp down dismount of the BFV in a typical operation.

One of the most important features is the compliment of weapon systems onboard the BFV. The vehicle's main weapon is the M242 25-millimeter fully automatic gun. The M242 has three rates of fire: *single shot, low rate,* and *high rate.* It can deliver armor piercing rounds against lightly armored vehicles to a maximum effective range of 1700 meters. Adjacent to the M242 is the M240 7.62-millimeter coaxially mounted machine gun. The M240 is used to suppress and defeat enemy dismounted forces out to a range of 900 meters. The BFV's main antitank weapon is the turret mounted TOW. The TOW missile is the optically tracked, wire guided missile with accuracy from 65 to 3750 meters. The TOW launcher can load two missiles but fires sequentially. Internal storage of the BFV can hold five extra TOW or Dragon/Javelin rounds or a mix. [Ref. 7]

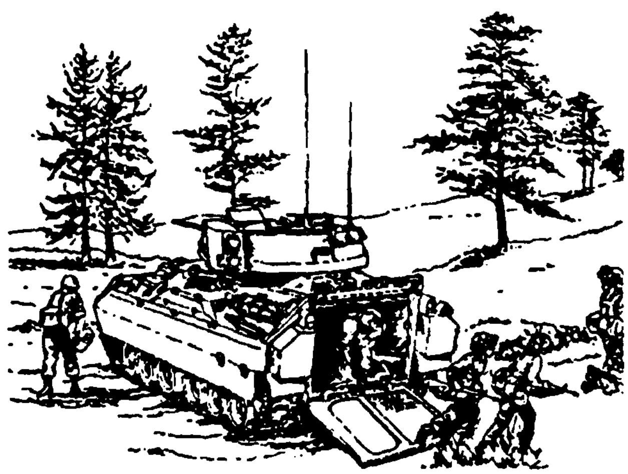

Figure 3. Dismounting the BFV with ramp down.

B. SCENARIOS

Regardless of an infantry unit's organizational equipment, the basic tactics are similar. In particular, the doctrinal employment of either the Dragon or the Javelin in a mechanized infantry unit is identical to that of a light infantry unit. In any case, the commander and platoon leader must consider the employment of both weapon systems. Each system's employment is dependent upon the type of mission. Two missions designed and simulated for this study are the deliberate defense and the movement to contact. These missions encompass both defensive and offensive tactics and maneuvers.

The main purpose of the movement to contact is to establish or regain contact with the enemy. As with any offensive operation, it is the intent of the commander to develop the situation, gain the tactical advantage, and then close with and destroy or neutralize his opponent. Because the movement to contact may often expose the attacking forces, it is doctrinal for the commander to establish locally superior combat power in forces and equipment. Conversely, the role of the deliberate defense is to defeat an enemy attack. By doctrine, it is not the intent to defend in place but rather to defend only until sufficient strength allows one to counterattack and return to the offensive. Generally, commanders use the deliberate defense to buy time, impede enemy forces while other friendly forces may attack, conserve forces, and hold key terrain that poses an advantage to its occupants. [Ref. 8]

The different nature of these operations offer a unique look at both weapon systems engaged in two extremely different scenarios. These missions will also deliver a comparatively robust analysis of the unit's effectiveness in either case. A comparison of results from these operations to those of Pate and McGuire may also provide supportive evidence to the Javelin's potential.

Prior to discussing the employment of the key antiarmor weapon systems in either types of missions, it is best to understand the organization of the mechanized infantry and opposing threat forces. The forces modeled are the mechanized infantry platoon and company employed in the deliberate defense and movement to contact, respectively. Threat forces consist of a mix of tanks, T-72s, and armor personnel carriers, BMP-2s with dismounting infantry. Both friendly and threat forces have the capability to fight their soldiers mounted or dismounted as the situation of the battle and terrain dictates. The friendly forces represent the quantity of soldiers, weapons, and equipment that are currently found in the US Army Modified Table of Organization and Equipment (MTOE) for each size unit.

Likewise, the threat forces are organized and equipped as typical of any former Soviet/Warsaw Pact force.

