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Battlefield Utility of Antipersonnel Landmines and Proposed Alternatives

(Analysis in Support of the NATO SAS-023 APM Study)

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Executive Summary

This study consists of work done in support of the U.S. delegation to the NATO SAS-023 Antipersonnel Landmine Study Group, supplemented by additional work done for the U.S. Office of the Secretary of Defense Antipersonnel Landmine Alternative Concept Exploration Program (Track III). It explores the battlefield utility of current antipersonnel landmines (APL) in both pure and mixed APL/antitank minefields and evaluates the value of military suggested non-materiel alternatives.

The historical record is full of examples where the presence (or absence) of antipersonnel landmines made a critical difference in battle. The current generation of military thinkers and writers lack any significant combat experience employing either mixed or antipersonnel minefields, which leaves a critical gap in available expert advice for policy and decision-makers.

Because of this lack of experienced-based professional military knowledge, Lawrence Livermore National Laboratory analyzed the employment of antipersonnel landmines in tactical mixed minefields and in protective antipersonnel minefields. The scientific method was employed where hypotheses were generated from the tactics and doctrine of the antipersonnel landmine era and tested in a simulation laboratory. A high-resolution, U.S. Joint Forces Command combat simulation model (the Joint Conflict and Tactical Simulation – JCATS) was used as the laboratory instrument. A realistic European scenario was obtained from a multi-national USAREUR exercise and was approved by the SAS-023 panel members. Additional scenarios were provided by U.S. CINC conferences and were based on Southwest Asia and Northeast Asia. Weapons data was obtained from the U.S. family of Joint Munitions Effectiveness Manuals. The U.S. Army Materiel Systems Analysis Agency conducted a limited verification and validation assessment of JCATS for purposes of this study.

There is a significant range difference for effective fire between attackers and defenders that is based on relative exposure and stability and favors the defense. Holding the attacker at a distance for a short period of time has a very large impact on the outcome of the firefight or engagement. Mixed minefields positioned at ranges in excess of 2000 meters provide the defender a large advantage against an armored vehicle assault. At 2000 meters or greater, the attacker's best tactic to breach a pure antitank minefield is to employ dismounted soldiers to neutralize the mines. Even though none of the defender's direct fire antipersonnel weapons can reach this far, his antitank weapons are very effective against vehicle-mounted breaching systems at this distance. Antipersonnel mines mixed with antitank mines prevent this dismounted breach. No advances in dismounted countermine equipment have neutralized the antipersonnel landmine in this application. Removal of the antipersonnel mine, however, makes the dismounted breach a highly effective technique and essentially nullifies the minefield. In a separate application, an antipersonnel minefield positioned at 200 meters from a defending

position serves as a protective barrier to severely punish a dismounted attacker attempting to close within effective (for him) direct fire small arms range.

Experimentally testing the principle tactical employments of mixed minefields demonstrated a consistent requirement for the APL component – the APL makes the minefield effective. It dramatically improves the effectiveness of the direct fire antitank weapons in the defense. It allows success for smaller defending forces, thus allowing significant economy of force in secondary areas. In many cases it significantly reduces defender casualties. In every vignette studied, employment of mixed minefields appreciably increased attacker casualties, which ranged two to ten times greater than the number of casualties resulting from minefields containing only antitank mines.

A limited examination of the extension of mixed minefield effects beyond the battle where employed was conducted using the European scenario. APL were employed in mixed minefields in the initial engagements along the Forward Line of Troops (FLOT). The attack then continued through two additional sets of engagements against forward battalion reserves and the brigade reserve. No APL were employed in these later engagements. When APL were present in the initial engagements the resulting additional attacker casualties caused sufficient modification to force ratios in the later engagements to make a win-lose difference. This would imply that the "combat multiplier" effect of APL extends far deeper than the point of employment and has significant implications when rolled up across a theater of operations. Current state-of-the-art computer simulations used to examine theater war do not capture this impact.

Changes to tactics and composition of small units were examined as potential non-materiel alternatives to APL. No suggested change in tactics or weapon's mix fully replaced the results obtained with APL. Most required force structure changes. Any alternative that increased the size of the engaged defender force also increased defender casualties. The two alternatives that most closely replicated APL were: employing large numbers of Claymore munitions fitted with remote demolition firing systems (not currently employed in this manner), and increasing supporting artillery or mortars accompanied by a large increase in small unit ground sensors – both dedicated to this mission. Both of these require additional materiel investment. The artillery or mortar solution requires a significant increase in those elements of the force.

Prologue

"Kind-hearted people might of course think there was some ingenious way to disarm or defeat an enemy without too much bloodshed, and might imagine this is the true goal of the art of war. Pleasant as it sounds, it is a fallacy that must be exposed: war is such a dangerous business that the mistakes which come from kindness are the very worst."[1]

Current policy of all NATO members excepting Turkey and the United States has eliminated the antipersonnel landmine (APL) from their military arsenals. Current US policy, as expressed in Presidential Decision Directive 64, is to eventually eliminate all US usage and destroy all US stockpiles of APL. It is important for all members to replace the battlefield utility of APL in some manner in order to not make the dangerous business of war more dangerous by increasing force risk and reducing force efficiency.

Examining the historical record, APL and mixed (APL and antitank) minefields have repeatedly proven themselves as critical weapons in battle. After Montgomery's victory at El Alamein in WWII, a severely mauled Africa Korps was able to escape and retreat 1200 miles without being overtaken and destroyed by the pursuing British because Rommel's engineers repeatedly blocked the route with undefended mixed minefields. These reduced the British "fully motorized 8th Army to an advance rate equivalent to that of Napoleon's infantry, over a hundred years before."[2] On each of the first three days of the battle of Kursk (July 1943, the largest armored battle in history) the Germans lost the equivalent of an armored division in the Russian minefields. The Russian antitank mines were protected by antipersonnel mines, which could only be breached at great cost. Over the course of the battle, mines caused 52% of German tank losses (805 tanks were destroyed by mines). Losses in this battle destroyed the German ability to conduct offensive operations on the Eastern Front for the remainder of the war.[3] On Omaha

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1 Clausewitz, C. von, "On War," edited and translated by Howard and Paret, 1993, Alfred A. Knopf, Inc., New York, page 83.

2 Schneck, W., "Case Studies in Effective Landmine and Countermine Operations," published in "Proceedings of the Fourth International Symposium on Technology and the Mine Problem," March 13-16, 2000, Naval Postgraduate School, Monterrey, CA "During their pursuit, the field companies of the Royal Engineers had managed to clear an average of 20 kilometers of road per day, at a cost of 170 sappers. Effectively, the pioneers had limited the sappers of the fully motorized 8th Army to an advance rate equivalent to that of Napoleon's infantry, over a hundred years before. The badly mauled panzerarmee was able to retreat 2,100 kilometers in 22 days without being cut off and destroyed by the 8th Army. With deadly effect, *Generalmajor* Karl Buelowius' pioneers and the men of the 90th *Leicht Afrika* Division had bought *Generalfeldmarshall* Rommel the time that he so desperately needed." Pg. 13.

3 *ibid,* "The initial minefields accomplished one of their objectives, slowing the German attack. Where the German breaching was accomplished by hand in daylight as in the 31st Infantry Division attack sector, this delay amounted to several hours, allowing the Soviets time to bring forward additional troops and prepare for counterattacks. The minefields also accomplished their second objective, inflicting casualties on the attacker. According to Soviet reports, during the first day of combat the Germans lost 98 tanks and assault guns and more than 2,000 soldiers in the minefields. About 75% of these loses were in the minefields laid

Beach, the US invasion force was stalled behind the seawall and almost destroyed -- partially because of the antipersonnel minefields covered by fire that were located immediately behind the seawall.[4] In Korea the antipersonnel mine was crucial in stopping massed infantry assaults and allowing retreating UN forces to retire and establish defensive lines *"Rifle and machine-gun fire did not stop the enemy, but the mines stopped them cold."*[5] History is full of similar examples of the application and criticality of this weapon.

Because of the historically demonstrated importance of APL all NATO nations are seeking appropriate alternatives that will provide similar APL battlefield contributions without adding to humanitarian concerns. Selecting an appropriate alternative requires a detailed understanding of what causes the APL and mixed minefield to be so useful and of the precise contribution that must be replaced.

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in advance. To put these figures in perspective, one should recall that this is about the same as the number of tanks in a typical panzer division on the north face of the Kursk salient. Thus, the Germans lost about the equivalent of the tanks of a panzer division in the minefields on 5 July. … On 6 July, the eight mobile obstacle detachments of the 13th Army sowed 9,000 additional mines which cost the Germans 88 tanks and self-propelled guns on the second day of the battle. The following day, 8,000 new mines accounted for another 93 tanks. … Of the 2,700 tanks and assault guns that the Germans committed to the battle, the Soviets claimed that 1,500 were destroyed, 805 by mines. Indeed, mines claimed 52% of the German tanks knocked out, 30% of the total number of committed tanks. **The Germans never regained the operational initiative on the Eastern Front after Kursk.** (emphasis added)" Pg. 8

[4] American Forces in Action Series "OMAHA BEACHHEAD (6 June-13 June 1944)," Historical Division War Department, Facsimile Reprint, 1984, CMH Pub 100-11, Center of Military History, United States Army, Washington, D.C., "…elements of the assault force were immobilized in what might well appear to be hopeless confusion. …Behind them, the tide was drowning wounded men who had been cut down on the sands and was carrying bodies ashore just below the shingle. Disasters to the later landing waves were still occurring, to remind of the potency of enemy fire. Stunned and shaken by what they had experienced, men could easily find the sea wall and shingle bank all too welcome a cover. It was not much protection from artillery or mortar shells, but it did give defilade from sniper and machine-gun fire. Ahead of them, with wire and minefields to get through, was the beach flat, fully exposed to enemy fire; …" Pg. 57

[5] Westover, J., "Combat Support in Korea," 1991, CMH Publication 22-1, Center of Military History, United States, Army, Washington D.C. "We completed our work at about 0200, and the minefield party began to withdraw. We were careful to go east of the field, to take advantage of the protection of the field itself. Just at that moment a company of North Korean infantry began an attack. They came from the direction of Yodek-tong, bunched up and running upright. Almost the entire company got into the first belt of mines before they hit the first trip wire and realized their predicament. Mines exploded and men screamed. The attackers turned in panic only to kick more of the trip wires. The whole affair lasted scarcely five minutes, yet we estimated a hundred casualties." Pg. 30. "Ten or fifteen enemy engineers moved along the road on their hands and knees, feeling for mines. When they reached the first activated mine and felt its pressure plate they jerked it out! The explosion killed every one of these men. The infantry, as we had anticipated, rushed for the shoulders of the road, and immediately ran into our maze of trip wires on the antipersonnel mines. Of the 50 to 100 men, surely half were killed. … On 5 September the enemy began a drive on the front of the ROK 8th Division (on our right) and by 9 or 10 September had taken Yongchon, some ten miles to our rear. The 19th Infantry was placed to protect our rear. Once more we had to shorten our line, and it was minefields that gave us time to move and erect a defensive barrier." Pg. 33. "As our infantry withdrew down the Yodok-tong road toward Hill 728, the enemy attacked banzai style and a regiment strong, through Minefields 2 and 3. These minefields had been built up to contain some five hundred antipersonnel mines, and we had them covered with small arms fire. Rifle and machine-gun fire did not stop the enemy, but the mines stopped them cold. They milled around for a few moments trying to find a passage, and the automatic weapons and mines wounded or killed five hundred. The attack soon stopped and our men withdrew without further interference." Pg. 34

Unfortunately, there is only limited and unquantified information on landmine contributions available to guide policy and military decisions. The United States, for example, has had extremely limited usage of minefields since the Korean War. No serving U.S. officer has actually employed mixed minefields in combat. Very few of them have actually employed APL in combat. The detailed sets of plans for Korean contingencies and the Cold War General Defense Plan for Europe all included extensive minefields which were never actually tested in combat. Landmine simulators are either not available or are insufficiently realistic to accurately portray their contribution in field exercises. Until very recently, no computer combat simulation model accurately portrayed landmine usage either at the tactical or operational level. Until the current effort to ban antipersonnel landmines became a serious issue, no analytic study had looked at their contribution. In fact, a U.S. General Officer Steering Committee chartered an Analytic Task Force at the Combined Arms Center in 1982 to study landmine contributions and determine how many the United States needed in the stockpile. This study was the last significant look at the problem until now and simply revealed the lack of data in this area.[6] The Analytic Task Force in turn recommended a study be conducted to quantify the military utility of antipersonnel landmines. That study was never conducted

Because of the lack of information on this subject, Lawrence Livermore National Laboratory (LLNL) has undertaken to support the Office of the Secretary of Defense program designed to find alternatives to antipersonnel landmines by assessing through combat simulations and analysis the battlefield utility of the APL and by comparing the equivalent utility of proposed alternatives. This work was extended to support the NATO SAS-023 Panel Military Applications Study on Alternatives to Anti-Personnel Mines through the U.S. delegation. *The work was performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.*

Previous work with an Army Training and Doctrine Command (TRADOC) Integrated Concept Team, the TRADOC Analysis Center at White Sands Missile Range, and the Dismounted Battlespace Battlelab Analysis Center had given LLNL a significant

[6] Waters, M.E. & Thurman, E.E. MAJ (1982) "Mine warfare analysis: analytic mine task force," Technical Memorandum 1-83, Ft. Leavenworth, KS: United States Army Combined Arms Center. "On the occasions when mine usage has been altered within a study, it has been demonstrated that mine warfare can mean the difference between winning or losing the battle. Yet a good measure for all of the contributions (beyond attrition) that mines bring to the battlefield has not been established" ... "The examination of the use and effects of antipersonnel mines had been minimal in past wargames. The lack of play of AP mines is due mainly to the measures of effectiveness which concentrate on kills within a highly mobilized threat force and the fact that dismounted troop movement within the scenario gamed is minimal. Because of the level of play required to accurately measure antipersonnel mine effects on dismounted forces, most models cannot portray antipersonnel mine effectiveness. Additional analysis is needed to evaluate the requirements of antipersonnel mines when used to supplement antitank mines and to examine antipersonnel mine effectiveness." pg. 24,

understanding of the problem.[7] The focus of that effort was to take a broad look at combat and to identify the critical functions performed by APL and their contribution to battle. As the study was under tight time constraints, the simulation teams were only able to use previously existing scenarios. Two major critical functions identified were the protection of scattered antitank mines in mixed minefields and protection of the small unit position from assault and overrun. The current study is an extension of the earlier LLNL work and focuses on these areas.

This report addresses the issues by first examining, in a qualitative way, factors critical to close combat. Antipersonnel landmine contributions are examined by comparing a number of scenarios fought both with and without antipersonnel landmines in a combat simulation. A scenario based on European terrain and employing a mix of combat systems was selected for this study by experts from EUCOM and approved by the SAS-023 Study Group. This scenario was used to examine many of the applications of APL. Experts from U.S. SOUTHCOM, CENTCOM, PACOM and TRADOC selected additional scenarios for a parallel study conducted by the United States. Results from this separate study both support the results of from the European scenario and extend them into other APL applications. These results are included in this report to provide a comprehensive assessment of the APL battlefield contribution. A series of proposed non-materiel alternatives were then substituted for the APL, the European simulations were re-run, and the battle results compared. Alternatives are ranked based on relative effectiveness in these scenarios.

[7] Greenwalt, R.J. and Magnoli, D.E., "Examination of the Battlefield Utility of Antipersonnel Landmines and the Comparative Value of Proposed Alternatives," UCRL-ID-130004, 23 December 1997, Lawrence Livermore National Laboratory.

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The LLNL study team is solely responsible for the analytic results presented in this report and the conclusions drawn from them

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Chapter One

Theoretical Underpinnings of Close Combat

Wars are composed of a series of campaigns made of battles that consist of engagements. Engagements consist of a network of small firefights between groups of attackers and defenders. When examined microscopically, wars are essentially fought by platoons and squads engaged in firefights.[8] Strategy and tactics are simply the techniques used to select the firefights.

The strategic level of war is the selection of objectives that achieve the national aim and the campaigns necessary to win those objectives. The operational level of war deals with the selection of campaign objectives and the battles to win the campaign. Tactics are the recipes employing fire and maneuver that are used to win the firefights, engagements, and battles. Thus tactics are embedded in the actions necessary to achieve the operational objectives, win the campaign, and thus win the war.[9]

At the engagement and firefight levels, the primary elements of tactics are fire and protection. The basic principle of firefight and engagement tactics is to bring as much firepower as possible to bear on the enemy.[10] Movement is a secondary element related to improving fire effectiveness.[11] Minefields affect movement and thus are secondarily related to fire. Minefields also are a component of fire, because of the direct casualties they cause. *The focus of this study is on the mine contribution to the engagement and the associated firefights as this level is where they primarily participate in combat.*

A critical measure of the degree of success in the firefight or engagement is the fractional exchange ratio (FER). This is the fraction of the attacking force that has been lost divided by the fraction of the defending force that has been lost. In other words, the percentage of the attackers that are lost for every one percent of defenders lost. If the

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[8] Patton, GEN G., "War as I Knew It," Pyramid, 1970, New York. Pg. 351.

[9] Ancker, C.J., Jr, "A Proposed Foundation for a Theory of Combat," in "Warfare Modeling," edited by Bracken, Kress, Rosenthal, 1995, Military Operations Research Society. "[C]ombat consists of comparatively small, terminating firefights combining into larger engagements ...The evidence is undeniable that the firefight is a comparatively small, terminating stochastic attrition process. ...The firefight is simply the basic building block. The usual way to label the hierarchy of aggregated combat levels in increasing order of complexity and magnitude, is firefight, engagement, battle, campaign, and war."

[10] Marshall, S.L.A., "Men Against Fire; the problem of battle command in future war." Peter Smith, 1978, Gloucester, Mass. "... inasmuch as the problem of how much fire can be brought to bear is the basic problem in all tactics. In fact., it is tactics in a nutshell, and the other elements of tactics are simply shaped around it." Pg. 51

[11] ibid. "Commanders in all ages have dealt with this central problem according to the weapons of their day and their imaginative employment of formations which would bring the maximum strength of these weapons to bear at the decisive point. Surely that is the heart of the matter so far as the mechanics of battle are concerned – to arrange men, to move them, to counter-move them, so that their own ranks will have a lesser exposure while their weapons are exploiting a greater vulnerability in the ranks of the enemy." Pg. 51

FER is 1.0, both sides are losing force at the same rate. If it is above 1.0, the attacker is losing force at a greater rate than the defender and if the fight proceeds long enough without change the defender will win. If it is below 1.0 the attacker is losing force at a slower rate than the defender and if the attacker perseveres he will win. FER is frequently used as shorthand to describe the quality of the engagement.

The basic tactics objective for the firefight or engagement is to obtain, through fire and maneuver, a favorable FER. Two categories of weapons are used to cause enemy casualties and achieve this, those that are aimed and fired "directly" at the enemy and those that are fired "indirectly" at a point on the earth's surface where the enemy is thought to be by gunners who cannot directly see their target. Each category has unique characteristics that must be understood to appreciate the dynamics of the firefight.

Direct fire effectiveness is based on the probability of hitting the target (represented by Ph), and the subsequent probability of causing a casualty (for our purposes represented by Pk). Attackers and defenders differ in direct fire effectiveness primarily because of differences in their ability to hit their opponent. This difference is caused by differences in stability, exposure, and target acquisition. The defender is typically stationary with a more stable firing platform, is protected by a fighting position, is camouflaged, and is shooting at a fully exposed opponent. The attacker is moving which gives him a less stable firing platform, is fully exposed, and is shooting at a much smaller and difficult to see opponent. Though the attacker's movement degrades the defender's ability to hit him, this is more than made up for by the much larger exposed target that he is presenting, his lack of protection, and the defender's stable firing position. Though the attacker's target is stationary, this is countered by the much smaller exposure of the defender and the difficulty the attacker has acquiring him. This difference in ability to see, hit, and destroy the target is responsible for the basic tactical principle that attackers must outnumber defenders.

In an attack, a defender fires at a single attacker, with some probability he will hit his target. Depending on the force ratio, some larger number of attackers will all be firing at the same defender, each with some lower probability of hitting him. The probability of the defender being hit is a cumulative probability based on hit probabilities of all of the attackers that are firing at him simultaneously. Both defender and cumulative attacker Ph rise as the distance between attackers and defender decreases.

A simplified analysis using rifle firing data showed that an attacking force's overall hit probability would exceed the defender's if they could bring a force consisting of four attackers for each defender within 100 meters of the defending position. The defender must prevent this by causing sufficient casualties to reduce the force ratio below four to one before the attacker gets to this range. Figure 1 compares attacker (referred to as the Red force in future) total hit probability for one engagement cycle against defender (the Blue force) hit probability for various force ratios of attacking Red against defending Blue. (An engagement cycle is defined as Blue firing once and the appropriate number of Red based on the force ratio returning fire once. Blue hit probability is defined as the probability that Blue hits one of the Reds. Red hit probability is the probability of at least one of the Red hitting Blue.) As long as the Blue hit probability line is above the appropriate Red probability line, Blue will cause more casualties and have a favorable FER. When Red's probability rises above Blue's, the opposite will be true.

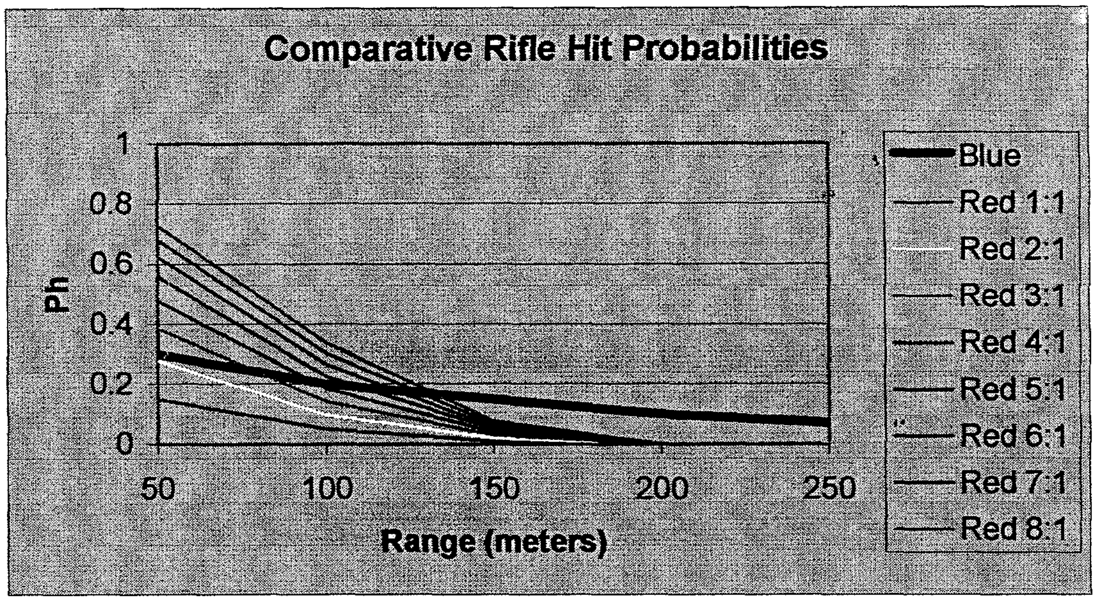

Figure 1, Rifle Hit Probabilities

A similar analysis using generic data for main battle tanks showed that the defending antitank weapons must effectively engage the enemy and reduce the force ratio below three to one before the enemy gets within 1500 meters of his position (figure 2).

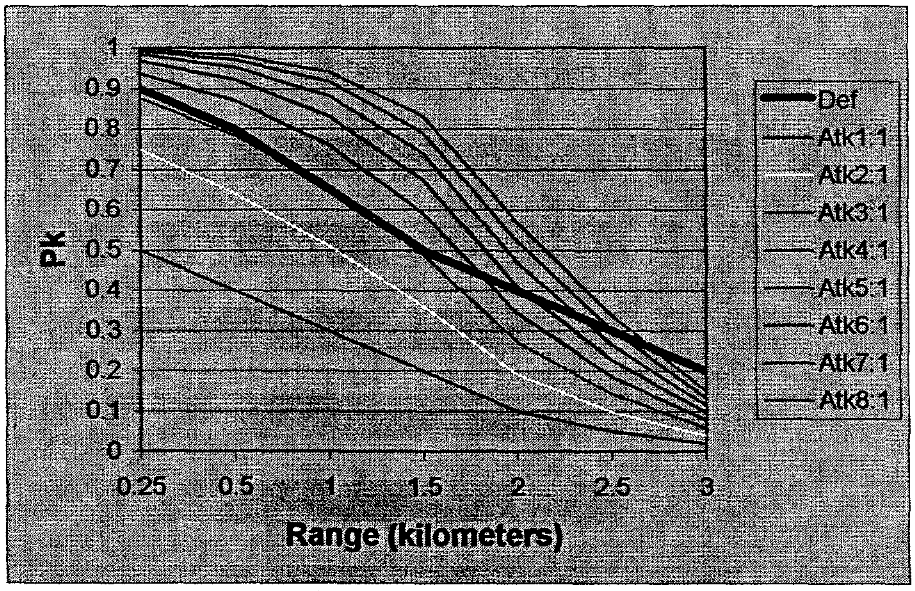

Figure 2, Tank Hit Probabilities

Indirect fire (from artillery or mortars) is a major force component employed against exposed, soft targets. The key to its effectiveness is ensuring that the projectiles impact on an area containing unprotected targets at the time they are present. This is difficult, as indirect fire has significant delays associated with striking a target: time to pass a call for fire to the firing unit, time to gain priority of fire from the firing unit, time to calculate firing data, time to aim and fire the guns, and time of flight of the projectiles. Because of these time delays it is virtually impossible for artillery to hit a moving target. Analysis using actual mortar data indicated that it would require firing 30 mortar projectiles to obtain a 50% probability of hitting a moving soldier. In addition, unless the projectiles detonate close to the soldier, they have little effect on his movement.[12]

Indirect fire has limited utility against a moving force. To be successful, the moving force must be stopped and held stationary for sufficient time for the artillery to strike. This is called "fixing" the force and is achieved either with obstacles such as minefields or with a sufficient volume of direct fire that the enemy is forced to go to ground.

A battle position is a stationary target and, as such, the time delay for indirect fire is irrelevant. Because of the ease with which indirect fires can repeatedly strike a battle position, the defender generally goes to great lengths to reduce his vulnerability. Design of a defensive position incorporates both protection and dispersion. Defenders dig themselves in (both infantry fighting positions and vehicle positions) and install overhead cover over individual and crew-served weapons. This requires the indirect fire projectile to either strike the position directly (or extremely close to the position – a matter of meters) or to send its fragments through small firing ports into the position. Dug-in armored vehicles must suffer a direct hit. Defending weapons are dispersed over a large area to dilute the effects of the artillery and reduce the probability that a given projectile will strike sufficiently close to any two positions to destroy both of them.

Massive artillery preparations during World War I, as well as the experience using extensive artillery bombardments in the Pacific island campaigns and the Normandy landings during World War II all demonstrated the ineffectiveness of indirect fire in destroying protected defenders. Using the Soviet's targeting norms, it requires approximately 600 122mm artillery projectiles to destroy 30% of a dug in rifle platoon. This quantity of ammunition would require almost an hour to fire by a battery, and would weigh over 42 tons.

Other than causing suppression or obscuration, indirect fire has very limited utility against a dug-in, protected defender unless fired in large quantities.

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[12] Raaen, CPT John, as quoted in Ambrose, S., "D-Day, June 6, 1944," 1994, Touchstone, New York, "After five minutes under artillery fire, you learned when you had to duck and when you didn't. You could tell from the sound of the incoming rounds where they were going to hit. If they were going to hit fifty yards away, it was too much trouble to hit the dirt. You just stayed up and kept moving." Page 453

Both the defender and the attacker employ a combination of arms against their opponent. The complementary effects of various lethal systems produce a result larger than the sum of the individual contributions.[13] As an example, a soldier exposed to direct fire from rifles or machineguns can protect himself by dropping to the ground. A soldier exposed to artillery or mortar fire protects himself by running out of the target area. If the soldier is exposed to both simultaneously, the action to protect against one puts him at risk from the other.

The attack

The attacker has the advantage of selecting the time and place of the attack. To succeed, he must reduce the FER below one (in other words, the firefight must destroy the defending force at a greater rate than the attacking force). As his force's ability to hit stationary defenders while moving is lower than the defender's ability to hit moving attackers, he must mass a large number of attackers against a small number of defenders and quickly move this force within effective range before accepting too many casualties.

The attacker's focus is to first mass overwhelming lethality against a small element of the defense and overwhelm it, then to attack and destroy the remaining defenders one element at a time. In order to do this, he must array the maximum amount of firepower against the initial point of attack and prevent the enemy from effectively responding.

The attacker seeks to:

- Reduce the effective number of defenders through maneuver. In other words, move his attacking force to a position where they can mass their fires against an isolated or weak point in the defense and overwhelm that point.
- Reduce the effective number of defenders through suppression. In other words, place sufficient fires on the defending position that they cause the defender to seek cover and not to return fires.
- Reduce the effective number of defenders through obscuration. Place smoke between attacker and defender so that the bulk of the defenders' weapons cannot be aimed against an attacker.
- Increase the actual number of attackers through closure speed. Move the attacking force fast enough to get sufficient force close enough to swell the number that can place effective fires on the defender.
- Increase the effectiveness of direct fires through range reduction to increase the attackers' probability of hitting defenders.

Freedom of maneuver is critical for the attacker!

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[13] Lind, William S., "Maneuver Warfare Handbook," 1985, Westview Press, Boulder, CO. " Combined arms hits the enemy with two or more arms simultaneously in such a manner that the actions he must take to defend himself from one make him more vulnerable to another." Pg. 20

The defense

The defender has the advantage of being able to prepare the ground for the fight. This means he can position his forces in battle positions that mutually support each other and mass their fires into preplanned engagement areas. He also can dig in his force to provide significant protection against both direct and indirect fire. He can camouflage his force to make acquisition difficult.

The defender's focus is to force the attacker to pass through an engagement area where concentrated defending fires have a high enough hit probability to cause sufficient casualties to the attacker to achieve a favorable FER. In other words, he wants to engage the attacker with as many weapons as possible at a range where the firefight will destroy the attacking force at a greater rate than the defending force.

The defender seeks to:

- Position his forces so that the attacker will have to cross engagement areas of mutually supporting defensive fires.
- Increase the effective number of defenders by ensuring they are positioned in concealed, fortified positions with wide fields of view and fire.
- Increase the effectiveness of the defenders by having engagement zones that are at sufficient distance that the attackers have little chance of employing effective fires in return.
- Increase the effectiveness of the defenders by holding the attacker at this range until the attacking force is reduced to the point that it can no longer prevail.

Reducing the attacker's freedom to maneuver is critical for the defender!

The antipersonnel landmine

The antipersonnel landmine fundamentally acts like a small, robotic infantryman assigned to defend a small piece of ground and who will reliably attack anyone who encroaches on his terrain. As such it is a part of the firefight and the engagement. It influences the tactics of both the attacker and defender. It is a defensive weapon, which contributes to the defensive components of both offense and defense. It serves to augment a force whenever the force is insufficient to deal with the enemy.

Within the engagement, the antipersonnel landmine provides some unique contributions. Because it is an explosive device, initial activation provides clear and early warning to defending forces of an intrusion. It will produce one or more casualties when activated. Once its presence is suspected it produces a delay as the attacker attempts to avoid it – which can make indirect fire effective. If the attacker breaches a lane through a minefield, it canalizes his force and meters it into the engagement. If employed within antitank minefields or in conjunction with other obstacles, it complicates and slows the attackers' ability to breach them.[14] The presence of the antipersonnel landmine also adds significant stress to the combined arms engagement, as the best defense against the landmine – slow movement to avoid the mine – is exactly wrong when under fire by direct or indirect fire means.[15]

The antipersonnel landmine has an additional feature. Because there is no active combatant opponent, the attacker has no one to engage and overpower – he cannot fight back. He is faced with a situation where his own action may produce lethal consequences to himself. The terrain itself offers some probability of lethality in a specific area and his movement within this area causes the lethal result. Additional forces on his side, added firepower, better tactics all are to no avail. He has only three possible courses of action open to him: accept the risk and subsequent casualties, avoid the mined area by going somewhere else, or stop his movement and deal with the mines. If circumstances require him to accept the risk and continue movement, there are psychological implications, as the lethal attack is both unpredictable and unpreventable. His risk (and psychological burden) increases with his forward movement. The impact of this psychological burden on the soldier and commander is not assessed in our study. Current analysis indicates it may be severe though it is currently unquantifiable (see Kolasinski[16]).

Minefield employments fall into two general categories: tactical and protective.[17] Tactical minefields are designed to increase the effectiveness of other weapons by manipulating the enemy's freedom of movement. They do this by forcing the attacker into an advantageous engagement area, holding him at sufficient distance to give the defender a probability of hit (Ph) advantage, or metering the attacking force into the engagement area so that the defender's rate of fire is effective. Protective minefields are a force protection system designed to counter overrun or infiltration. Basically they augment the defending fires: their primary function is to directly cause casualties during an assault with a secondary function of providing alert in the event of infiltration.

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[14] Greenwalt, R.J. and Magnoli, D.E., "Examination of the Battlefield Utility of Antipersonnel Landmines and the Comparative Value of Proposed Alternatives," UCRL-ID-130004, 23 December 1997, Lawrence Livermore National Laboratory. "...critical APL missions ... provide close protection, protect AT mines, protect against infiltration, disrupt operations ..." pg 3

[15] Lind, William S., "Maneuver Warfare Handbook," 1985, Westview Press, Boulder, CO. "Combined arms, like other elements of maneuver warfare, seeks to strike at the enemy psychologically as well as physically. ... Either choice gets him in trouble, and the fact that his problem has no solution strikes at his mental cohesion." Pg. 20

[16] Kolasinski, E. M., "The Psychological Effects of Anti-personnel Landmines: A Standard to which Alternatives can be Compared," Engineering Psychology Laboratory Report 99-2, 12 April 1999, Department of Behavioral Sciences and Leadership, United States Military Academy. "The major factors involved in the psychological effects of APLs are control, the inability to fight back against them, risk, and uncertainty....[A] primary aspect of APLs is that they remove control from the soldier over their own actions, safety, and destiny." Pg. 44

[17] U.S. Department of the Army Field Manual, FM 20-32, "Mine/Countermine Operations," 29 May 1998, "Tactical and protective obstacles have different purposes with regard to the enemy's maneuver. This difference causes them to have a particular relative place on the battlefield. Tactical obstacles attack enemy maneuver and are placed on the battlefield where the enemy maneuvers from march, prebattle, and attack formations. Protective obstacles are used to protect the force from the enemy's final assault onto the force's position. Protective obstacles are close to defensive positions and are tied in with the FPF of the defending unit." Chapter 2

Tactical minefields have four distinct functions:
-Disrupt, which is designed to break formations and movement timing in order to disconnect elements in a coordinated attack and meter attacking force elements into the battle (it is not necessary to cover a disruptive minefield by fire in order to do this).
-Turn, where the minefield either entices or forces the attacker into a desired direction in order to control enemy movement into an engagement area or away from a protected area (if the enemy is not turned the minefield must perform like a blocking obstacle).
-Fix, where the minefield is used to first disrupt a portion of the attacking formation, then disrupt another portion in unpredictable fashion causing maximum confusion, delay the force while it negotiates the minefield. and restrict the rate of passage of the force through the mined area in order to hold the enemy within the engagement area.
-Block, where the minefield provides so difficult a breaching problem that the attacker must stop his forward motion and employ a deliberate breach.

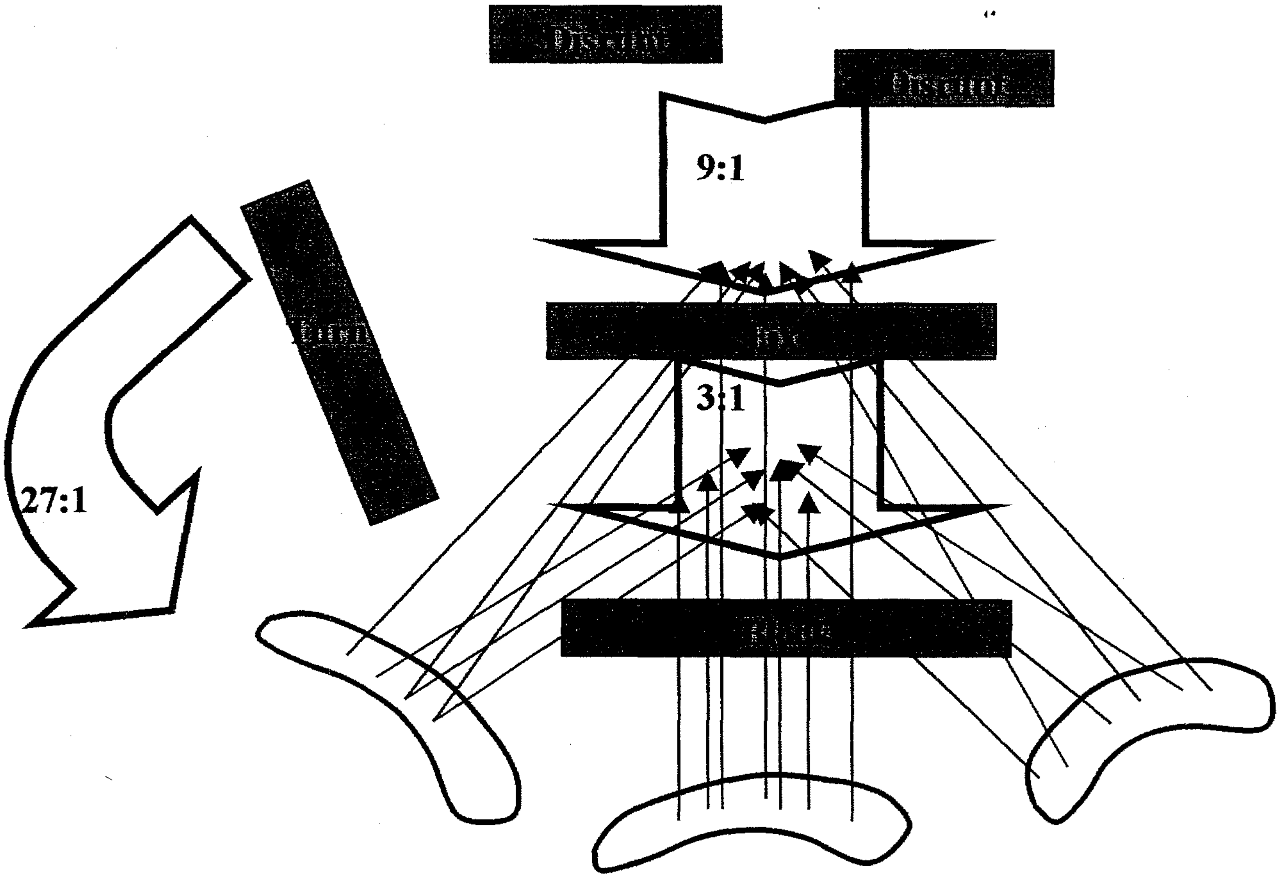

Figure 3, Tactical Minefield Missions

Figure 3 graphically illustrates these missions. The attacker, portrayed with the red arrows, is seeking to attack the defender who is portrayed with the blue positions. The attacker has begun the attack with a nine to one force ratio. If possible, he would like to attack from a flank so that he is only attacking a small portion of the defender and can achieve a 27:1 force ratio. The turning obstacle discourages this and keeps him exposed to all fires in the engagement area directly in front of the defender. The fixing obstacle holds the attacker at a range where the defender's fires are more effective, reducing the number of attackers through casualties and metering to a three to one force ratio. The blocking obstacle stalls the attack before the close assault and the force ratios are such that the defender should prevail. The disruption obstacles help break up the attacking units timing so that following forces are delayed until the leading forces are destroyed.

Each tactical minefield function is designed to attack the enemy's freedom of maneuver in a somewhat different manner. Protective minefields are simpler, as they are designed to basically cause casualties and thus protect against infiltration or assault. The primary contributions that the minefield makes to each of its classical missions are shown in Table 1.