1. Friendly Forces - Mechanized

a. *Organization and Equipment*

At its basic level, the mechanized infantry company consists of three platoons of four BFVs each and a company headquarters. The company headquarters also has a BFV which is manned by the commander, master gunner, driver, and the fire support officer. The platoons operate under the direction and guidance of the commander but to the orders of the platoon leader and platoon sergeant. The decentralized control allows the platoons to fight rapidly in a variety of situations requiring mounted and dismounted tactics. Each platoon has two sections, A and B, with two BFVs per section. Sections A and B consist of two squads of nine men. Each squad has three crew members and six members of a fire team. On order, each squad's fire team dismounts to form the ground maneuver element. During sustained dismounted operations, the ground maneuver element is commanded by the platoon leader. Meanwhile, the platoon sergeant controls the movement of the BFVs and provides fire support to the dismounted portion of the platoon. [Ref. 7]

Weapon systems organic to the mechanized platoon enable it to mass a wide variety of both small arms and antiarmor fires. Complimenting the BFV's weapon systems, the dismounted fire teams each typically have the antiarmor specialist, two automatic riflemen, and three riflemen. The platoon thus has a composite list of the following key antiarmor systems and weapons.

1. 4 BFVs with coaxial machine guns.
   4 X 7 TOW missiles (basic load).
   4 X 1 M242 .25 millimeter automatic guns.

2. 4 Antiarmor specialist.
   4 X 2 Dragon/Javelin missiles (Movement to Contact) or 4 X 4 Dragon/Javelin missiles (Deliberate Defense).

Assuming time permitting, the Dragon/Javelin gunners have an additional two missiles per system for the deliberate defense mission. The remaining weapon systems are small arms. These include the M16A2 rifles and the M249 Squad Automatic Weapons (SAWs) which are individually assigned and carried by certain soldiers in the platoon.

b. Tactics of the Antiarmor fight

Tactics, techniques, and procedures for employing antiarmor weapon systems are as much a commander's prerogative as they are a science. There are however, some basic doctrinal and tactical principles that should be observed. Based on the estimate of the situation, the commander decides where to position the antiarmor weapons. Ideally, he places the weapon systems in such a manner as to take full advantage of each system's range and capabilities. The commander, guided by experience and doctrine, balances his decision with information about the mission, enemy, terrain, available troops and time (METT-T).

During the estimate of the situation, the commander has more time to plan the positioning of his antiarmor assets in the deliberate defense than in the movement to contact. Once the battle begins, the conduct of the antiarmor fight in the movement to contact relies heavily on the commander's intent and guidance, given prior to the mission, and the resulting actions of the antiarmor specialist. Nevertheless, the commander's concerns for the employment of antiarmor weapon systems in the offense are the same as those measures he applies in the defense.

In defensive operations, particularly the deliberate defense, the commander's goal is to array his antiarmor weapons such that their fields of fire are directed primarily at the enemy's flanks and rear. By design, armored vehicles are more vulnerable when exposed to flank and rear shots. The effectiveness of TOW and Dragon fires are greatly reduced against the more heavily shrouded frontal slope of armor vehicles. In these instances, the Javelin weapon system has the advantage to fire indirectly at oncoming targets as a top attack weapon.

Antiarmor engagements require clear fields of fire. Both the TOW and Dragon weapon systems cannot have obstructions in the flight paths of the missiles. Any large obstacles may damage the guide wires and prevent the missiles from engaging their target. This includes large bodies of water that potentially cause electrical failure of the guide wires that trail the missile's flight.

The position of antiarmor weapons should provide mutually supportive and interlocking fires. The TOW engagements although capable of 3750 meters, cannot be supported beyond 2000 meters by either the Javelin or the Dragon. Employment of each system must consider the synergistic effect that occurs when integrating all antiarmor fires to one engagement area. In the defense, the commander designates this engagement area with trigger lines which span the range of all weapon systems. Once in the engagement area, enemy targets are destroyed in mass by cross coverage of fire from all weapons.

In the movement to contact, the antiarmor weapons generally play a supportive, overwatching role for the maneuvering units. Antiarmor weapons must be able to place fires rapidly to cover the flanks and prevent enemy forces from reinforcing the objective or counter-attacking the main body of the maneuvering units. The tactics to employ the antiarmor weapons are similar to the defense but, when the mission occurs, there is less time to establish engagement areas with interlocking fires.

2. Enemy Forces - Mechanized/Armor Heavy

a. Organization and Equipment

Enemy soldiers and equipment are representative of a mechanized/heavy force similar to the former Soviet/Warsaw Pact. Weapons capabilities and acquisition devices of the tanks and armored vehicles are upgraded to provide a contemporary study against a more modernized opponent. Day and night vision devices are modeled as having the same capabilities as current US forces. Also, enemy small arms weapons are considered equivalent in firepower and lethality against friendly forces weapons of the same caliber.

In both missions, the opposing forces portray a T-72 tank company task organized with one mechanized platoon with three BMP-2's and 11 man squads each. The tank company is composed of three platoons and one headquarters section. Each platoon has three tanks. Including the commander, the company maintains ten tanks with the 120 millimeter smooth bore main gun. The T-72 tank's main gun has an effective range out to 2000 meters. The range and high explosive antitank rounds make the T-72 a significant threat to the BFV.