Table 1, Minefield Contributions

	Disrupt	*Turn*	*Fix*	*Block*	*Protect*
Casualties	X	X	X	X	X
Operational Delay	X				
Delay in Engagement Area			X	X	
Metering			X		
Influence Enemy to Avoid		X	X		

The category "Casualties" is self-explanatory, the threat of casualties causes the enemy to respond to the minefield. "Operational Delay" refers to the slow-down in enemy approach (prior to engagement) due to confusion and interference from minefields. "Delay in Engagement Area" means holding the Red force under fire at a range where defender's fires are more effective than the attacker's during the engagement. "Metering" means reducing the rate of passage of forces through the obstacle and arrival at a favorable range to the defenders. "Influence Enemy to Avoid" means providing sufficient knowledge that a minefield is present (and its rough limits) so as to convince the enemy to change course.

APL are general purpose weapons, much like rifles, and contribute to many missions. The APL Track III program focuses on two APL missions: the APL component of the mixed minefield and the non-self-destruct (NSD) antipersonnel mine in the protective minefield role. The mixed minefield is primarily used as a tactical minefield where the APL protects the antitank mine, while the NSD mine is principally used in a protective minefield to protect the defending force. These APL missions are the focus of this study.

Countering the minefield

When an attacker encounters a tactical minefield, his objective is to retain his freedom of maneuver and not react according to the defender's design. In most cases his best course of action is to pass his force through the minefield as rapidly as possible (while keeping casualties to a minimum) and not be held up or deflected by it. He does this by conducting a breaching operation.

Breaching a minefield is a complex combined arms undertaking that will not be described here in any detail.[18] Actual breaching techniques (physically eliminating mines to produce a set of paths or lanes though the minefield) fall into two general categories: mounted (or mechanical), using armored vehicle-mounted equipment; and dismounted, using soldiers employing man-carried systems. Equipment types used against surface minefields are listed in Table 2. The breaching technique chosen depends on maximizing speed and minimizing risk to the force (details of breaching techniques are described in Appendix C).

Table 2, Breaching Systems

Type	System	Effective Distance
Mounted	Plow/roller	Contact
	Rocket-propelled line charge	100-130 meters
	Magnetic signature duplicator	<10 meters
	Vehicle weapon	200 meters
Dismounted	Hand-placed explosives	Contact
	Hand-thrown grapnel	15 meters
	Rocket-propelled line charge	45 meters
	Rifle-launched grapnel	85 meters
	Small arms	200 meters

If the breach effort is unopposed, the mounted systems are the fastest method to construct a lane through the minefield. Their short effective distance requires the carrier vehicle to be well within range of defending fires, and consequently at high risk from the defenders' antiarmor weapons. The plow/roller and magnetic signature duplicator require the vehicle to traverse the minefield to leave a cleared lane. The line charge must be launched from the edge of the minefield, and then the lane must be proofed (neutralization of mines verified) by a plow/roller system driving through the lane. Vehicle weapons are not effective against small surface mines, such as the Volcano mine, as small terrain irregularities serve to provide cover and concealment. They are effective against a larger surface mine device.

Dismounted systems are all short-distance systems that require the soldier to move through the minefield. In the past, engineers seldom employed dismounted breaching techniques. Almost all minefields were protected by antipersonnel mines, which made this an extremely slow and hazardous procedure. The hand-thrown grapnel was the only standoff technique that could counter the tripwire and it was painfully slow. The rocket-propelled line charge and the rifle-launched grapnel have not significantly improved this

[18] U.S. Department of the Army Field Manual, FM 3-34.2, "Combined-Arms Breach," 31 August 2000.

capability against a mixed minefield, due to the width of the lane required for vehicles and the depth of the mixed minefield. Both of these systems are ineffective against a mixed minefield (details are covered in Appendix C).

With the elimination of antipersonnel mines, however, dismounted techniques become practical against the scattered antitank minefield where the mines are on the earth's surface and easily seen with the naked eye. Without the risk of antipersonnel mines, the engineer can move at a fast walk or with short rushes, to cross the minefield and eliminate the antitank mines.

Tactical minefields are optimally employed at a range of 2000 to 3000 meters from the defender where the defender has a high hit probability and the attacker does not. (If the minefields were positioned at closer ranges, the attacker would have enough volume of sufficiently accurate fire to destroy the defender without having to cross them. At greater ranges the defenders weapons don't reach the attacker, making breaching simple.) Defending antitank fires from dug in tanks and antitank missile systems have high hit probabilities at these ranges and are used to cover tactical minefields. Defending antitank systems, particularly tanks, are not easily suppressed by the attacker's weapons and they employ thermal sights that can see through obscuring smoke. These systems are very effective against forces attempting to bull through the minefield or employ armored vehicle-mounted mechanical breaching equipment. The defender, however, does not have direct fire antipersonnel weapons that are effective at these ranges and must rely on indirect fires to attack dismounted soldiers.

Tactical mixed minefields must be breached and passed by attackers with minimal loss of their high-value armored vehicles. Most potential opponents have demonstrated a willingness to risk dismounted soldiers to prevent losses of tanks and armored carriers. This is particularly true of opponents that have a coercive form of government[19] or a high level of religious fanaticism (such as Iran during the Iran-Iraq war of the 1980s). If a technique employing dismounted soldiers to breach has a possibility of success it will be attempted and must be countered to ensure minefield effectiveness.

Mixed minefields are used to reduce the attacker's breaching options. Dismounted soldiers can breach a pure antitank mine minefield in a matter of minutes. This was illustrated by the British breaching Field Marshall Rommel's minefields at the battle of El Alamein in WWII. His initial minefields contained only antitank mines due to a shortage of antipersonnel mines.[20] The British quickly breached them. His second belt of minefields included antipersonnel mines and so delayed the British that the entire 10th

[19] Toppe, Generalmajor A., "Demolitions and Mining," MS # P-074, translated by J.B. Robinson, Historical Division, Headquarters, United States Army Europe, 1953, "2. Personnel losses – in contrast to tank losses – make no impression on the Russians." Pg. 19

[20] Rommel, Field Marshel E., "The Rommel Papers," edited by B.H. Liddel-Hart, 1953, Harcourt, Brace, Jovanovich, Inc., New York, "We wanted to ensure that the work of clearing the minefields proceeded at the slowest possible speed and not until after our outposts had been eliminated. Most of the mines available in Africa were unfortunately of the anti-tank type, which infantry could walk over without danger. They were, therefore, comparatively easy to clear." Pg. 300.

Armoured Division attack failed to achieve its first day objectives.[21] The APL component makes the dismounted breach very costly in terms of casualties and delay, and forces the attacker to use mechanical breaching systems. This is to the advantage of the defender, as generally the attacker has limited mechanical breaching equipment and will produce fewer lanes. It also allows the defender to effectively reply to the breach attempt by using his long-range antitank systems against the mounted breaching systems.

The protective minefield is installed within rifle range (200 meters) of the defender where the attacker is expected to assault. The defender can mass effective direct fire from rifles and machineguns at this range that will prevent the attacker from stopping to conduct a dismounted breach.

The protective minefield, encountered unexpectedly, can cause an attack to stumble as the assault force faces the new threat and attempts to determine an appropriate counter. This serves to make the defending fires even more effective by allowing them more time

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[21] Schneck, W., "Case Studies in Effective Landmine and Countermine Operations," published in "Proceedings of the Fourth International Symposium on Technology and the Mine Problem," March 13-16, 2000, Naval Postgraduate School, Monterrey, CA. " … the sappers of the 3rd Field Squadron had been 'working like demons' to complete their breaches through the last Axis minefield across 'Boat' and 'Ink" tracks. His sappers worked steadily under continuous fire from the German grenadiers as they crept forward, sweeping, marking, lifting, and taping. It was now getting on towards 0600 and the eastern sky was beginning to change from black to gray as the stars faded. Major Moore described the progress; "*Eventually we found indications that we had reached the far side of the minefield. The blue light had long since been shot away. As Sergeant Stanton was hammering in the last of the mine markers in an 8yd gap, I ran through the gap in a tearing hurry. There were by my estimate less than 20 minutes left before dawn would break...* " ... From the entrance to the breach, over the crest of Miteiriya Ridge, in the expanse between the two Axis minefields, Major Moore could see the tanks of the Sherwood Rangers Regiment lined up, nose to tail, waiting for the word to go forward. Major Moore ran back to the first tanks, the nine Crusaders of A Squadron. Jumping on the lead tank, he shouted, "*For God's sake, get up as quickly as you can, or you'll run into trouble.* " ... as the Crusaders deployed from the opening of the breach, their black shapes became silhouetted in the dull gray light. Almost immediately, there was a terrible 'clang' as an armor-piercing round struck the lead Crusader that Major Moore was guiding forward. He at once ran back to the next tank in the line and guided it around the first. Within a few meters of the first tank, it suffered the same fate. He ran back for a third, with the same result. … Now that the German panzerjagers were beginning to see their targets more clearly, it became very dangerous for the tankers. Indeed, in the first five minutes of this action, six tanks from the Sherwood Rangers Regiment were hit and burning. Of the six remaining Crusaders, soon two more were hit, with the squadron claiming two German tanks knocked out. The twenty Grants of B Squadron followed close behind the Crusaders into the heavy fire, quickly losing four tanks. At this point, the rest of the regiment, including the Shermans of C Squadron, was still jammed up nose-to-tail behind them in the long, narrow breaches over the crest of the ridge as the eastern sky behind them continued to brighten. Lieutenant-Colonel Kellett now ordered the surviving Grants of B Squadron to form a double column on either side of him and to engage the German panzerjagers. While the better-armored Grants provided covering fire, the rest of the regiment attempted to turn around where they were in the 8-yard (7.3-meter) wide breaches in the minefield and withdraw back behind the shelter of Miteiriya Ridge. In the increasing light, three more Crusaders and four more Grants were soon knocked out. The crews of these tanks were machine-gunned as they attempted to flee their stricken mounts. Soon, the markers put up by the sappers had been knocked down by the shellfire, so that other tanks, trying to deploy to a flank, drove into the Axis minefield. Consequently, the 10th Armoured Division failed to reach its objective." Pg. 5

to engage the enemy before the enemy is within effective range for his own weapons. As this is basically a psychological reaction, it is not analyzed in this study.

The best course of action for the assault force is to bull through the protective minefield, trading the probability of death or injury from a mine against the certainty of death or injury from massed direct and indirect fires if it stops. The minefield is simply an additional lethal force the defender has employed against the attacker. Casualties from mine detonations serve to reduce the number of attackers closing to within effective range of the defender.

Chapter Two

Analytic Process

The process employed for this analysis began with a study of the basic combat theory and current tactics described in Chapter One. From this study, a set of hypotheses was developed and tested in a computer combat simulation. Validated hypotheses and insights gleaned from the simulation runs were then used to generate the baseline assessment of the contribution of antipersonnel and mixed minefields to battle.

The analysis instrument

The study used a stochastic, entity-level interactive combat simulation as a laboratory instrument to assess the contribution of the landmine in a number of scenarios and vignettes. Using these as a baseline, the same simulation and vignettes were then used to compare the contributions of various proposed non-materiel and materiel alternatives. An interactive simulation was used because of the need to examine the mixed minefield mission in detail and the necessity to examine alternatives to protect the antitank mine in the same detail. Rule-based simulations have a far more difficult time accurately depicting the dismounted breach of a mixed minefield because of the large number of force organizational and movement changes that must be made during the fight to account for casualties in the breaching teams.

There was concern that results from simulation would be skewed and inaccurate since a major effect of a minefield is human fear, which no simulation can directly model. Conversation with Dr. Eugenia Kolasinski Morgan, a psychologist with extensive experience studying antipersonnel landmine psychological effects, indicated that the combat simulation used adequately accounted for this factor in its operational response.[22]

Tactical modeling was conducted in-house using versions 2.4 and 3.0(beta) of the Joint Conflict and Tactical Simulation (JCATS), a lineal descendant of Janus, the Army's current entity-level interactive model. JCATS is a multi-sided, interactive, entity-level conflict simulation employing actual three-dimensional terrain, and physics-based movement, acquisition, probability of hit (Ph), and probability of kill (Pk) algorithms. Current analytic users (in addition to a large number of training users) including the

[22] Kolasinski Morgan, Eugenia M., Ph.D., Paper "*Including the Soldier in Military Simulations*: Modeling the Psychological Effects of Anti-personnel Landmines," presented at the 45th Annual Meeting of the Human Factors and Ergonomics Society, 8-12 October 2001. "Even though soldiers may experience great fear upon encountering APLs, the only relevant consequence of that fear as far as mine warfare simulation is concerned may be whether or not the troops decide to avoid the area or clear the mines and, if clearing, how long the clearance operation takes. This dramatically simplifies mine warfare simulation as it suggest that detailed inclusion of the psychological effects may not really be necessary for adequate simulation of mine warfare." … "Thus, appropriate representation of only the operational effects of APLs may not explicitly represent their psychological effects, but may still provide results that are 'good enough.'" Pg. 4.

Institute for Defense Analysis, the U.S. Army Dismounted Battlespace Battlelab, the U.S. Air Force Force Protection Battlelab, U.S. Special Operations Command, the U.S. Joint Forces Command (JFCOM), and the RAND Arroyo Center.[23] The JFCOM Joint Warfighting Center sponsors JCATS and maintains configuration control. The Army Materiel Systems Analysis Agency (AMSAA) conducted a limited Verification and Validation of the JCATS simulation for this study.

The analysis scenarios

Korean and Southwest Asian scenarios were provided by a Warfighters' Conference, which included representatives from both Korea and USCENTCOM. The European scenario was provided by USEUCOM. Each scenario was based on a U.S. brigade fighting against an enemy division. (Scenario terrain details are shown in brief in Table 3, with other details discussed in Appendix B.)

Table 3, Scenario Terrain

Name	Location	Terrain	Vegetation
SWA1	National Training Center	Rolling desert valley w/mountains	Desert scrub
SWA2	National Training Center	Rolling desert valley w/mountains	Desert scrub
NEA1	Korea	Rugged hills with small valleys	Thick forest
NEA2	Korea	Open rice paddies w/forested hills	Stubble
EUR1	Germany	Compartmented hills and valleys	Open forest

A TRADOC Integrated Concept Team developed a series of detailed vignettes from the first four scenarios that allowed examination of critical engagements within the brigade battle. A panel composed of members of the NATO SAS-023 Antipersonnel Landmine Study Group analyzed the European scenario and developed the tactics and vignettes for study. Table 4 (found in the next chapter) provides information about these vignettes.

The same TRADOC Integrated Concept Team provided the minefield tactics and threat counters for each vignette. (Breaching tactics and timelines are discussed in Appendix C.) Weapon effectiveness data was obtained from the Department of Defense series of Joint Munition Effectiveness Manuals augmented by additional data provided by AMSAA.

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[23] McNaugher, Thomas L., Acting Director, RAND Arroyo Center Letter to Mr. Walt Hollis, Deputy Undersecretary of the Army for Operations Research, dated 22 June 2001, "We would much appreciate your help in (1) obtaining release of JCATS for support of any RAND project involving constructive or virtual simulation ... JCATS provides analytic capabilities currently unobtainable from any other source. It thus satisfies Arroyo's need to have the best means available to analyze pertinent systems, doctrine and organizations as it continues to explore current and future challenges to U.S. national security and U.S. Army operations."

The simulation process

JCATS simulations were conducted using a standard three-step process. First, a JCATS scenario was constructed from digital elevation data, topographic features, Red (attacker) and Blue (defender) forces, and Red and Blue force missions. Each defending entity (soldier or combat vehicle) was carefully placed on the terrain and assigned fields of regard (observation and fire) to optimize its function. This was done to account for the precise positioning decisions normally made by junior officers and NCOs on the ground constructing the defense. Minefields or minefield alternatives were carefully positioned on the terrain while considering the lines of sight of all of the defenders for the same reason. Once the defense was established, the attacking forces were positioned with movement orders adjusted to optimize their attack plan and maximize the benefits gained from the natural protection of the terrain, again to account for the decisions made by the attacker's junior leaders on the ground during the attack.

Second, the vignette was "debugged," which meant a careful independent adjustment of both defense and attack to ensure that both were the best they could be with the knowledge available to their side. This involved stepping through the engagement and making many minor adjustments to movement routes and defensive fire plans to account for microterrain effects and leader decisions based on situational knowledge gained during the engagement. During this step critical points where the dynamics of combat could require human decisions and changes were identified. (The scenario would be run without human intervention as much as possible to reduce human-induced variability.) In-house tactical experts would then watch the scenario play out to ensure that the behaviors of both sides were not only doctrinally correct but also responded to the engagement in a logical way.

Finally, the vignette simulation was run a number of times to collect statistics. This data was captured in the form of data event files containing hundreds of thousands of lines for each run. These data event files were then post-processed to extract critical data. The actual number of runs for each vignette was established by the variation noted in the results. Vignettes with large variations in results were run more times to establish greater confidence in the results obtained.

The analysis

The final step in the process was the actual analysis of data. After data extraction the vignettes were run in a replay mode that allowed the analytic team to better understand timing of critical events and the relationships between them. The team sought insights into why the particular numeric results occurred. The actual results were then used to either validate or eliminate the original hypotheses.

The initial portion of the study, to determine the battlefield contribution of the APL/mixed minefield, focused on the overall battle results. When the APL or mixed minefield was replaced with a non-materiel alternative (such as additional artillery support) it was compared in the same framework.

Chapter Three

Battlefield contribution of the antipersonnel landmine

Five battles were used as a base to extract eleven engagements for analysis. The battles consisted of a brigade attack up a desert mountain valley in Southwest Asia (SWA1), a brigade defense on the same Southwest Asian terrain (SWA2), a brigade defense in hilly Korean terrain (NEA1), a brigade defense across rice paddies in Korea (NEA2), and a brigade defense in compartmented European terrain (EUR1). The scenarios covered a variety of terrains: open desert, compartmented forests and fields, and heavily vegetated hills. They also included a variety of forces sizes and force ratios. Some engagements Blue should win, some should be doubtful, and some Blue should lose.

Mixed minefield

Mixed minefields (standard combinations of APL and antitank mines) were examined based on the tactical mission the minefield was to perform. Table 4 lists the specific vignettes. The force ratio displayed is the ratio of Red to Blue.

Table 4, Tactical Obstacle Vignettes

Minefield Mission	Blue Force Size	Force Ratio	Engagement Vignette
Disrupt (mixed)			N/A
Fix (mixed)	1 Company	12:1	EUR1(610)
	1 Company	12:1	EUR1(611)
	1 Platoon	36:1	EUR1(612)
	1 Battalion	8:1	NEA2
Turn (mixed)	1 Company	6:1	SWA1
	1 Company	6:1	SWA2(S)
Block (mixed)	1 Company	12:1	SWA2
	1 Platoon	8:1	SWA1

Disruption minefields are designed to attack the enemy's timing by causing a part of his force to fall behind through casualties and confusion. The primary minefield contributions to accomplishing this are casualties caused to the Red force, and the operational delay provided by enemy countermine operations. APL provide little advantage in a minefield employed to disrupt the enemy. As the minefield frequently is not covered by fire, or is at extreme range, a mechanical system can breach with safety.

The intent of the minefield is achieved by simply causing the enemy to have to pause and breach. This case, consequently, was not examined.

The most common use of a mixed minefield is to fix the enemy for destruction by other weapons. The minefield contributions that cause this to happen are casualties to the Red force and the "holding power" of the minefield (the length of time required for the attacker to traverse the field). Three engagements employing fixing minefields (EUR(610), EUR(611), and EUR(612)) were selected from the European scenario. All three of these had a defender fighting in broken terrain with short engagement ranges against a threat equipped with an earlier generation of equipment. A fourth engagement was selected from the NEA2 scenario where both the defender and attacker had comparable equipment, but the engagement ranges were long. These engagements are shown in Figure 4.

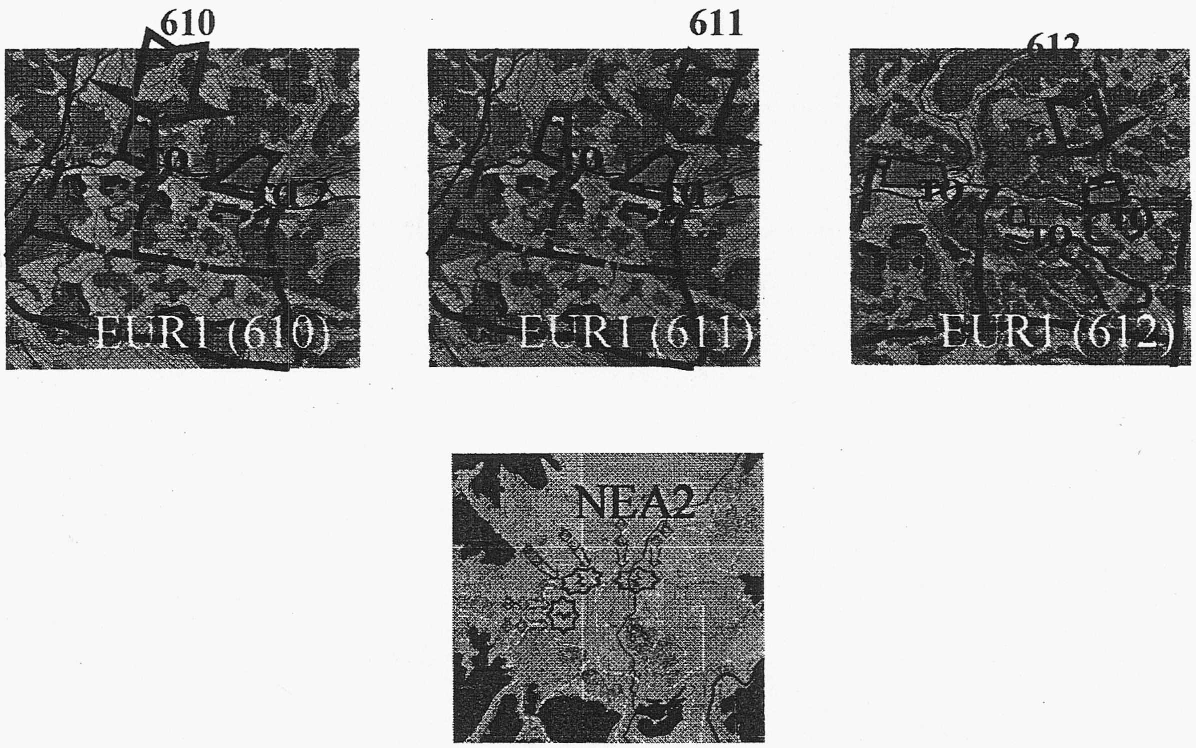


Figure 4, Fixing Vignettes

As these were mounted engagements, the critical weapon systems were the antitank systems (tanks and antitank missiles). Losses to the attacking Red forces from all weapons are shown in Figure 5.

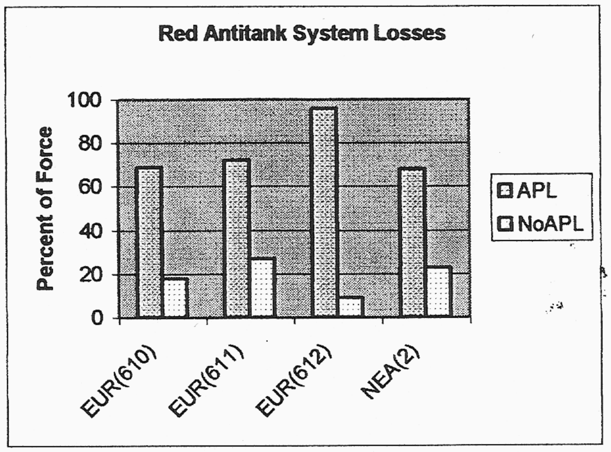


Figure 5, Fixing Obstacle Red AT System Losses

In all four engagements, the attacker used dismounted breaching techniques in the NoAPL case. This allowed him to hold his antitank systems back out of the fight until the breach lanes were completed, then to rush them through the lanes. In the APL case, the attacker typically lost all of his tank-mounted breaching equipment along with some other armored systems protecting that equipment while conducting the breach and then had to meter his force through those lanes that had been completed.

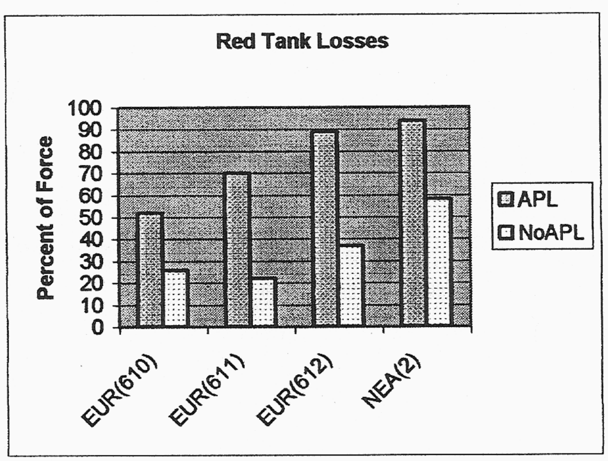


Figure 6, Fixing Obstacle Red Tank Losses

Considering tanks alone shows similar results (tank numbers were included within the antitank system numbers in the previous figure). The attacker is at a severe disadvantage if he cannot employ a dismounted breach technique against the surface emplaced modern tactical minefield. In the absence of APL the dismounted breach is his best tactic against a fixing obstacle.

Another attribute was measured in the EUR scenario – the engagement duration for EUR610, EUR611 and EUR 612. Figure 7 sketches the battle sequence.

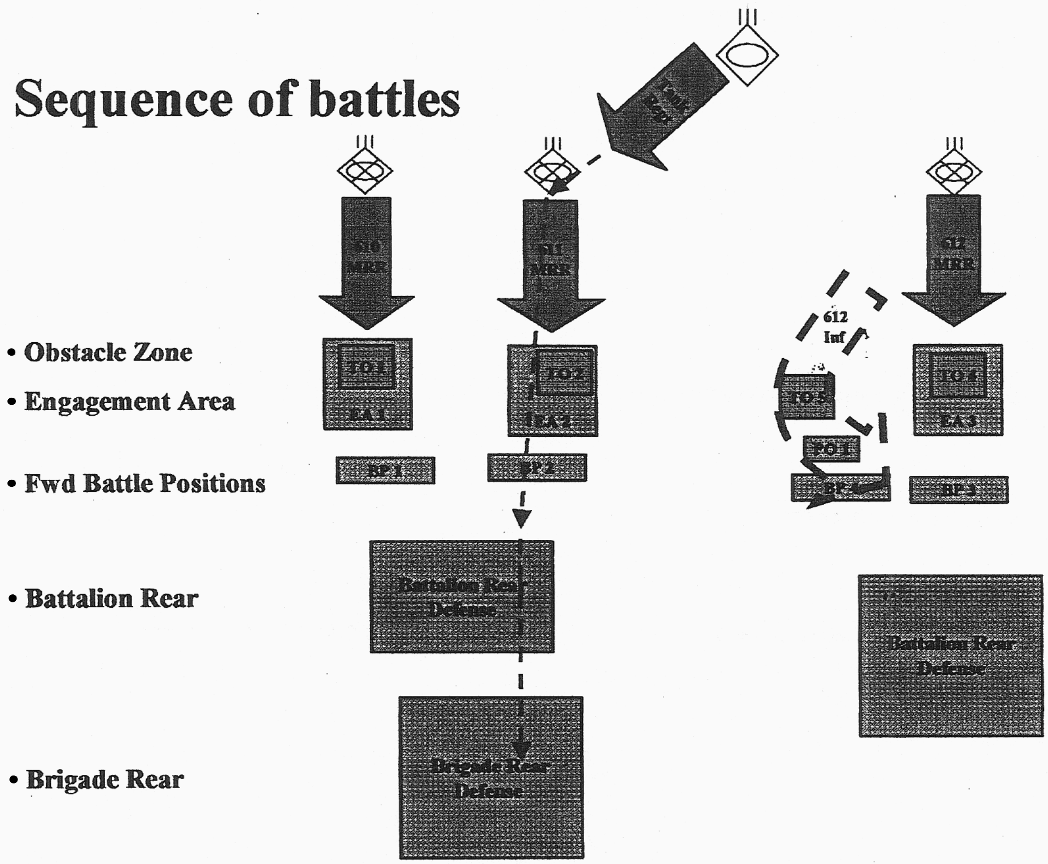


Figure 7, EUR Scenario Sketch

This reflects that EUR610 is the attack of the 610th Motorized Rifle Regiment through Tactical Obstacle Zone 1 (TO1) across Engagement Area 1 (EA1) and assaulting Battle Position 1 (BP1). EUR611 is the corresponding attack of the 611th Motorized Rifle Regiment through TO2, EA2 and assaulting BP2. This attack will later be followed by the Tank Regiment, which will attack through the battalion and brigade reserves to seize the final objective. EUR612 is in two parts – the first is a dismounted attack by 612 infantry to seize BP4 and eliminate antitank fires, and the second is an attack by the armored elements of the 612 Motorized Rifle Regiment through TO4, EA3, to assault BP3 and continue on to the brigade rear.

TO1, TO2, and TO4 are groups of mixed minefields. In the NoAPL case, the APL component is eliminated and these are pure antitank minefields. Because of the different breaching techniques required in the two cases, and because of the difference in passage time of the attacking force based on number and width of lanes, the battle duration changes significantly. Figure 8 charts the timelines for the critical events in each engagement.

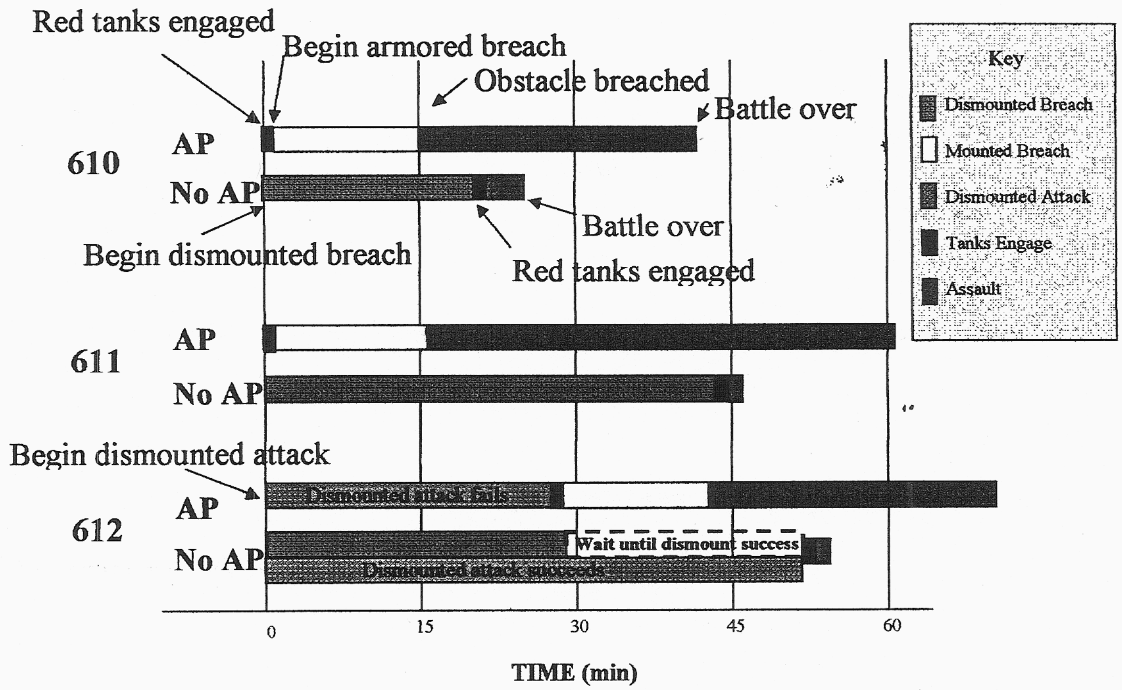


Figure 8, EUR Timelines

In each engagement, removing the APL from the mixed minefields shortened the overall engagement time. This is not the critical factor, however. The heavy black line in each timeline shows when the armor battle began. From the start of the armor battle until the end of the engagement (labeled "Battle over") is the critical duration where tank is fighting tank. This duration is significantly shorter when APL are not involved. Table 5 lists these times.

Table 5, Armor Vehicle Engagement Duration

	EUR610	EUR611	EUR612
APL/Mixed Minefields	41 min	61 min	72 min
NoAPL	4 min	3 min	3 min

In the NoAPL case for each engagement, the dismounted forces breached lanes through the minefields while the armored vehicles were held back out of direct fire with the defenders. When the lanes had been completed, the armored force assaulted rapidly through the lanes and quickly overcame the defenders. When APL were in the minefields (mixed minefield case) the attacker employed mounted breaching equipment, which required him to move his tanks and antitank missile firing vehicles forward to engage defenders attacking the breaching attempt. Fewer lanes resulted and the attacker traversed them at a slower speed (they were much narrower than the ones made by the dismounted force). This caused him to lose more armor (he was at a range disadvantage against dug-in defenders) and caused a much longer armored vehicle engagement.

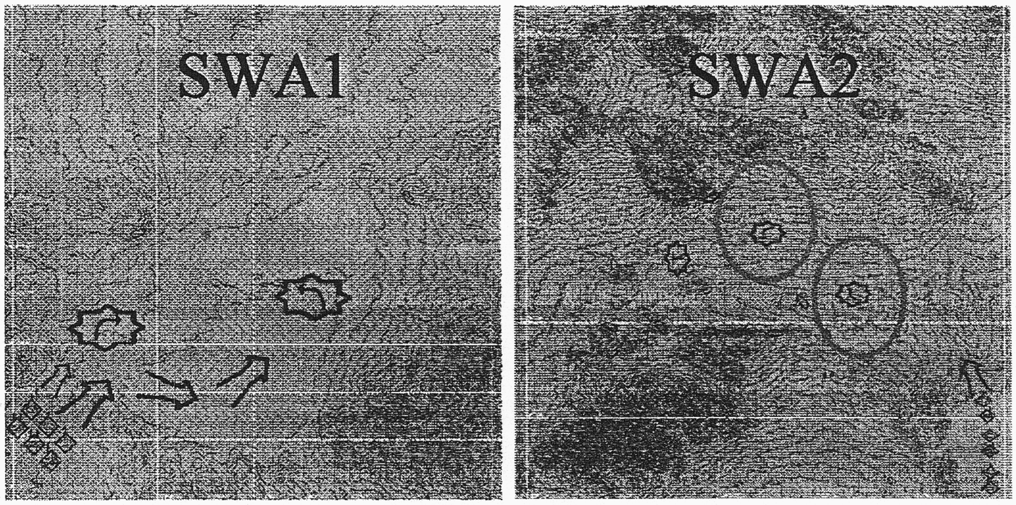


Figure 9, Turning Obstacle Vignettes

Turning obstacles are of particular importance where the terrain doesn't naturally canalize the attacker into a confined engagement area. This is especially true where engagement ranges are very long, and the attacker can avoid defending fire by simply remaining out of range. These obstacles manipulate the enemy force maneuver, either by enticing him to go in a different direction that apparently meets his mission requirements or by forcing him to do so. Minefield characteristics that may cause an enemy to turn are detectability (as he must know there is a minefield present) and casualties caused to the Red force. Two engagements where turning obstacles were important were selected from the battles SWA1 and SWA2 and Red losses in those engagements are shown in Figure 9.

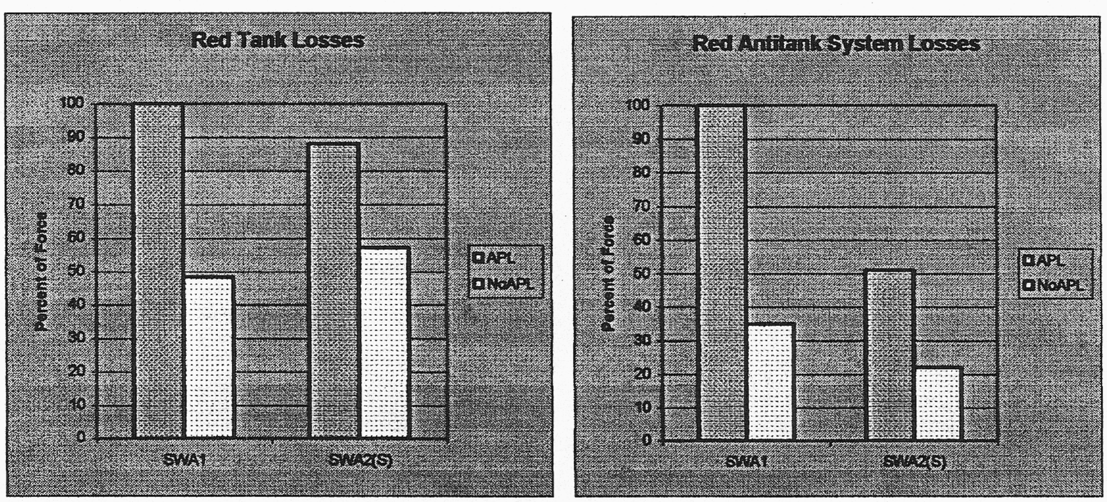


Figure 10, Turning Obstacle Red Losses

In the absence of APL, the attacker was able to breach the minefields with dismounted soldiers without risking his armor. The minefields did not force him to turn, and he was able to directly attack the defending unit. When APL were present, he did not risk his vehicles breaching and turned to bypass. Because of this, the obstacles accomplished the defender's intent. This made a significant difference in the results (see Figure 10). Not only did the attacker lose far more tanks (on the order of twice as many) in the presence of APL, he also took significantly more casualties to all of his antitank systems. APL considerably enhanced the turning obstacle function.

Blocking obstacles are designed to stall the enemy and force a decisive engagement with the aim of stopping his advance along a particular avenue. To do this, the blocking obstacle must be deep, strong, and difficult to breach. The minefield characteristics required are lethality (causing casualties) and delay in order to hold the enemy in the engagement area.

Since the turning obstacle in SWA1 must act as a blocking obstacle if the enemy continues to attack through it, the blocking function was also examined in this scenario. To do this, the attacker decision was set to attack through the obstacle system. The results are shown in Figure 11.

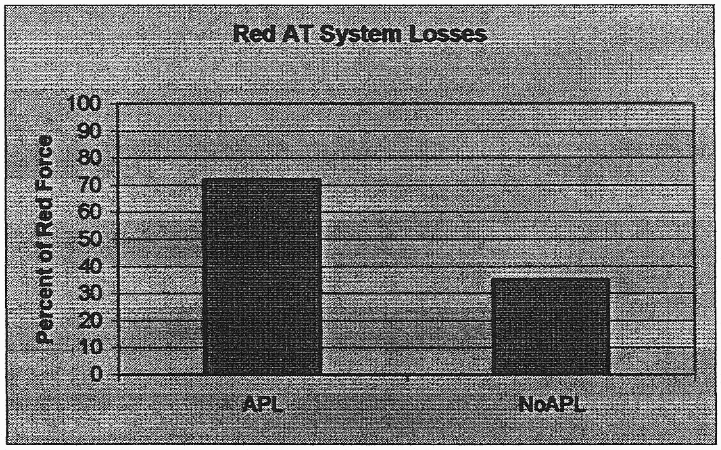


Figure 11, SWA1 Blocking Results

A second example examined was the blocking obstacle at the end of the valley in SWA2(W) see Figure 12).

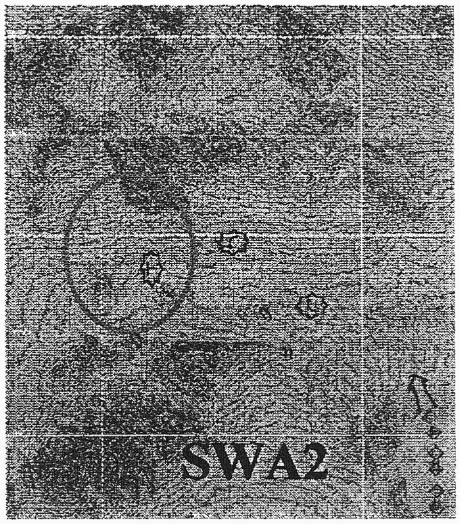


Figure 12, Blocking Obstacle Vignette

By the time the attacker reached the blocking obstacle, he had run the gauntlet of the forward defenses in SWA2. In order to standardize the analysis, these were ignored and the full Red force was used in the attack against the end of the valley. This produced a force ratio for this engagement of 6.15:1 – where the attacker would be expected to win. The obstacle is quite complex, consisting of two minefields in depth with an antitank ditch in between.