The BMP-2 is a light armored personnel carrier. Its main weapon systems include a 30-millimeter cannon and an AT-5 Spandrel. Respectively, these weapon systems are capable of suppressing and inflicting damage on the BFV at close ranges within 1000 meters with small arms fire and out to 3000 meters with antiarmor missile fires. As an advantage, the BMP-2's low profile and speed make it a difficult target.

b. Tactics and Doctrine

The essence of speed dictates that the enemy forces prefer to remain in a column or march formation. Generally, the tank company is the lead element. Once battle is eminent, the tank company and its mechanized platoon deploy laterally on line with its platoons in column. This is doctrinally referred to as the prebattle formation. Immediately before combat, the company further disperses into an attack formation with platoons on line or in wedge formation. Once within small arms range of the objective, the infantry squads dismount the BMP-2s and begin to conduct a close combat assault. As a unit, the BMP-2s will support their dismounts as they try to fire and maneuver toward their objective in order to disrupt, expose, and break through any weakness in the opposing defense. The strict discipline in formations emphasizes swift and efficient movement. This achieves a concentrated effort to punch through front line defenses and shatter an opposing weaker rear objective. If successful, lead units break through and create a safe passage for follow-on forces. [Ref. 9]

A defense posture is assumed when enemy forces cannot continue on the offensive. The defense is considered only temporary until additional resources allow the offense to continue. When it becomes inevitable to defend, the platoons create strongpoints with squads and vehicles dispersed in V-type wedge formations. Making use of the terrain, the defensive positions focus on canalizing the attackers into fire sacks which are covered by all organic weapons of the platoons and company.

III. EXPERIMENTAL DESIGN

A. JANUS(A) AS A HIGH RESOLUTION COMBAT MODEL

1. The Model

Janus(A) is a stochastic, interactive, high resolution land combat computer model. Multiple players can utilize it simultaneously as a training tool for tactics and combined arms warfare. More importantly, to the analyst, Janus(A) provides a method of generating multiple simulation runs and output data that model combined arms warfare. Interactions between opposing modeled forces apply stochastic processes in detection, acquisition, and engagement algorithms, giving the model a realistic ability in determining kills. Janus(A) is one of the primary high resolution models for the US Army and has gained acceptance by the other Armed Services.

Janus(A) can be designed to model realism through several variable factors. Weapon systems and terrain are two of the most influential of these factors. These factors can randomly and systemically affect the events of any scenario. Other factors such as weather, chemical environment, mines, and smoke add even more realism when brought into play. As a high resolution model, Janus(A) simulates both friendly and enemy units, weapons, and equipment as they are affected by these factors. As a point, successful missions accomplished in Janus(A) take into consideration the effects of these factors and conditions.

The engagements in Janus(A) are calculated and resolved by detection, acquisition and engagement algorithms of weapon systems. An engagement occurs only when an element of a force is within line of sight and range of an opposing weapon system. With the exception of artillery fires, all engagements are direct fire exchanges. The direct fire exchange is a limitation which directly affects the accuracy in modeling the Javelin's top attack capability. As a result, all Javelin fires are simulated in Janus(A) as direct fires upon the frontal slopes or flanks of targets.

The outcome from each engagement is either a miss or catastrophic kill. The probability of hit, Ph, and probability of kill, Pk, data utilized by Janus(A) are developed through tests and studies done by the Army Material Systems Analysis Agency (AMSAA) and its affiliated agencies. These data, unclassified and classified, are inputs for numerous systems including typical NATO and former Soviet/Warsaw Pact weapons. Conducting Janus(A) simulations with this database allows for extensive data collection on weapon engagements and system detections by equipment typically used in today's modern battlefield. [Ref. 10]

2. Terrain

Terrain files in Janus(A) are derived primarily from the Defense Mapping Agency data. These are digitized images of selected areas that are imported into scenarios built by the modeler. The images graphically illustrate vegetation, road networks, urban areas, elevation and contour lines. The terrain in Janus(A) version 3.17 has 50 meter resolution and can be displayed with grid designations that accurately represent the area of operations that correspond to the actual military map. [Ref. 10]

All scenarios in this analysis are developed using the terrain map of Fort Hunter Liggett, California. The location was selected because it offers a wide variety of terrain such as hills, valleys, open areas and a mix of low to thick vegetation. The efficacy of Janus(A) to incorporate the terrain increases the realistic representation of the scenarios. The effects of terrain impact upon combat operation in such areas as weapons engagements, line of sight, and rates of movement.