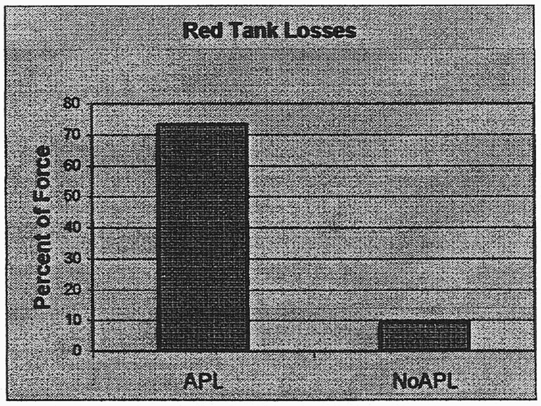


Figure 13, SWA2 Red Tank Losses

The APL made a considerable difference. Red lost seven times as many tanks when he was forced to conduct a mounted breach under fire as when he could breach with dismounted forces (see Figure 13). A similar result was observed across the board with all antitank systems (tanks as well as BMP infantry fighting vehicles) (see Figure 14).

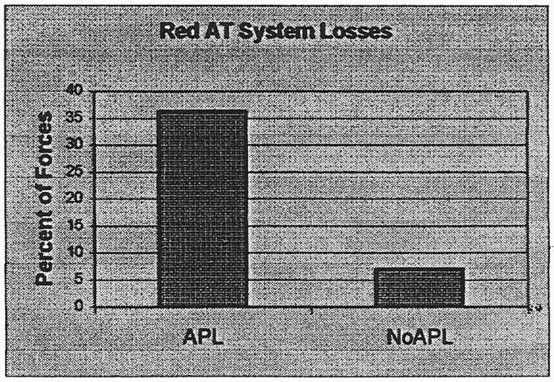


Figure 14, SWA2 Red AT Losses

The massed defending fires in SWA2 cause the difference between SWA1 and SWA2. In either case, the APL is critical to the blocking obstacle function.

Protective minefield

Protective minefields are designed to cause casualties. The minefield contribution to the engagement is additional casualties to the Red force. It provides alert and broad area warning (all defenders receive the warning simultaneously as they hear the detonation), but this function can be accomplished by other systems equally well so it was not studied. It provides a psychological boost to the defenders, as there is a lethal automatic barrier between them and the enemy but this also was not studied, as it is not easily quantified. It also may cause an attacking force to hesitate and slow its attack. The worst case for the defender was examined where this hesitation effect did not occur. Protective minefields were examined in two scenarios, NEA1 and EUR(612) as shown in Table 6.

Table 6, Protective Vignettes

Mission	Blue Force Size	Force Ratio	Engagement Vignette
Protect	1 Company	3.5:1	NEA1
	1 Platoon	7.1:1	EUR(612)

The NEA1 engagement has a dismounted infantry battalion attacking through very close terrain into the flank platoon of a defending infantry company. The infantry company is protected by a protective minefield in the 400 meter open area to its front (see Figure 15).

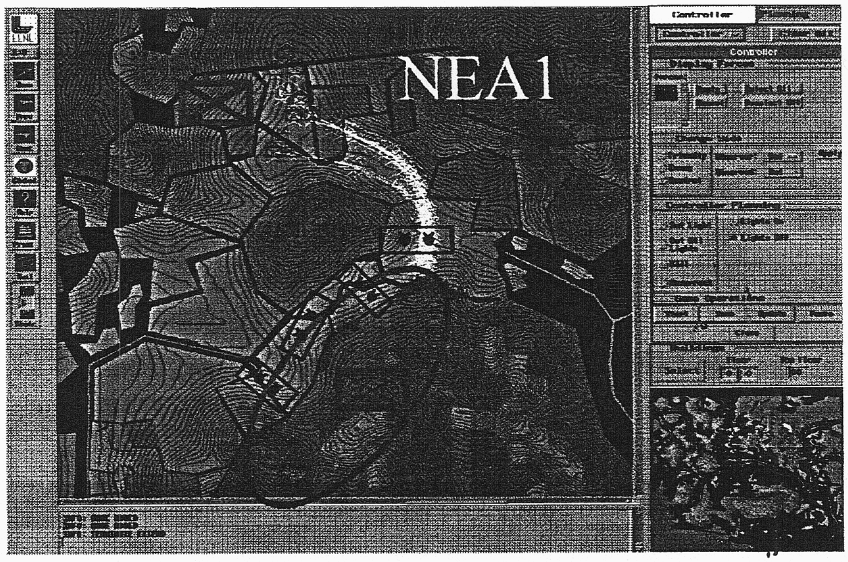


Figure 15, Protective Obstacle NEA Vignette

The attacker will attempt to overrun the flank platoon, and then attack across the company position, destroying one platoon after another. Though the overall force ratio is 3.5:1, because the attacker is striking the platoons one after another sequentially, the force ratio in the initial fight against the first platoon position is actually 10.5:1.

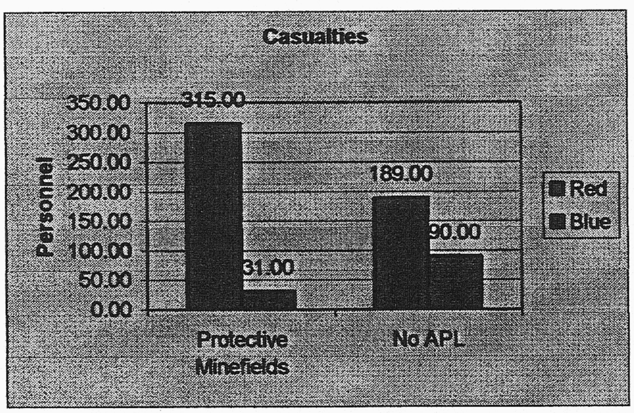


Figure 16, NEA1 Protective Minefield Casualties

APL made the difference between winning and losing. In the absence of APL, all defenders died while the attacker lost 60% of his force. With the APL protective obstacle, the attacker lost his entire force, while the defender lost only 33% (see Figure 16).

Fractional Exchange Ratio (FER) is sometimes a better measure of the quality of the battle for the assault phase through a protective obstacle because of the variation in Blue casualties. Figure 17 shows the FER comparison at the end of the battle.

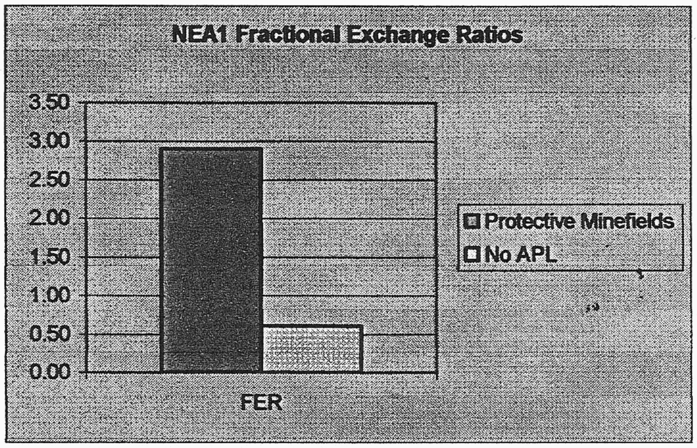


Figure 17, NEA1 Protective Obstacle FER

FER shows a dramatic difference. With a protective APL minefield, Blue had an overwhelming win with a FER of 2.9; that is, for every 1 percent of the Blue force lost, almost 3 percent of the Red force became casualties. Without APL, however, Blue lost force almost twice as fast as Red and consequently lost the engagement.

The other protective obstacle vignette came from the EUR(612) engagement (Figure 18).

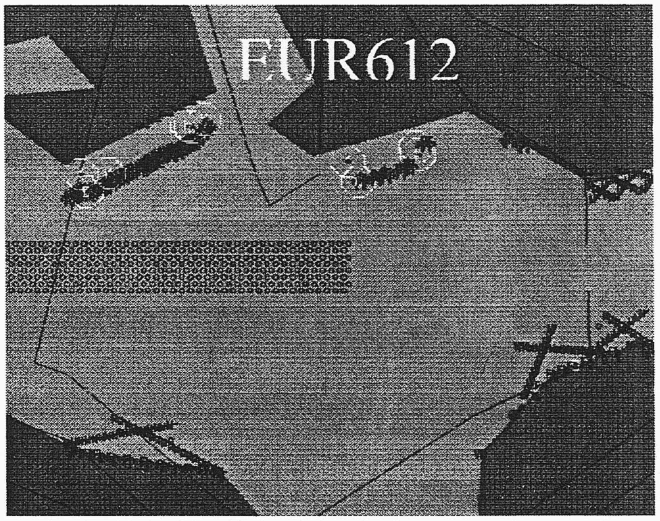


Figure 18, Protective Obstacle, EUR Vignette

This engagement has a defending platoon facing a dismounted attack out of the forest by two companies. The engagement range is about 400 meters. The protective obstacle is located about 200 meters in front of the defender.

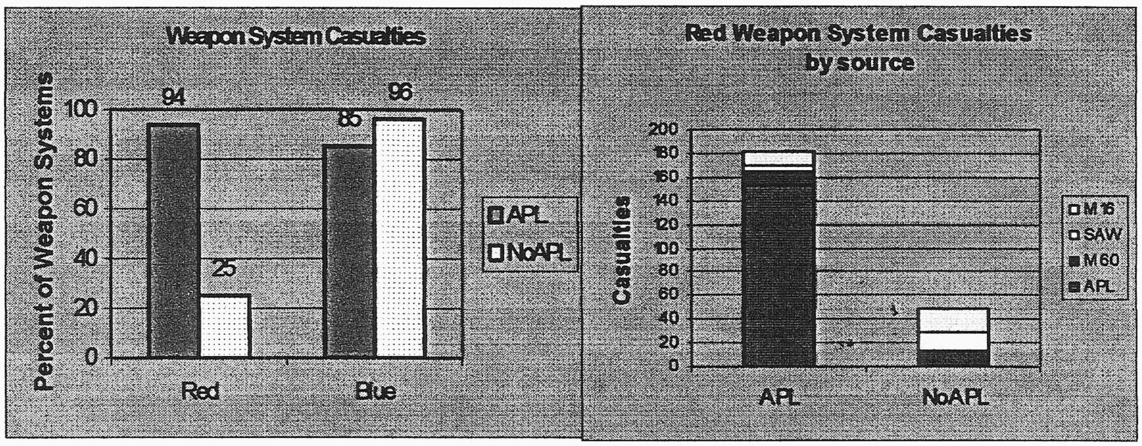


Figure 19, EUR612 Protective Obstacle Casualties

Blue suffers serious losses in both cases (see Figure 19). The most significant difference APL make is whether Red wins or loses. Red never won when APL are present, and lost almost all of the assaulting force. The graph showing casualties by source shows why – the APL cause the bulk of the Red casualties. Again, FER is a good shorthand measure to show the quality of the engagement. Figure 20 displays the FER for both cases at the end of the battle.

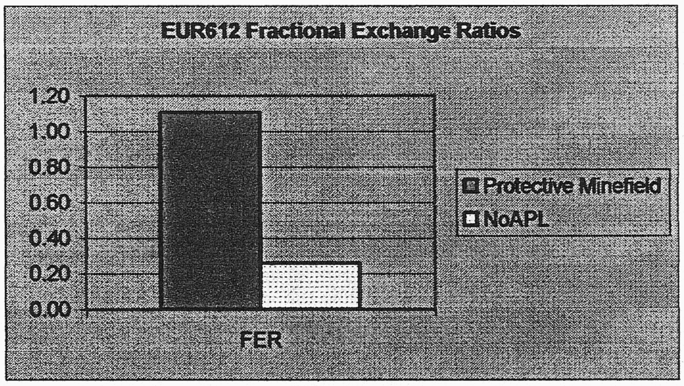
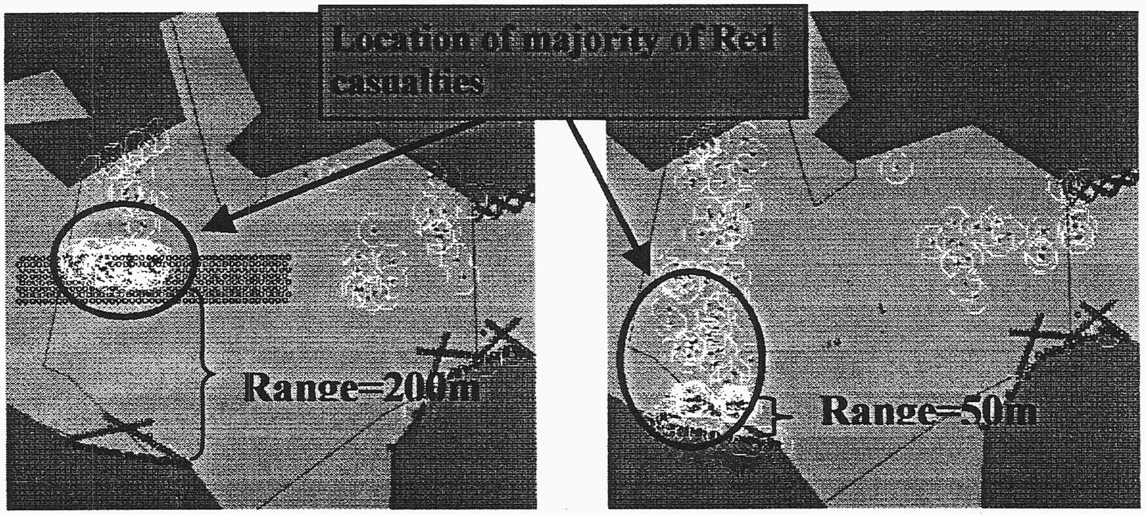


Figure 20, EUR612 Protective Obstacle FER

The force ratio in this engagement is so skewed in Red's favor that Blue takes serious casualties even when Red loses (the case with the protective APL minefield). When no minefield is present the FER shows Blue losing force over three times as fast as Red.



APL NoAPL

Figure 21

Figure 21 illustrates another factor impacting the shift in FER. The white circles in the figure show the location of every casualty in a representative simulation run and thus highlight where the bulk of the engagement occurred. The protective minefield essentially moved the center of mass of the Red engagement from 50 meters to 200 meters -- this shifted the hit probability strongly in favor of the defender in the direct fire engagement.

APL contribution summary

Every vignette required tactical compromises on the part of Blue because of limitations of terrain and forces, so that the ability to mass Blue fires and the minefield distance in front of the defense varied considerably. In every examined case the APL made a significant contribution to the defense. Removal of the APL from the mixed minefield in the seven vignettes reduced Red armor casualties to only11% - 49% of those they received with mixed minefields. (As a rough comparison, across all of the vignettes the removal of APL caused Red losses to average only 32% of those when mixed minefields were employed.) Table 7 lists the casualties for NoAPL for each vignette as a percentage of the casualties produced when the full mixed minefields were employed.

Table 7, Red Casualties without APL as percent of Mixed Minefield Casualties

	Turn		**Fix**				**Block**	
Scenario	SWA1	SWA2	NEA2	EUR610	EUR611	EUR612	SWA1	SWA2
NoAPL	35%	43%	34%	26%	37%	11%	49%	19%

A similar result was noted for the APL-pure protective minefield. Table 8 compares Red casualties in the two protective obstacle vignettes.

Table 8, Red Casualties without APL as a percent of APL Minefield Casualties

	Protect	
Scenario	NEA1	EUR612
NoAPL	10%	27%

Removal of the APL minefield caused a significant reduction in Red casualties during the close assault of the defending Blue position in both vignettes.

The protective minefield allowed Blue to win in both cases examined (Blue otherwise lost). This is shown by remarkably similar FER changes in Table 9.

Table 9, FER in Protective Obstacle Vignettes

	NEA1	**EUR 612**
Protective Minefield	2.90	1.11
No APL Minefield	0.60	0.26
APL FER improvement	483%	427%

Though the EUR612 defense was far more difficult for the Blue defender than the NEA1 defense (as shown by the respective FER), the reduction in FER when the protective APL minefields were removed is remarkably similar. Red did four to five times better in both cases – which made a win-lose difference.

Operational Implications

There has been much discussion on the question of APL value to the theater operation. Current theater-level computer simulations use terrain hexagons, which are quite large relative to the size of an engagement, and determine battle outcomes mathematically based on initial conditions and force ratios (Lanchester models). Minefields, if modeled at all, cause a delay and some additional casualties if the opponent enters a hexagon where they are employed. This is basically an additive process in terms of casualties and movement rates. The contribution of APL mines, either as stand-alone minefields or as a component of a mixed minefield, is totally invisible.

There was no intent to analyze the operational impact of APL as a part of this study. Because three engagement vignettes were selected from the same scenario, however, we noted some interesting results that caused us to look deeper into APL contributions at the battle level. This produced some unexpected insights that have operational level implications.

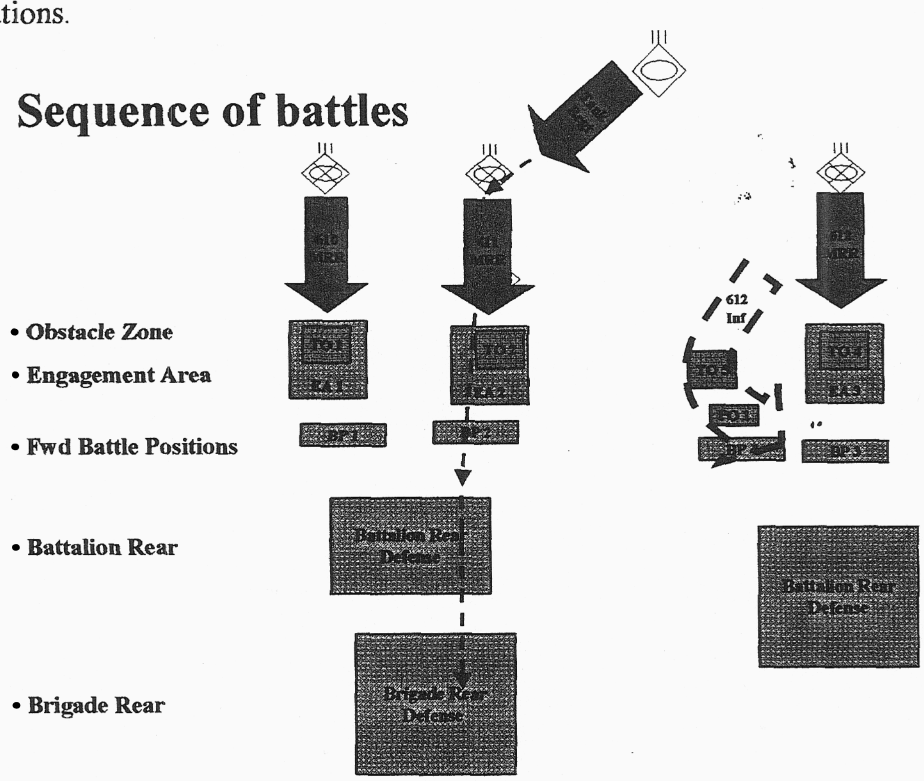


Figure 22, EUR Scenario Sketch

Figure 22 is a copy of Figure 7 and shows in sketch form the entire EUR scenario. The attacks by 610 and 611 Motorized Rifle Regiments on the western side of the area of operations constitute the main attack, and the Tank Regiment will follow 611 MRR to continue the attack through the defending brigade sector. The attack by 612 MRR on the east is a supporting attack designed to confuse and pin down defending reserve forces. If successful, it will also continue through the entire brigade sector.

APL were only played in the forward engagements (those obstacle zones shown in green). TO1, TO2, and TO4 were mixed minefields, while TO3 and PO1 (protective obstacle zone 1) contained only APL. For the NoAPL case, TO1, TO2, and TO3 consisted of only antitank mines and the other two zones were not present. APL were not played for the two subsequent engagements in the battalions' rear areas against the battalion reserves or in the brigade rear against the brigade reserve.

We noted that the forward use of APL made the difference between winning and losing the brigade battle. This caused us to look more closely at the successive force ratios (which depended both on surviving forces and on new forces fed into the successive engagements). Considering the main attack avenue first, Figure 23 shows the successive force ratios for the NoAPL case. Where one side has been totally destroyed, instead of force ratio that force is shown as zero and the opponent's remaining force size is shown.