3. AUTOJAN

Janus(A) has the capability to create multiple simulation runs with independent results using the AUTOJAN mode. To operate in this mode requires a previously recorded run of an original simulation which has been performed interactively. Once the original simulation is recorded, the AUTOJAN feature calls upon the record for the history of all weapon systems movement routes, engagement postures, and fields of view. Independent trials of the same mission are repeated in AUTOJAN by randomizing the seed used by the detection, acquisition, and engagement algorithms. Each run repeated likewise provides postprocessed information of the results. [Ref. 10]

The AUTOJAN feature does, however, restrict the use of the mount/dismount capabilities of an interactively played scenario. In the original simulation, mounted forces must be dismounted immediately prior to contact with opposing forces. This allow each dismounted element to have separate movement routes, engagement postures, and fields of view before its carrier vehicle is possibly eliminated by a catastrophic kill. In the AUTOJAN run, the carrier may not become a catastrophic kill, in which case, all techniques and movement histories applied to the dismounted forces are still a part of the original record.

B. METHODOLOGY

1. General

The Mechanized Infantry model testing is varied across two types of missions and the two weapon types, Dragon and Javelin. Each scenario test includes eleven runs of each mission per weapon type. The deliberate defense and the movement to contact missions are both iterated using the

AUTOJAN replay feature. After each run, data is postprocessed, collected, and then transferred onto a spreadsheet for further analysis. At this point, hypothesis testing is conducted for each MOE to investigate signs of significant differences caused by the effects of the two antiarmor weapons systems.

2. Assumptions

Typical hypothesis testing using parametric techniques assumes, for example in a t-test when comparing two means, both populations are normally distributed and their variances are equal. Common parametric techniques rely on this assumption. It is, however, not uncommon for data not to follow these assumptions and to bring the validity of the parametric procedure into question. In order to circumvent this difficulty, nonparametric statistical procedures may be used. Mendenhall states:

> Research has shown that nonparametric statistical tests are almost as capable of detecting differences among populations as the parametric methods (of preceding chapters) when normality and other assumptions are satisfied. They may be, and often are, more powerful in detecting population differences when the assumptions are not satisfied. For this reason many statisticians advocate the use of nonparametric statistical procedures in preference to their parametric counterparts.[Ref.11]

The statistical analysis of Pate and McGuire indicates that the output from the Light Infantry simulation runs is not entirely normally distributed. From these findings, it is assumed that the output from the mechanized forces scenarios will not necessarily provide evidence of normally distributed samples of data. It is, however, assumed that the data are independent random samples from two populations with the same shape and a scale that is ordinal. On this assumption, it is reasonable to hypothesize that there may exist a shift in medians between these two populations. It is acceptable then to choose the Mann-Whitney test [Ref.11]. The Mann-Whitney test provides a nonparametric method to test for significant differences between two populations medians of unknown distributions.

3. Mann-Whitney Nonparametric Test

Results of each mission are evaluated using quantifiable measures of effectiveness. The basic analytical objective is to determine if the proposed scenarios reveal a difference between the two mechanized unit configurations. Hypothesis testing under the Mann-Whitney approach involves pairwise comparisons between the medians of each MOE for each different type of mechanized unit.

The Mann-Whitney method first involves ranking together the two samples of data from each MOE. Smallest observations are given rank 1, second smallest, rank 2, etc., until all observations are ranked. Observations that are tied are each assigned the average rank order. The sum of the ranks of the first sample are calculated and labeled the test statistic, W. Small values for the test statistic, W, indicate that the median for the first sample is smaller than the median of the second sample. Conversely, large values of W indicate that the median for the second sample is smaller than the first. [Ref. 12]

In each scenario, the Mann-Whitney tests will be:

$$H_0 : \eta_1 = \eta_2,$$

$$H_1 : \eta_1 \neq \eta_2.$$

Where:

η_1 = the median of each MOE in an applied Dragon scenario i,

η_2 = the median of each MOE in an applied Javelin scenario i,

for i = 1 to 2 (deliberate defense, movement to contact)

C. MEASURES OF EFFECTIVENESS (MOE)

The purpose of an MOE is to capture a specific data element that best investigates the operational effectiveness of the Dragon and Javelin equipped mechanized scenarios. The MOEs considered in this study are characteristic of the MOEs required by the Critical Operational Issues and Criteria (COIC) developed by OPTEC. The critical issues and their required data elements can be found explicitly in the Test and Evaluation Plan (TEP) that was used for the IOTE of the Javelin for Light Infantry [Ref. 13]. Using this as a guide, the MOEs established for this study investigate four areas: range, survivability, dominating antiarmor systems, and lethality. In detail, these MOEs are as follows:

1. MOE for range of engagement per unit type.

   Data element : *Antiarmor engagement range of each type unit*.

2. MOE for force survivability.

   Data element: $\dfrac{\textit{number of blue forces survived}}{\textit{number of blue forces starting}}$

3. MOE for target stolen by antiarmor system.

   Data element: $\dfrac{\textit{\# of threat vehicles destroyed by Dragon/Javelin}}{\textit{\# of threat vehicles destroyed by M2 BFV}}$.

4. MOE for lethality (force exchange ratio).

   Data element: $\dfrac{\textit{Red losses/TotalRed forces}}{\textit{Blue losses/Total Blue forces}}$.

These MOEs are selected because they compare and contrast the issues of whether or not the Javelin enhances the operational effectiveness of the Mechanized Infantry. All MOEs are quantifiable in terms of numeric values or as ratios obtained from each simulation run's output.

IV. ANALYSIS OF RESULTS

For simplicity, Janus(A) references missions numerically. The mission numbers used as labels in graphs in this chapter are listed in Table 1. For each unit type there are 11 runs conducted for every mission. This includes one original human interactive run and ten AUTOJAN runs. Collectively, the ten AUTOJAN runs save 60 man hours of computer simulation time when each mission averages one and a half hours real time.

Mission Number	Mission	Unit Type
500	Deliberate Defense	Mechanized Platoon with Dragon
501	Deliberate Defense	Mechanized Platoon with Javelin
525	Movement to Contact	Mechanized Company with Dragon
526	Movement to Contact	Mechanized Company with Javelin

Table 1. Numeric assignment of Janus(A) mission.

A. ANTIARMOR ENGAGEMENTS

The box plot analysis of the antiarmor engagement ranges illustrated in Figure 4 indicates that there is a slight difference in the median ranges between unit types for the defensive mission. The reason for this result is that the employment of the Javelin is similar to the Dragon due to the restrictive nature of the Fort Hunter Liggett terrain. As a consequence, the defense missions 500/501 are developed with the intent to draw the threat vehicles into an engagement area 500 to 1500 meters in depth. The small differences in engagement ranges is also explained by the number of TOW missile fires that tend to raise the averages of the unit's range of antiarmor engagements. The effect of the TOW missiles in raising the averages is also noticeable in the movement to contact mission. This is particularly due to the significant increase in the number of TOW missiles. The basic load for missions 500/501 requires a mix of 16 Dragon/Javelin missiles and 28 TOW missiles. On the other hand, the basic load for missions 525/526 requires a mix of 24 Dragon/Javelin missiles and 84 TOW missiles.

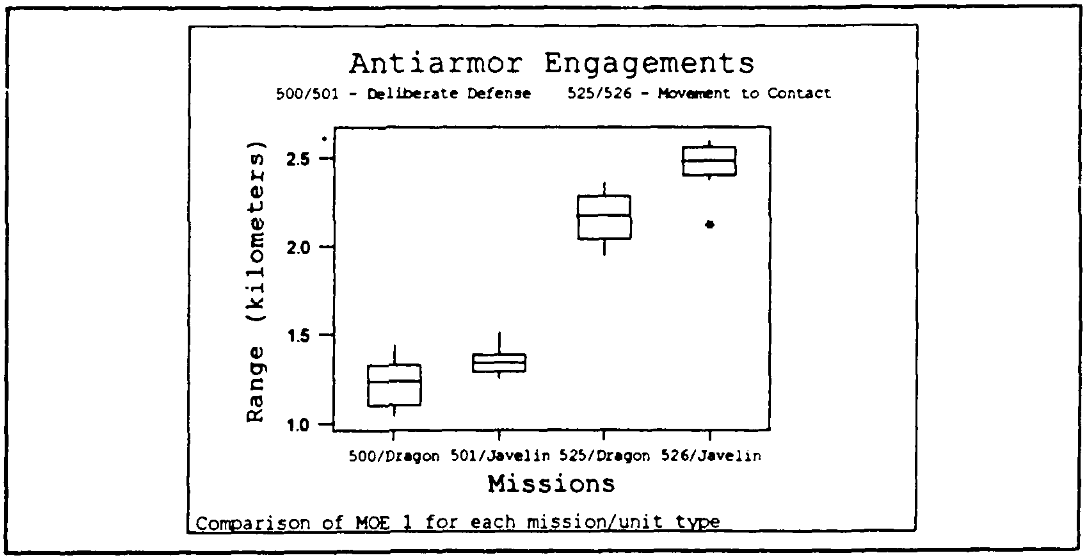

Figure 4. Box plot diagram of antiarmor engagements.
Note: Engagements include mix of Dragon/Javelin and TOW.