Main attack (610 & 611) force ratios -- NoAPL

	Tanks	All AT Systems
• Obstacle Zone	4.3:1	11.5:1
• Engagement Area	49:0	88.3:1
• Fwd Battle Positions	48:0	24:1
• Battalion Rear	15:1	29:0
• Brigade Rear	15:1	5.9:1
End of Battle	18:0	3.6:1

Red Win

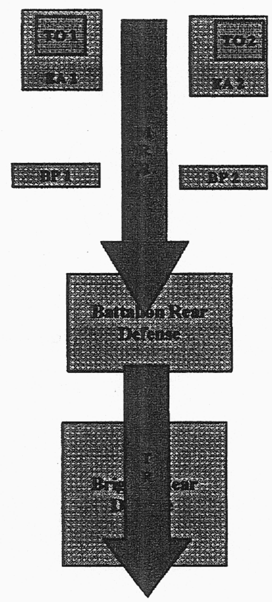


Figure 23, Main Attack Force Ratios, NoAPL

In this case Red entered the battle with a force ratio of tanks of over four to one, and a total antiarmor system force ratio advantage of over eleven to one. By the time he had passed through the engagement area his antitank system advantage was over 88 to one, as he had destroyed most of the defenders. His tank advantage was 49 to zero as no Blue tanks survived.

The 610 and 611 MRR were able to accomplish their objective, defeat of the defending battalion, and pass the Tank Regiment through to attack the brigade reserve. Even though Blue employed attack helicopters and A-10 aircraft in the fight against the tank regiment, the battle ended as a Red win with 18 surviving tanks.

Figure 24 shows the same force ratio sketch when APL were employed in the initial minefields.

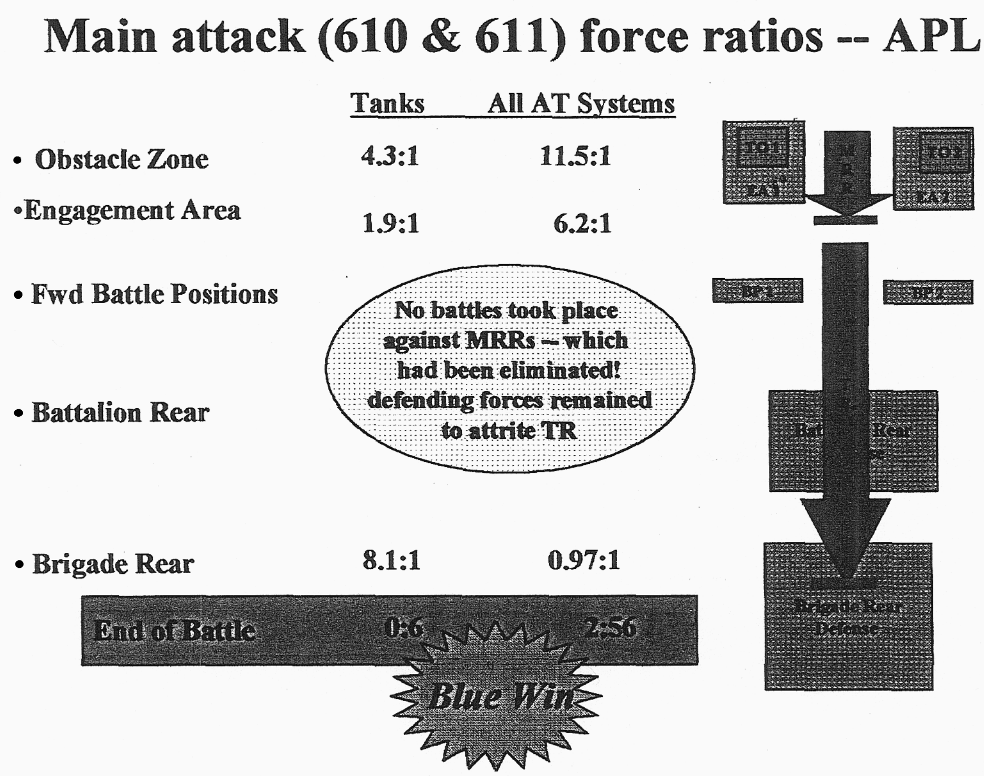


Figure 24, Main Attack Force Ratios, APL

Starting force ratios were the same. In this case Red was forced to employ his armor to protect mounted breaching equipment producing the lanes through the minefields. Red was down to only 1.9 to 1 in tanks when exiting the engagement area (6.2 to 1 for all AT systems) and was unable to overrun the forward battle positions. The Tank Regiment was forced to fight through the battle positions and was incapable of penetrating the brigade rear defense. The battle ended as a Blue win with all Red tanks destroyed while Blue retained six.

The secondary avenue of approach on the eastern side of the brigade was more complex, but produced a similar outcome (the EUR612 vignette). The force ratio schematic is shown in Figure 25.

Supporting attack (612) force ratios - NoAPL

	Dismounted Infantry	Tanks	All AT Systems
• Obstacle Zone	20.3:1	7.8:1	9.3:1
• Engagement Area	13.3:1	10:1	65:1
• End of dismount battle	219:0		
• Battalion Rear		3:1	5.5:1
• End of battle		16:0	120:0

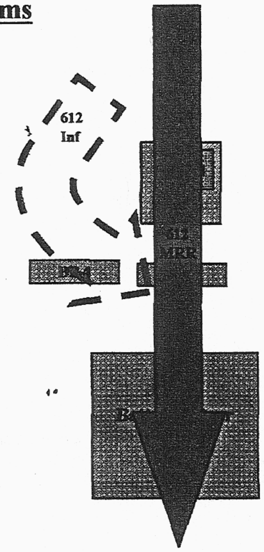


Figure 25, Supporting Attack Force Ratios -- NoAPL

The schematic shows the force ratios for the dismounted infantry attack (the dashed red arrow on the left) separate from the armor systems. The attacking regiment begins with an overwhelming force ratio – over 20 to 1 in dismounted infantry and almost 8 to 1 in tanks. The attacker finished the initial engagement where minefields were employed with a 10 to 1 advantage in tanks. The fight through the battalion reserve dropped this ratio to 3 to 1, primarily because this area is broken ground with a large number of antiarmor ambushes that allowed the small battalion reserve to be highly effective. At the end of the battle Red won with 16 tanks remaining out of 31.

Figure 26 shows the same data in a schematic for the case where APL were employed in mixed minefields and also in APL-pure minefields supporting the dismounted infantry defense.

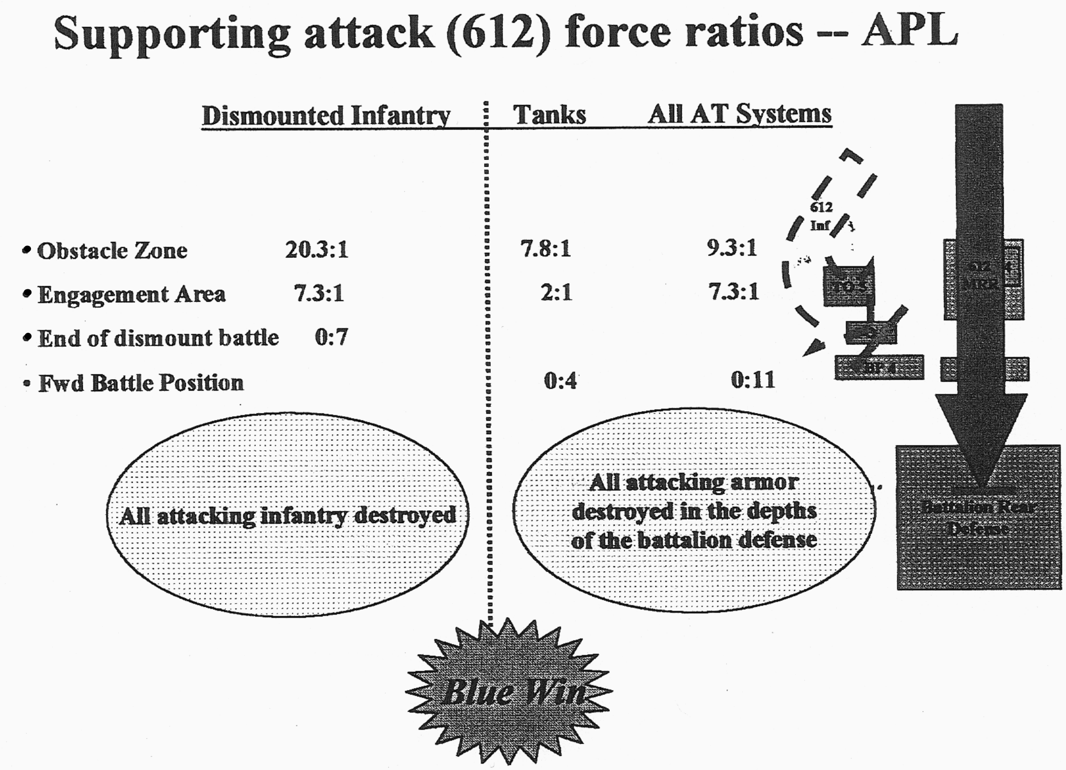


Figure 26, Supporting Attack Force Ratios -- APL

The APL minefields made a critical difference to the defense against the dismounted attack on the left. Blue had a dismounted platoon defending and employed two sets of APL minefields in support. The initial minefield was a turning minefield to cause the attacker to change his approach and thus form a concentrated target for the defender's mortars. The surviving attackers still had a 7.3 to 1 advantage over the defenders, but had to attack through a protective APL minefield that assisted the defenders' defeating them. The failure of the dismounted attack left Blue with a coherent anti-armor defense when the mounted attack (the solid red arrow on the right) began. That, plus the necessity of conducting a mounted breach through the mixed minefields, changed the force ratio at the end of the engagement area battle from 65 to 1 down to 7.3 to 1. This severe reduction in Red armor in the forward battle allowed the battalion reserve to defeat the remainder.

Across the entire battle (610, 611, and 612) APL caused 8% additional losses to Red anti-armor systems during the breach attempt in the initial engagements (the additional losses were all tanks or tanks carrying breaching equipment). This loss of a critical weapon system and subsequent metering of attackers through the obstacle system resulted in 67% more AT losses for Red forces while attaining the initial MRR objectives – which caused Red to ultimately lose the battle.

The APL contribution, therefore, extended far deeper than the engagement where it was directly employed. The results of the forward battles fought by three companies, *strongly influenced by the presence or absence of APL,* determined the brigade victory.

This example did not allow an exhaustive assessment of APL contributions to combat in a theater, however, it did suggest that simply adding some additional casualties and causing a slight change in movement rates is inadequate to describe the impact of APL. It appears that any reduction in primary combat systems resulting from the employment of APL in the initial engagements will be multiplied in following engagements. If APL were employed in each engagement level in the battle, instead of being a multiplicative effect it would be exponential through compounding of losses.

Though not a factor in this scenario, another significant implication is that the loss of breaching assets in the initial minefields would have major impact on the ability to traverse minefields encountered later.

This limited analysis implies that the "combat multiplier" effect of APL extends far beyond the point of employment and has significant implications when rolled up across a theater of operations. Current computer simulations used to examine theater war do not capture this impact.

Chapter Four

Battlefield contribution of non-materiel alternatives

The basic requirement for a non-materiel alternative was that it must use existing units and systems to accomplish the APL mission. Possible non-materiel alternatives to APL were identified by the Warfighters' Conference held at Fort Leavenworth in July 1999, the TRADOC Integrated Concept Team meeting held at Fort Leonard Wood in August 1999, and the Warfighters' Conference held at Carlisle Barracks in November 2000.

Non-materiel alternatives were employed in the same engagements used for the baseline APL contribution measurements. The defender's missions remained the same, but he employed his forces differently to accomplish them.

Mixed minefield non-materiel alternatives

Replacing the mixed minefield with a force of infantry located close to the obstacle could protect the antitank mines from dismounted breaching. Making the antitank minefield three times as deep could slow the attack because of the need to breach the greater depth. It would also allow the covering antitank fires more opportunity to destroy the attacking armor as it was metered through these longer lanes. Adding a protective force of infantry to these deeper minefields could prevent dismounted breaching. These alternatives were studied using the SWA1 engagement, where an added platoon of infantry covered each minefield belt (which doubled the defending force). The results are shown in Figure 27.

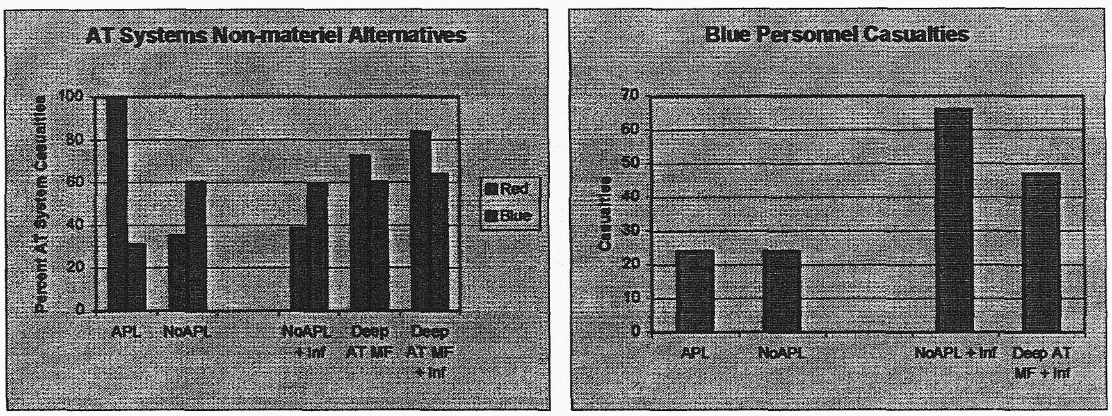


Figure 27, Non-Materiel Alternatives, SWA1

None of the proposed alternatives achieved equivalent results to the APL case. Adding infantry to the original AT minefield showed a slight increase in Red casualties compared to the NoAPL case. Making the minefield deeper was far more effective, essentially doubling Red casualties. Adding infantry to the deeper minefield provided an additional 10% to Red casualties. The second chart shows a significant increase in the number of

Blue casualties when infantry are added to either case. This occurs because there are more Blue forces present to be targets.

Additional tanks were inserted to provide more long-range antitank lethality. In the EUR(610) engagement, the number of tanks was doubled to two companies. Because of the constricted terrain, this doubling of firepower successfully produced the same Red casualties as the APL case. The Blue AT system casualties tripled, however. The number of Blue tanks was also doubled in the NEA2 engagement. Because of the large number of Red long-range AT systems (AT5 and AT8 missiles), this produced only 4% more Red casualties while costing all of the additional Blue tanks as casualties.

Adding additional Blue forces as an alternative caused a large increase in Blue force casualties in every case examined.

Protective minefield non-materiel alternatives

Because of the unique nature of the protective minefield, where the attacker doesn't have the option of breaching, the non-materiel alternatives selected were methods designed to increase lethality. The intent was to replace the casualty-causing ability of the APL with some other casualty-causing mechanism.

Additional Rifle Squads

The first alternative examined was to increase the number of defending infantry squads. The EUR(612) infantry defensive engagement was used as the tactical model (Figure 28). A new base case was developed that consisted of three defending squads armed solely with rifles. This was then increased to four, five, and six squads.

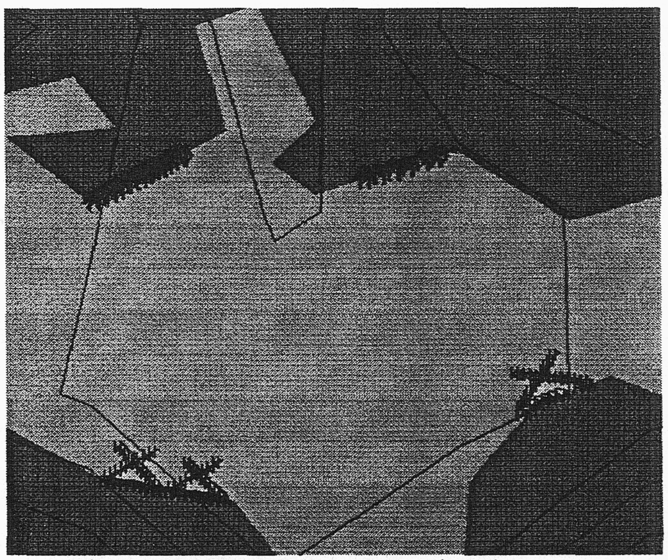


Figure 28, Protective Obstacle Vignette

Six defending squads caused the same number of Red casualties as three squads reinforced by a protective APL minefield. This also resulted in twice as many Blue casualties (Figure 29).

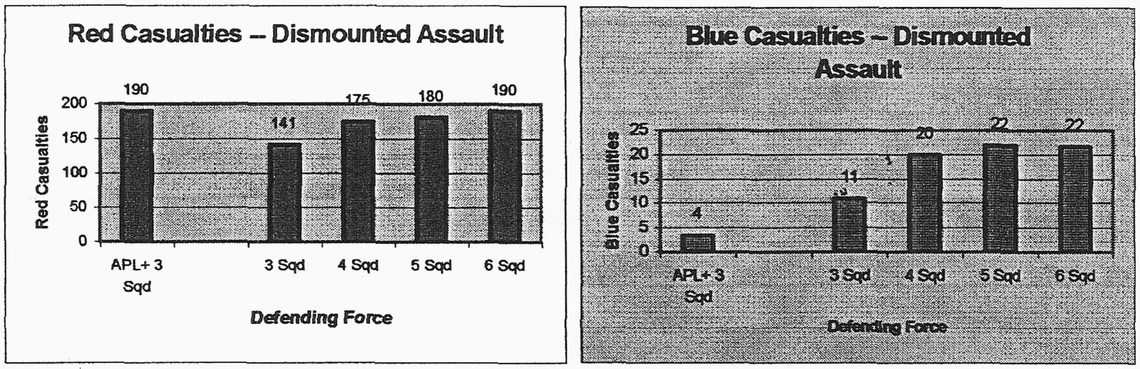


Figure 29, Additional Squad Results

In the remaining assessments, various existing systems were added in greater numbers to a constant strength rifle platoon to assess the value of additional lethality from more effective weapons (or from the delaying value of additional wire obstacles). An additional measure of effectiveness was used for this assessment – the number of times that Red would win. The key shows how well the attacker fared. Yellow meant he ended with one platoon on the defending position, orange meant he had two platoons, and red meant he ended the engagement with over two platoons on the defending platoon position. Green meant he failed.

Additional Machineguns

Each rifle squad contains one medium machinegun (M240). These were parametrically increased until the squad consisted only of machinegun teams (five per squad, or fifteen total). At fifteen machineguns, Red suffered the same number of casualties, on average, as in the APL case. There was a slight reduction in Blue force casualties. Red did, however, win the battle 38% of the time versus 0 wins in the APL case. Since the attacker might destroy defending machineguns early or late, the actual battle results had a great amount of variance – in other words, the results were far less predictable for the defending commander. The additional machineguns caused Blue to expend almost 11,000 rounds of ammunition of all types, compared to 4,000 in the APL case.

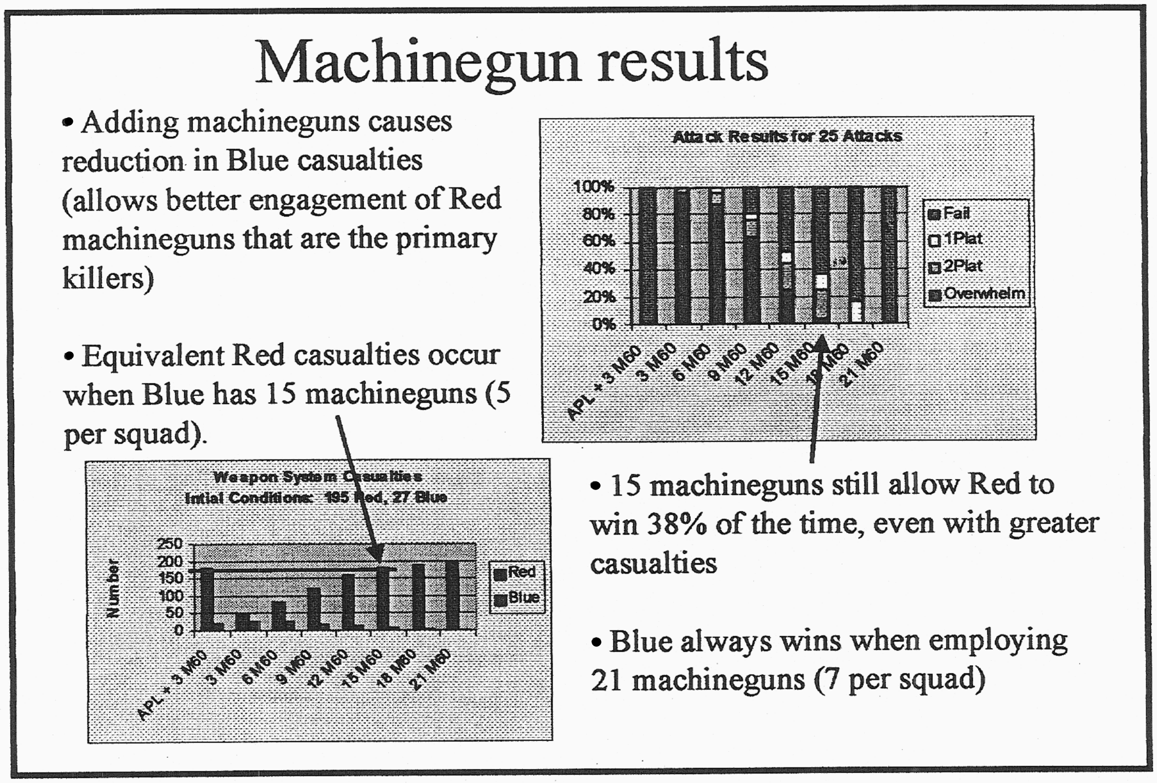


Figure 29, Additional Machineguns

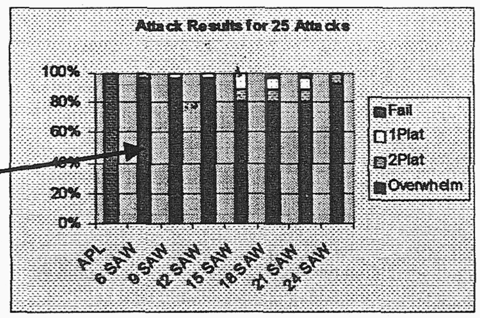
Additional Automatic Rifles

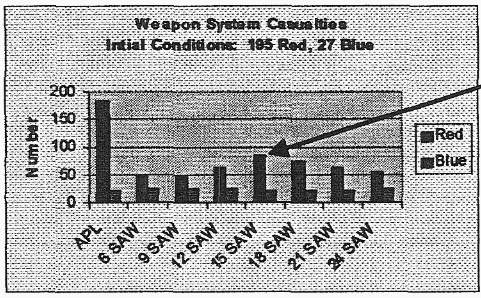
Each rifle squad contains two M249 squad automatic rifles (SAW). These were parametrically increased until the squad consisted of its machinegun team and eight SAW (for a total of 24 SAW in the defense). In general, this increase was ineffective. The SAW did not have the lethality at long range to overcome the Red medium machineguns, and by firing, they simply exposed themselves to long range destruction by the Red machineguns. Red continued to win the battle almost 100% of the time, and Blue casualties remained constant. This alternative provided no benefits.

The strange result of Red casualties decreasing when the number of SAW were increased beyond 15 is due to target acquisition by Red. As the rifleman would not fire until the attacker had come within range, he was hard to detect by the Red machine gunners until late in the battle. When he had a marginally effective (at long range) SAW, his firing didn't accomplish much more than revealing his location to the Red machineguns. As more SAW replaced riflemen, more Blue were destroyed early. (This would be corrected if the SAW gunners held their fire until the attackers were close – a trade-off of survivability against higher numbers of Red casualties.)

Automatic rifle results

- Additional automatic rifles does not provide results comparable to the APL case
- Increasing beyond the 6 SAW baseline produces only minor improvement in battle outcome





- Increasing the number of SAW up to 15 shows an increase in Red casualties – but past that point the number decreases
- Blue casualties stay relatively constant

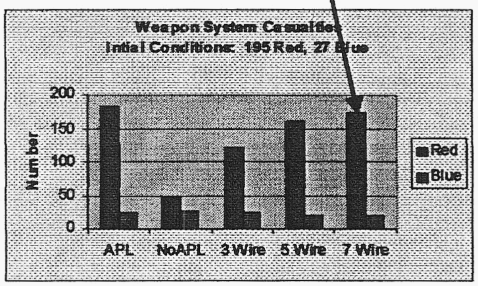
Figure 30, Additional Automatic Rifles

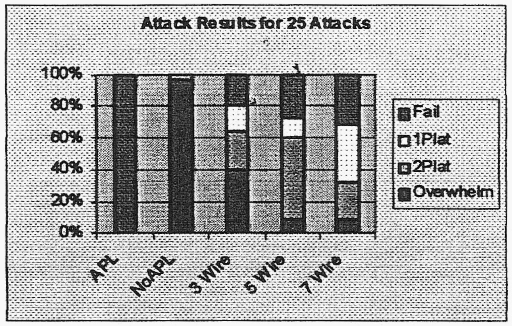
Additional Barbed Wire Obstacles

The APL minefields were replaced by increasing numbers of barbed wire obstacles (in addition to the protective wire in place at the defending position). Initially three wire obstacles were installed 200 meters from the defenders. This was then increased to five, and finally seven. The intent was to delay the attackers at extended range while the defenders continued to fire upon them. Seven obstacles provided the same number of Red casualties, on average, as the APL case with a slight reduction in Blue casualties. Red won the engagement 70% of the time, however, versus 0% in the APL case (the variability was due to early or late destruction of Blue machineguns which were the critical Blue force weapon). The wire obstacles also required 30 tons of material and 350 man-hours to construct vs. ½ ton and 30 man-hours for the APL fields.

Barbed wire results

- 7 wire obstacles provides almost identical Red casualty results as the APL case – with a slight reduction in Blue casualties





- This improvement in Red casualties is not reflected in battle results

- Even with 7 wire fences, Red wins almost 70% of the time

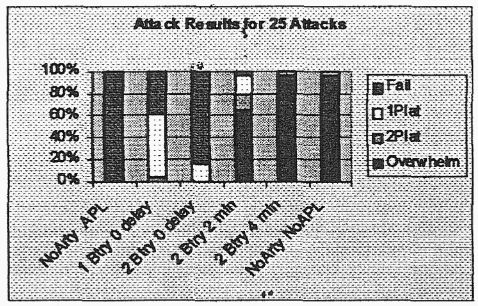
Figure 31, Additional Barbed Wire Obstacles

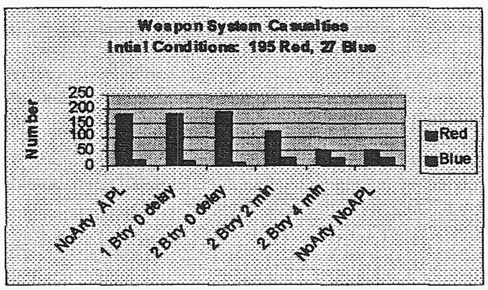
Dedicated Artillery

The defending platoon was provided a dedicated battery of artillery (155mm howitzers). Normally the platoon would share this quantity of artillery with 6 to 12 other platoons with similar missions. The battery was assumed to be in a ready-to-fire condition and could fire immediately upon arrival of the attacking force. The Red force won 60% of the time, though the results were on average similar to the APL case in terms of casualties. The artillery was then increased to two batteries (12 guns) and the time delay before the guns fired was parametrically varied from zero delay to 2 minutes delay, and finally four minutes delay. Two batteries firing with zero delay provided casualty results similar to the APL case, but Red still won 20% of the time. At four minutes delay the results were equivalent to having no artillery. From actual training data, artillery fire takes from ten to twenty minutes to arrive after the call for fire – which would have produced no effect in this engagement. As stated earlier, it is very difficult for artillery to hit a moving target. The two batteries of artillery fired 29 tons of artillery ammunition.

155mm artillery results

- Zero delay means rounds are fired as soon as the attack is detected
- 1 battery firing still allows Red to win 60% of the time, even though casualties are equivalent to the APL case





- 2 batteries with zero delay allows a Blue win over 80% of the time and better casualty results than the APL case
- 2 batteries with a 2 minute delay is ineffective in terms of battle results
- 2 batteries with a 4 minute delay is equivalent to no artillery

Figure 32, Dedicated Artillery

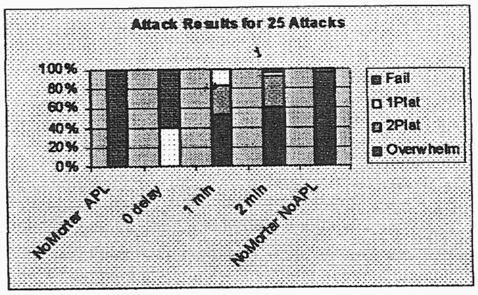
Dedicated Mortars

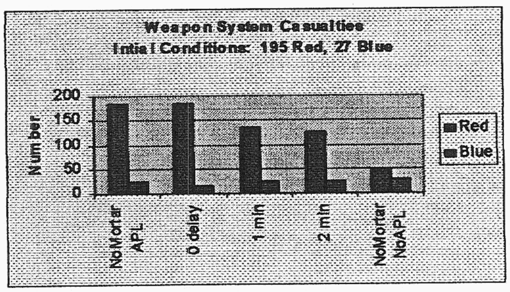
The defending platoon was provided exclusive use of the company mortars (three 60mm mortars). Mortar fire was parametrically varied, with values of zero delay, one-minute delay, and two-minute delay. At zero delay, the mortar fire produced, on average, the same Red casualty results as the APL case but Red won 40% of the time. At one and two minutes delay Red won almost all of the engagements.

60mm mortar results

- Only zero delay produces significant differences in battle results, and Red still wins 40% of the time

- Zero delay causes better casualty results than the APL case





- Even though Red wins with 1 or 2 minutes delay in mortar fire, he receives sufficient casualties to be combat ineffective

Figure 33, Dedicated Mortars

Remote Fire Claymores

Finally, the unit employed the Claymore munition with remote demolition firing devices. The Claymore is a small sheet of explosive faced with 700 ball bearings encased in plastic and normally fired by a defender transmitting a firing signal over a length of wire. The remote-demolition firing device is a special purpose device used to send a radio signal to destroy a demolition target, such as a bridge. Combining these two allowed the Claymores to be positioned farther out from the defender than the normal fifty-foot range with the wire system. Forty Claymores were installed in the engagement area in two lines, at 200 meters and at 400 meters from the defender. The Claymores produced, on average, the same Red casualty result as the APL, however, Red won 13% of the engagements. The Claymores weighed less than 200 pounds.

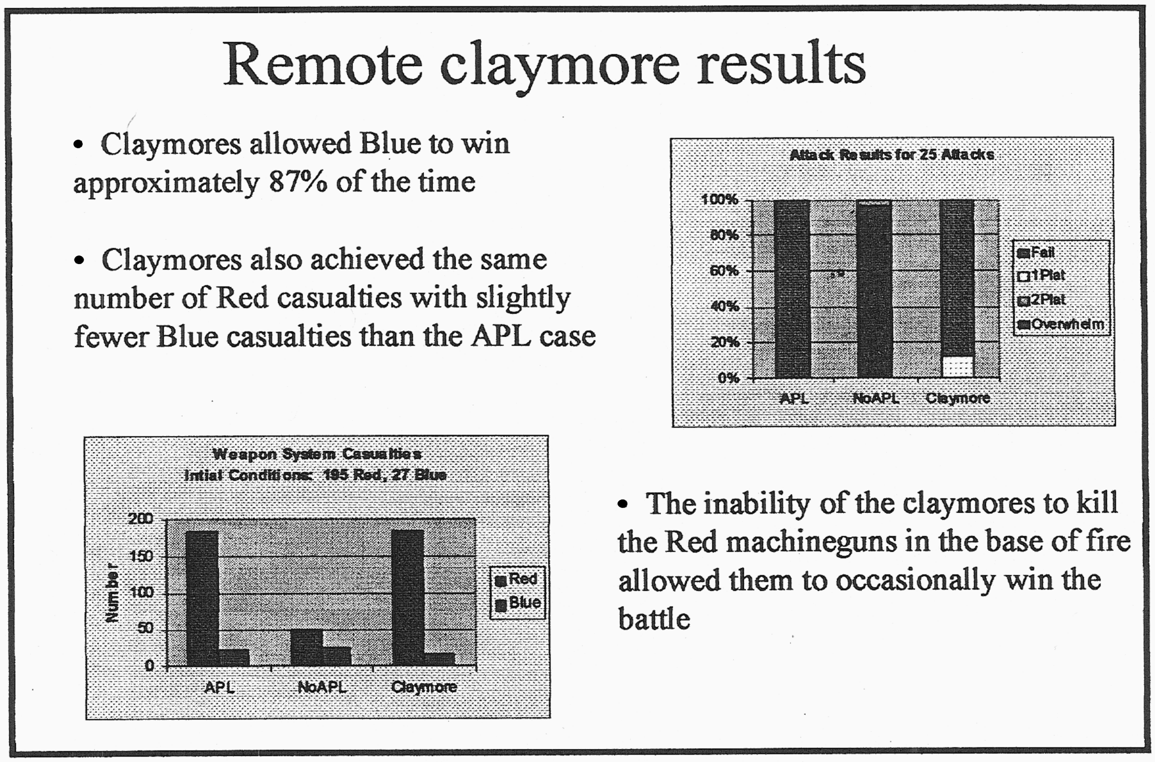


Figure 34, Remote Claymores

Summary Comparison

Figure 35 compares the alternatives using the Red win measure of effectiveness.

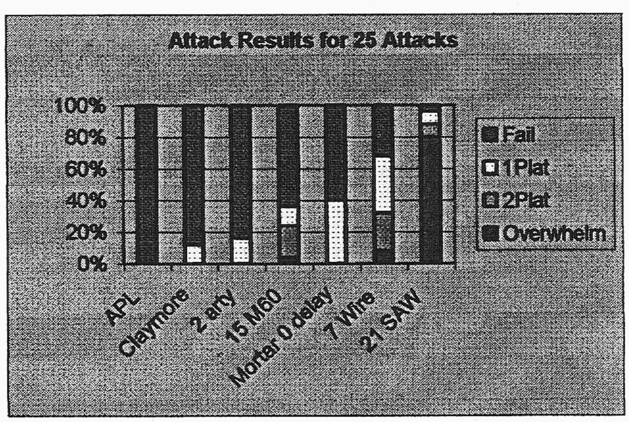


Figure 35, Comparison of Protective Obstacle Non-Materiel Alternatives

From this comparison it is clear that no non-materiel alternative completely replicates the APL contribution. The figure shows that the two best solutions were the Claymore alternative, or two dedicated artillery batteries firing with zero delay (if that were possible through use of sensors or some other means to predict when the artillery must be fired). Even with these alternatives, Red won occasionally.

Another assessment was conducted for the case of the attacker employing artillery-generated smoke to shield his attack from the defenders as he crossed the open area to get within effective firing range. When smoke was employed, only the APL case allowed the defender to win. In every other case the attacker always won. Sensors (type undefined) were employed to provide data about when to shoot. When sensors were employed and the attacker used smoke, the Claymore allowed the defender to win 95% of the time. No other alternative worked.

Impact of Smoke

- Red employs artillery smoke as a visual barrier in front of the Blue position
- Neither side can see their opponent until the assault force closes to within 100 meters of the defenders
- Blue machineguns fire along their final protective fire lines when they first detect the assault force

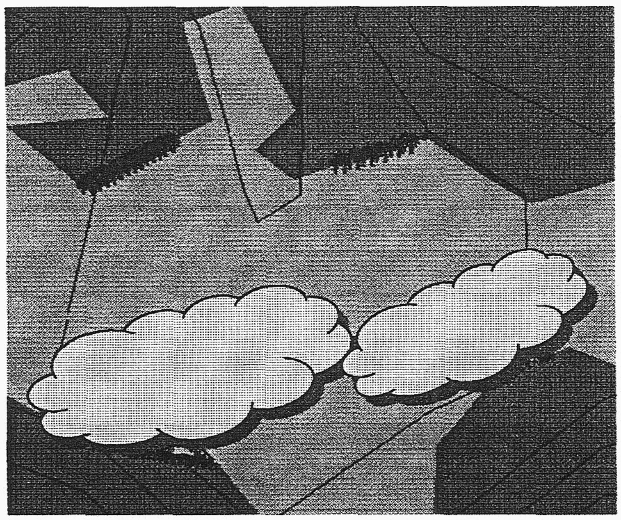
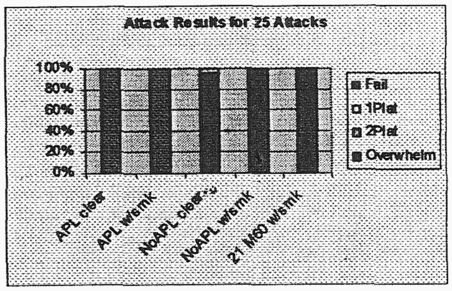


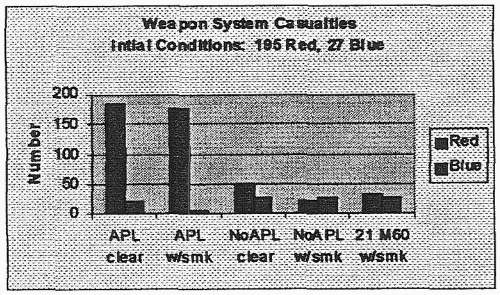
Figure 36, Smoke Application by Red

Results of Smoke

- Smoke totally shuts down direct fire until the assault force is within 100m of the defenders

- APL with smoke provides better Blue results, as the few survivors of the minefields are significantly outnumbered





- With smoke Red wins with very few casualties if APL are not present

- Without APL, nothing that delays at a distance is useful, since the defender cannot see to call artillery accurately or to employ direct fire

Figure 37, Smoke Results

Additional Marksmanship Training

A final study was conducted on the benefits of improving rifle marksmanship through additional training. The M16 rifle is capable of hitting a target at 600 meters. Rifle marksmanship training exposes pop-up targets at 500 meters and the expert is expected to hit with a high percentage at this range. Battle data, however, shows low probability of hitting a target at 200 meters. Soldiers are only able to train in rifle marksmanship once or twice a year due to training range and ammunition availability. This study examined results if additional training improved soldier hit probabilities. We adjusted marksmanship incrementally (the probability of hitting the target at 50 meters was moved out to 100 meters, the probability at 100 meters was shifted to 150, etc.) and measured the result in terms of Red casualties. In this case, Blue was armed with rifles and had Claymores in front of the platoon position.

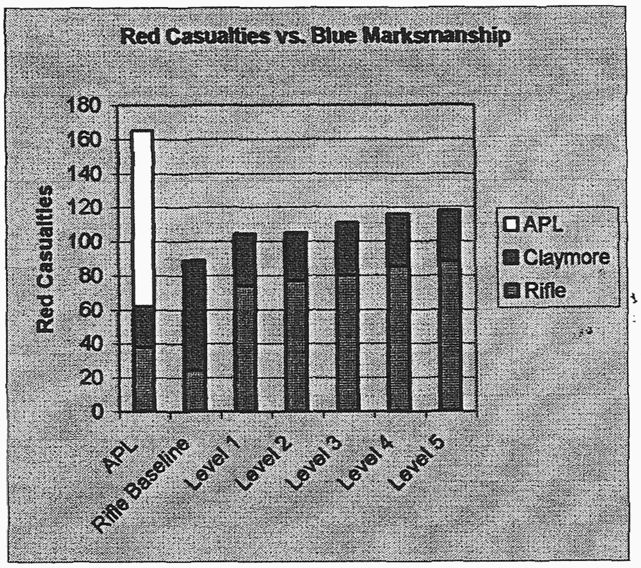


Figure 38, Rifle Marksmanship Improvement Comparison

Figure 38 shows that increasing rifle marksmanship did not make up for the loss of APL. In the rifle baseline (no APL) the rifles caused only 24 casualties, while the Claymores caused 65. The first increase in marksmanship, pushing the hit probabilities out 50 meters, caused a huge jump in rifle-caused casualties. Rifles caused 72 casualties. The drop in Claymore casualties was due to fewer attackers left for the Claymores to strike. After the first jump, the improvement in rifle marksmanship shows only slightly higher numbers of Red casualties. This implies that added training could produce more effective riflemen but the benefits of additional training beyond the first increment could be marginal.