Table 2 summarizes the results of the Mann-Whitney tests for mission pairs 500/501 and 525/526. Despite the slight similarities in medians for the defensive missions, at the 0.05 significance level, the null hypothesis that the median range of engagements are equal is rejected.

Missions Pairs	Median	Test Statistic, W	P-Value
500 501	1.2340 1.3408	91.0	0.0215
525 526	2.1720 2.4793	74.0	0.0006

Table 2. Mann-Whitney test for antiarmor engagements.

B. SURVIVABILITY

Force survivability shows significant differences between unit types. In the most significant case, the Javelin equipped unit achieves an 85% survivability rate in the deliberate defense. The Dragon equipped unit, on the other hand, suffers the loss of almost half of its force. In both missions, the level of unit survivability is due primarily to the dismounted Javelin gunner. Given an armored threat, the Javelin gunner is difficult to detect. As a result, Javelin gunners survive longer and continue to inflict heavy losses on opposing forces.

The significant differences are illustrated in Figure 5. For each mission pair box plots support rejection of the null hypothesis by showing no overlapping distributions. Accordingly, Mann-Whitney test results in Table 3 clearly indicate a significant difference between Dragon and Javelin equipped units.

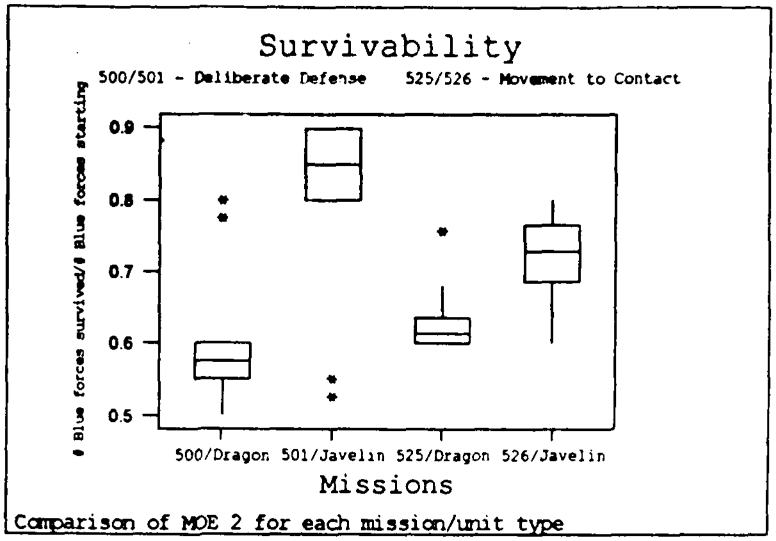

Figure 5. Box plot diagram of blue force survivability.

Missions Pairs	Median	Test Statistic, W	P-Value
500 501	0.5750 0.8500	85.0	0.0071
525 526	0.6143 0.7286	82.0	0.0039

Table 3. Mann-Whitney test for blue force survivability.

C. TARGET STEALING

The high survivability of the Javelin gunner contributes to an unexpected rise in the number of Javelin versus TOW kills in both missions 501 and 526. It also explains how the medians of each mission with the same antiarmor weapon systems are near equal. The Javelin with its increased Ph and Pk capability is a highly effective and dominating antiarmor system on the modeled battlefield. Figure 6 illustrates the difference in the medians of target stealing between weapon systems. In both missions, the results demonstrate a relatively higher median of Javelin/BFV kills than Dragon/BFV kills. The results in Table 4 similarly indicate that there is a significant difference in the mission pairs. Mann-Whitney tests estimate that in both cases there is less than a two percent chance of committing a type I error in rejecting the null hypothesis.

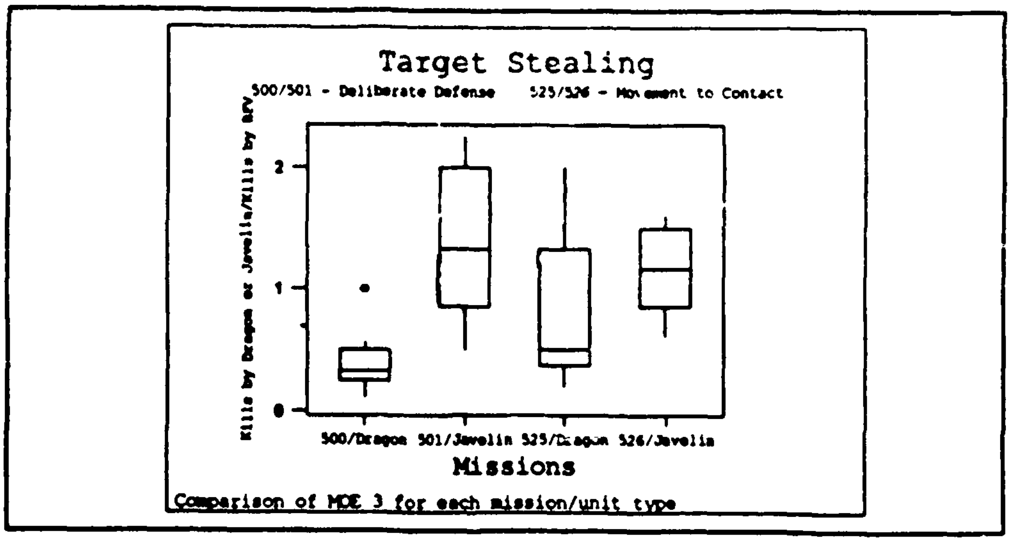

Figure 6. Box plot diagram of armor target stealing.

Missions Pairs	Median	Test Statistic, W	P-Value
500 501	0.3333 1.3333	71.5	0.0003
525 526	0.5000 1.1667	90.5	0.0197

Table 4. Mann-Whitney test for target stealing.

D. LETHALITY

The analysis of missions 500/501 and 525/526 indicates that the medians of lethality are also significantly different between each unit type. Notably, the number of enemy forces destroyed in the deliberate defense with the Javelin significantly out number those with the Dragon. This is evident in the graphical comparison of the force exchange ratios depicted in Figure 7. As another point, similarities in results of each mission with Dragon indicate that there is only a linear increase in the force exchange ratio between unit types. Hence, a blue force with Dragon does not demonstrate an increase in lethality as it gains an increase in the number of Dragons.

Of the MOEs, lethality is the strongest indicator of a difference between blue forces with Javelin and blue forces with Dragon. Results of the Mann-Whitney tests in Table 5 show expected significant differences between medians. More importantly, the test indicates a relatively small level in P-values in rejecting the null hypothesis when it is false.

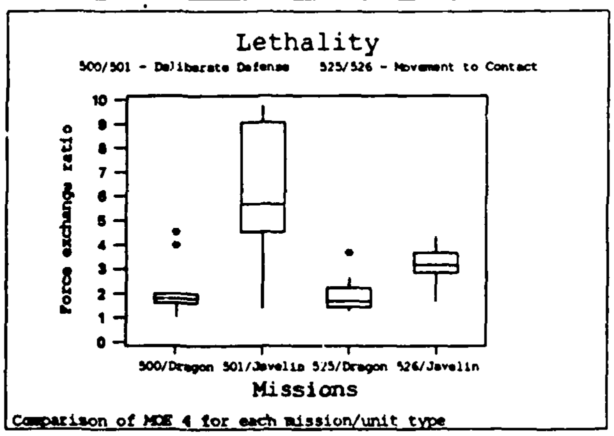

Figure 7. Box plot diagram of blue force lethality.

Missions Pairs	Median	Test Statistic, W	P-Value
500 501	1.7600 5.7020	79.5	0.0023
525 526	1.6780 3.1510	79.0	0.0020

Table 5. Mann-Whitney test for lethality.

V. CONCLUSIONS AND RECOMMENDATIONS

While the purpose of this thesis is to examine the potential of the Javelin Antitank Weapon System in a mechanized environment, it also illustrates the utility of Janus(A) model research for the US Army. Use of Janus(A) can support the research of past and present tactics and weapon systems design. Janus(A) may also be utilized to study the development of future tactics and weapon systems design. Janus(A) used in support of the test and evaluation process may also conserve resources.

This thesis examines two typical missions of the Mechanized Infantry. The actual field execution of the deliberate defense and movement to contact in an operational test requires months of effort just in the planning and preparation phase. During the execution of these missions, data collection in most cases is difficult. In comparison, Janus(A) simulations provide multiple executions of these missions in hours with accurate results from each employed weapon system.

A. CONCLUSIONS

This thesis shows that the operational effectiveness of the mechanized infantry is enhanced when fielded with the Javelin. Examination of the two proposed missions provides sufficient and conclusive evidence for significant differences between the unit types with Dragon versus

Javelin antiarmor weapons. Our results agree with those of Pate and McGuire. A summary of findings may be found in Table 6.

In both scenarios, the Javelin equipped Mechanized Infantry prove to be superior to the current Mechanized MTOE with Dragon with respect to antiarmor engagement range, blue force survivability, target stealing, and lethality. These four MOEs are statistically different to less than a five percent level of significance.

	Mission: Deliberate Defense Pairs: 500/501		Mission: Movement to Contact Pairs: 525/526	
MOE	P-value	Does Javelin cause a significant difference?	P-value	Does Javelin cause a significant difference?
Antiarmor Engagements	0.0215	**YES**	0.0006	**YES**
Survivability	0.0071	**YES**	0.0039	**YES**
Target Stealing	0.0003	**YES**	0.0197	**YES**
Lethality	0.0023	**YES**	0.0020	**YES**

Table 6. Summary of test levels of significance.

While the statistical analysis certainly shows that the Javelin enhances the unit's operational effectiveness, it may still be difficult to measure other advantages not defined in terms of MOEs. Many commanders may describe these advantages in terms of saving lives, time, and maintaining flexibility on the battlefield. For each commander, these advantages are personally weighted by how much he values each contribution provided by the Javelin.

As an example, the results of the antiarmor fires indicate that engagement ranges for the mechanized infantry platoon with the Javelin in the defense extends hundreds of meters further than with the Dragon. This same finding is true for the mechanized company in the movement to contact mission. In both cases, the Javelin provides better standoff with longer distanced armor kills. To the military commander, this standoff gives a tactical advantage on the battlefield. The more standoff he has, the more capable his force is to ward off the threat of close combat and slow the tempo of the enemy attack. Additionally, by delaying the enemy, the commander gains more time to make tactical decisions.

Further, when standoff no longer exists, enemy tank fires expose the vulnerability of the BFV. When opposing tanks penetrate the standoff range of the TOW missiles, blue forces lose a number of their BFVs. In some cases, units with the Dragon suffer the loss of all the BFVs. The force survivability at this point begins to decrease at a quicker pace. This is primarily due to the lack of support the Dragon provides outside a range of one kilometer. With a range of two thousand meters, the Javelin reduces the number of enemy tanks closing in on the BFVs. Thus, the observations of both the defensive and offensive operations show that the Javelin helps sustains force survivability at a much higher level. Particularly in the defense, force survivability is improved almost thirty-three percent more than observed with the Dragon. To the company commander this implies that possibly one third more of his combat power, namely a platoon, may survive.

Additionally, the fire and forget capability of the Javelin, gives the gunner the potential to shoot, move, and seek cover. Unlike the BFVs, the Javelin gunner is therefore less likely to be exposed to enemy fires. This gives the Javelin gunner the ability to survive longer on the battlefield and continue to destroy targets. As a result, both missions show that the Javelin destroys at least five of the ten vehicles from the opposing tank company. This peculiarity of the Javelin brings about an option for the commander not to expose and employ all his BFVs but rather make better use of his Javelin gunners. This option gives the commander more flexibility on the battlefield when employing his soldiers and equipment.

With the addition of the Javelin, the lethality of the commander's forces is increased. In both scenarios, the Javelin individually destroys three times more enemy vehicles than the Dragon. At this rate, four Javelins employed at the platoon level have the potential to destroy as many armor targets as the twelve Dragons at the company level for the same mission.

In summary, the results of the experimental data analysis indicate that the Javelin performs in a superior manner to the Dragon across all four measures of effectiveness. These results support evidence that the Javelin equipped mechanized unit has the ability to kill enemy forces from greater distances and with greater lethality, while maintaining improved survivability. In essence, two platoons with Javelin exhibit the combat power in terms of survivability and lethality of one company (three platoons) similarly equipped with Dragon. For the military commander, the contributions of the Javelin make it possible to increase the robustness of the mechanized force. As a conclusion, the Javelin's qualities make it a favorable alternative for the Dragon and prove it to be a worthy combat multiplier to the Mechanized Infantry's arsenal.

B. RECOMMENDATIONS

In this study, the Javelin weapon system is determined to be a favorable replacement for the Dragon in the deliberate defense and movement to contact missions. In both scenarios the Javelin plays a supportive role. This method of employment provides a genuine representation of how the Javelin is primarily employed in the field. The

Javelin is not a close combat assault weapon nor should it be modeled as such. The Javelin's primary mode of fire is top attack. Janus(A), however, models the Javelin as a direct fire (line of sight) weapon. The Javelin's ability to fire above trees and other ground clutter, deviations in elevation of terrain, and dust and smoke close to the ground allow it to maintain a high probability, Ph, of hit. In Janus(A), Ph is degraded based upon the number and level of vegetation cells that a weapon's line of sight passes through to the target. Due to this present representation and the advent of the Javelin's top attack mode, it is recommended that the Janus(A) model be refined to represent the high trajectory firing which is characteristic of the Javelin.

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