Chapter Five

Conclusions

Current Minefield

At the firefight and engagement level, the mixed minefield is a significant combat multiplier. It dramatically improves the effectiveness of the direct fire antitank weapons in the defense. It allows success with smaller Blue forces, thus allowing significant economy of force in secondary areas. In many cases it significantly reduces Blue casualties. *It has been demonstrated in every vignette studied that employment of mixed minefields appreciably increases Red casualties.*

The impact of the APL extends beyond the engagement where employed. The mixed minefield causes the attacker to change his mode of attack and to lose additional armor fighting through the obstacle. This loss early in the battle is compounded through every subsequent engagement through reduced force ratios and higher casualty rates for the attacker. Simulations that simply add up casualties and slow the attacker's rate of advance seriously under report the impact of APL in a theater of operations.

Non-materiel Alternatives

No suggested change in tactics or weapon's mix fully replaced the results obtained with APL. Most required force structure changes. Any alternative that increased the size of the Blue force also increased the number of Blue casualties (there were more targets for Red to attack).

Two alternatives closely replicated APL results, remote fired Claymores and dedicated artillery with sensor support. The Claymore system does not require an increase in forces, but the artillery alternative requires a large increase in artillery support. Both of these alternatives required some materiel investment – providing remote firing systems for existing Claymore munitions for the Claymore alternative, and providing increased numbers of sensors for both the Claymore and the dedicated artillery solution.

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Appendix A

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Appendix B

Scenario Details

Four scenarios were modeled to establish the contribution of current antipersonnel landmines and to then estimate the contribution of the various contractor proposals. These scenarios were created at CINC conferences to maximize realism from the warfighter perspective so as to measure the impact of this weapon on overall operations. The scenarios were developed for Europe, Southwest Asia, and Northeast Asia, and pitted differing sizes of forces against each other. In all cases the blue (US) defenders were smaller than the red attackers.

Blue was outfitted with standard US weapons and weapons that are projected to be available in 2006, appropriate to the size of the defending force. Various levels of support were provided to Blue, including artillery and engineers, again appropriate to the scenario. Red forces were provided current Russian equipment and used tactics similar to the defunct Soviet Union. The modeling team took great pains to ensure that Red used tactics that made sense for the given situation; oftentimes the Red tactic was changed to help improve the probability of success of the intended Red operation based on considerations from the system under investigation.

European Scenario

The European scenario played a Red Motorized Rifle Division (four regiments) against a Blue mechanized brigade. The terrain was situated just east of Nuremberg and was primarily hilly and wooded, with many small villages. Blue set up defenses in-depth on the south bank of an east-west river, with companies providing the forward defense along three anticipated avenues of attack. Three of Red regiments had a specific attack route and objectives to achieve. Two regiments, 610 and 611, had objectives of establishing river crossing points, clearing obstacles and minefields, and destroying the forward defenses so as to allow a tank regiment to pass through and engage the defending brigade rear area and open a route to the autobahn further south. Antitank minefields were sited to meter the rate of arrival of Red forces. Because of the foliage and terrain, the minefields were too close to Blue defenders for optimum coverage during Red mounted or dismounted breaching (see Figure 1).

Figure 1. Red Movement, Blue Defense, and Purple Minefields

The 612 regiment provided a supporting attack to the east of the 610/611 areas and had rougher terrain to fight through. The intent was to fix the Blue defender's reserve with this thrust to keep it from being shifted to the main attack area in the west. A large dismounted Red force attacked through defended woods to hit the flank of the main Blue defense and destroy Blue antitank systems before the regiment's armor breached through minefields and engaged a series of Blue defenders hiding in small valleys,. Blue had indications of this large dismounted force and fired pre-planned artillery fire on an avenue Red was detected within. Surviving Red infantry then had to cross a defended open meadow (400 meters) to continue their attack. Blue defense consisted of obstacles, both APL minefields and wire, covered by small arms and semi-automatic weapons. Again, Blue could not optimally site the minefields due to the foliage and terrain. Red could detect the defenses, but could not avoid them due to their need to meet required timing for their flank attack (see Figure 2).

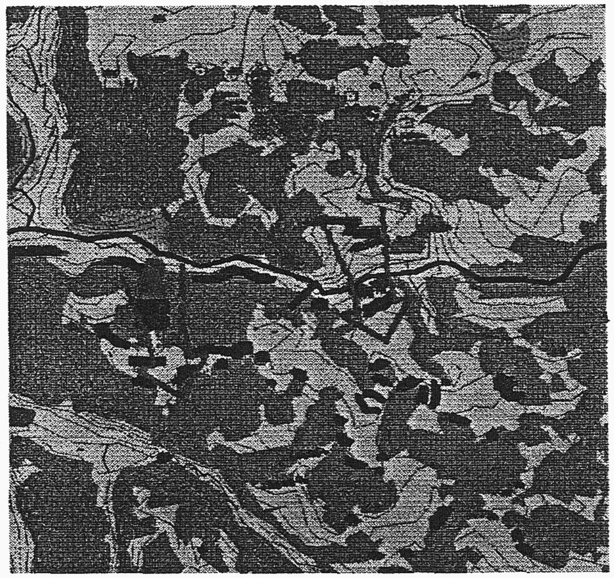

Figure 2. EUR 612 Red Movement, Blue Defense, and Purple Obstacles

Southwest Asia Scenario

This scenario was broken into two vignettes called SWA1 and SWA2. SWA1 modeled a Red tank battalion with an attached mechanized infantry company attacking through a desert valley into the rear of a Blue brigade attack. Two Blue tank platoons (a reduced strength company) was dug into two opposite overlooking mountainsides to defend this avenue. Red's objective was to traverse the valley to destroy the Blue artillery (in the brigade rear). Blue's objective was to guard this avenue, destroy Red and disrupt the tempo of operations using protected minefields. The minefields were meant to turn Red's advance into an engagement area where Blue could mass fires from both platoons. Red's response to Blue fire and discovery of the minefields was to turn two of his three company columns away from the protected minefields in order to swing around to the defender's flank, while simultaneously conducting a hasty breach and attack by the first company that encountered mines. Blue also had artillery support to suppress Red's dismounted breach efforts (see Figure 3).

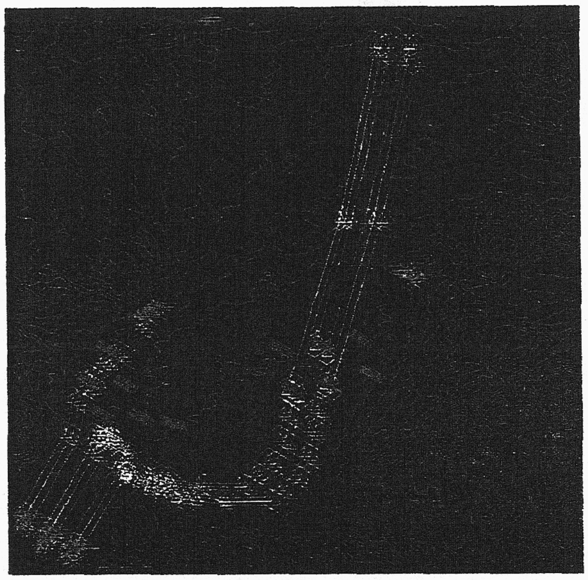

Figure 3. SWA1 Red Movement, Blue Defense, Purple Minefields

SWA2 modeled a Red mechanized regiment with an attached tank company against two Blue companies (one mechanized infantry, one tank). Again, Red had to traverse a desert valley (different than SWA1) to reach a further objective. Blue's objective was to block Red from reaching his destination. To that end, Blue positioned platoons in the hills overlooking the valley floor and placed turning minefields and blocking minefields with tank ditches in Red's anticipated path. Blue had optimum coverage of all minefields to thwart any breaching attempts (see Figure 4).

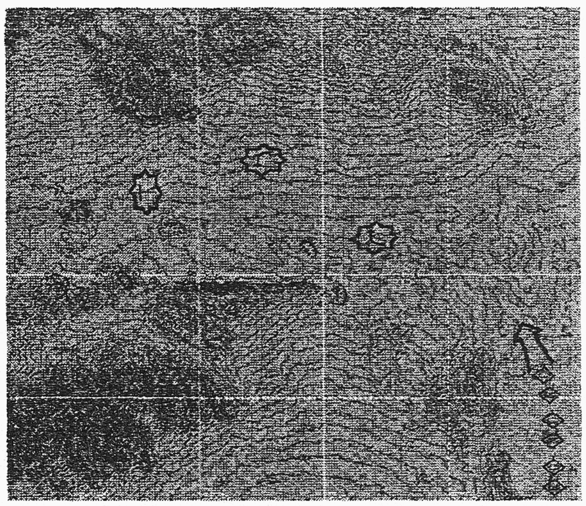

Figure 4. SWA2: Red Movement, Blue Defense, And Green Minefields

Northeast Asia Scenario

Two Red regiments were deployed against a dug-in Blue battalion on two hillsides. Red's objective was the hill the main Blue force was dug into. Blue's objective was to hold the hill at all costs. Red arrayed his battalions to approach from the west, northwest and north. Blue anticipated those lines of approach and sited anti-tank minefields at optimum distances in those directions. The minefields were meant to meter Red forces and slow the attack. Blue also sited a company on a small hill out of sight of the attackers at the beginning of the operation, but with good lines of sight against the attacker's flank later in the battle (see Figure 5).

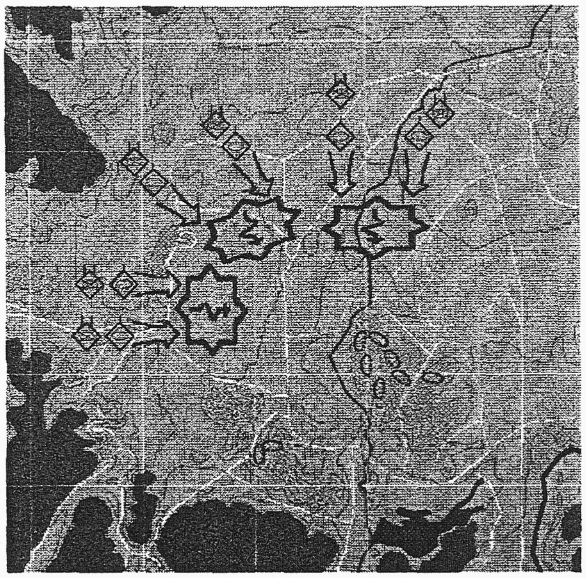

Figure 5. NEA: Red Movement, Blue Defense, And Green Minefields

Appendix C

Breaching Techniques

Breaching a minefield is a complex combined arms operation that requires forces to suppress enemy fire, secure the breach site, obscure the site from enemy force observation, reduce the obstacle, and assault the enemy. Building a passage lane through the obstacle is referred to as "reducing" the obstacle. In order to accomplish these tasks, the combined arms force organizes a support team, a breach team and an assault team. This appendix discusses the techniques employed by the breach team to reduce the obstacle.

The breach team mission is one of extreme risk. Not only is there risk from the mines in the minefield, the team is also the target for all of the defender's fires (both direct and indirect) to prevent if from accomplishing its mission. To lessen this risk the breach team must minimize its exposure and complete the task quickly.

The reduction task consists of three components: removing mines from the lane, "proofing" the lane to ensure it is mine-free, and marking the lane (the entrance, sides, and the exit). The analysis focused on the mine-removal task, as this is the critical component of the mission. There are a large variety of marking and proofing techniques available, their efficiency or lack thereof apply equally to all competing alternatives, and deficiencies in these areas will generally not cause the attacker mission failure.

It is extremely difficult to determine the boundaries of a surface, scattered minefield, as there is no geometric pattern. A vehicle striking a mine, or an individual seeing one, has no information on the size or orientation of the field. A minefield reconnaissance can provide rough details, but will still only approximate the position of the minefield edges. For this reason, the typical breach lane is started well before the minefield and continues well past the assumed far edge.

Reduction techniques fall into two general categories: those that use vehicle mounted equipment and those that use handheld equipment employed by dismounted soldiers.

Mounted Breaching Techniques

Mounted breaching equipment is affixed to an armored vehicle; typically a tank chassis but sometimes on a light armored personnel carrier chassis. Chassis selection is dependent on the weight and motive power required by the type of equipment. Both carriers protect the system against small arms fire and fragmentation weapons but not against antitank fires.

Mounted breaching techniques use the principle of treating an area of ground (the lane) to remove or destroy any mines that might be present without actually detecting and locating the mines. The current techniques were developed to breach the older buried mines but remain in use against the surface scattered systems. Basically they either physically move the mines to the side (with a blade or plow) or cause the mines to detonate through fuse activation (employing overpressure from a roller or line charge against pressure or tilt-rod fused mines or a spoofing magnetic signature for magnetic fused mines). Regardless of the technique used, the process is passed through the minefield along the path of the proposed lane to eliminate any mines that might be present.

The Mine Removal Solution

Armored vehicles are not designed like bulldozers to provide the low speed power necessary to move large quantities of earth in order to plow mines out of the way. Consequently most mine plow vehicles only push a small plow in front of each track with an opening between them under the center of the hull where the earth is not plowed. These are called track-width plows as they only remove mines directly in front of the vehicle's tracks. The plows push soil and any mines to either side of the tank. Most tanks can be fitted with this type of plow, though thereby causing an uncomfortable degradation in tactical mobility for their crews.

Certain breaching vehicles have been specifically designed to plow mines out of a lane. These, like the U.S. Army Grizzly, are unique vehicles capable of low speed power and typically fitted with full width snowplow like blades with lower edge teeth extending into the ground. Unlike tank-mounted plows, the numbers of these breaching vehicles available to an attacker are very limited and once destroyed they cannot be replaced.

Plows and blades produce a lane relatively quickly. The vehicle must travel at a slow speed to ensure that the blade follows the earth's surface and doesn't either dig in too deeply or skip over low spots, however this is much faster than any dismounted technique. Anything that hinders plowing will disrupt this breaching technique. A ditch, wall, roadway, area of heavy tree roots, buried poles or rails, or large rocks in the minefield will make plowing impossible. A vehicle carrying a plow or blade cannot climb a vertical step, so a side-hill cut in front of or in the minefield will stop them. It is relatively easy for a defender to protect his minefield against plowing by employing protective measures such as these.

Vehicle-mounted plows and blades produce a lane only slightly wider than the vehicle. The track-width plows also leave an uncleared strip down the centerline of the lane. This requires the armored force using the lane to pass through the minefield very slowly in order not to stray from the cleared tracks. A vehicle passing through a lane that is stopped by a mine detonation blocks the lane, which causes following vehicles to risk leaving the cleared area to pass around it.

It is not possible to widen a plowed lane with additional passes of plow-equipped vehicles. As the mines are moved to each side of the lane, plowing to the side will move any mines there back into the previously cleared lane. This limits lane width to that provided by a single pass.

The plowing action may cause mine detonation because of earth pressure against the mine pressure fuse. Plows and mineclearing blades are designed to withstand 2-3 heavy mine detonations before requiring repair. The consequence of this is that losses of mineclearing systems are quite severe due to antitank fires, occasional mines detonating under tracks or hulls of the clearing vehicles, and blade damage from mine detonation. As an attacking force progresses through mined areas, its ability to breach decreases as breaching assets become exhausted.

The Mine Destruction Solution

The same vehicles that can mount mine plows can mount a set of heavy rollers designed to put pressure equivalent to a tank on the mine pressure plate and cause it to detonate. The design of the rollers is not simple, as they must put a sufficient load (on the order of 300-500 pounds) onto the pressure plate while not allowing the weight of the roller to be supported by the adjacent soil. The roller also must be designed to vent the explosion in order to survive, as its function depends on the mine detonating.

Mine rollers are extremely clumsy devices that seriously degrade vehicle maneuverability. As such, they generally are not fitted until the force is upon the minefield. The mine rollers only clear a narrow area directly in front of each vehicle track, as they are too heavy and unwieldy to be constructed as full-width devices. Simple ditches easily defeat mine rollers.

Mine rollers are only effective against pressure fused and the simplest magnetic fused mines. Simple double-impulse pressure fuse (available since WWII) that causes mine detonation the second time they are activated easily counter the roller. They cause the mine to detonate under the track of the rolling vehicle. Mine rollers are not effective against US surface scattered, magnetic fused mines.

Line charges destroy pressure-fused mines through overpressure activation of the fuse or by sympathetic detonation of the main high explosive charge in the mine. Sympathetic detonation is only effective for a short distance and will not produce a vehicle lane. Because of the interaction of the airblast wave with the ground, there is a "skip zone" on each side of the charge where mines are not detonated.

Line charges are carried across the minefield by means of a rocket, and are fired from an armored vehicle or from a trailer towed by an armored vehicle. Line charges produce a wide lane (on the order of 10 meters wide) and up to 185 meters long. They require the carrier vehicle to proceed to the assumed edge of the minefield, launch the rocket, and detonate the charge. Because of the skip zone, the lane must be "proofed" with another technique – generally rollers or plows.

Line charges are generally not effective against US scattered magnetic-fused mines.

Magnetic Signature Projectors generate a strong magnetic field (which can vary according to some electronic algorithm) to "spoof" magnetic fuses and cause mine detonation at a distance in front of the vehicle. These false targets do not easily fool sophisticated magnetic fuses.

Gunfire can be employed against surface mines. The coax machinegun on the tank, and the cannon-machinegun combination on the infantry carrier are both stable firing systems with good sighting systems that can accurately engage mines. This technique does not work well if the ground is irregular or has any sort of vegetation, as the mines are extremely difficult to see (as proved in tests of the US systems at Hunter-Liggett).

Dismounted Breaching Techniques

Dismounted soldiers must locate each antitank mine in the lane area and individually remove or destroy it. There is no <u>area</u> treatment system that will destroy or remove antitank mines that is light enough for employment by dismounted soldiers.

The Pop & Drop Solution

If the surface scattered antitank minefield does not contain antipersonnel mines, it can be breached quickly by dismounted soldiers using the pop & drop technique. This technique involves a squad of soldiers moving quickly through the minefield (at a fast walk if not under direct fire, using 3-second rushes if exposed to direct fire), locating the mines, and placing a prepared demolition charge on it. In the classic pop & drop, each charge had a short time fuse and fuse lighter (generally a two minute fuse) that was lit by the soldier when he placed the charge. Other soldiers moving at the same rate simultaneously marked the lane edges. This technique could breach a 100-meter deep minefield in less than five minutes. A more conventional method had a length of detonating cord affixed to each charge that was clipped to a line of detonating cord (a line main) unrolled down the center of the lane. When all soldiers had exited the minefield, the detonating cord was fired to detonate all charges simultaneously. This method would breach the minefield in less than 10 minutes.

If the minefield was beyond the defender's direct fire range (approximately 1100 meters for the 7.62mm machinegun, 1600 meters for the .50 caliber machinegun, or 2000 meters for the Bradley cannon) the only threat was from artillery or mortars. Adjusting fire onto a moving breaching force is extremely difficult and takes more time than the force is exposed.

If APL protect the antitank mines, dismounted forces must deal with APL trip wires before using this technique.

The Thrown Grapnel Solution

Physically finding trip wires and avoiding them is very time consuming and hazardous. The grapnel was invented to speed this process by not having to actually discover the wire, but use a linear system to snag it if present.

The thrown grapnel is a set of welded hooks fastened to a line and thrown by the soldier over the minefield. The procedure is for the soldier to start well before the assumed edge of the minefield and throw the grapnel. Before the grapnel and attached line land, he must drop to the prone position case a tripwire should be activated. The soldier then retrieves the grapnel, while remaining in the prone position, by pulling on the line to hook any trip wires and detonate the associated APL. This is repeated several times to ensure that all trip wires have been caught. The soldier then must move forward into the cleared lane and repeat the process until he has worked his way across the minefield.

To ensure that the full 5-meter vehicle lane is clear of trip wires, soldiers must work grapnels down each side. This is a very hazardous process, as the lethal radius from bouncing mines approximates the distance a soldier can throw the grapnel. Any ground roughness or ground cover vegetation will make retrieving the grapnel difficult and less effective in capturing trip wires. This process is normally only used as a last resort (and will result in large numbers of casualties from indirect fire to the breaching teams).

The Rifle-launched Grapnel Solution

Most armies have some form of a rifle-launched grapnel to allow soldiers to clear tripwires more safely than with the thrown grapnel. The longer range of the rifle-launched version allows for a significant standoff while retrieving the grapnel.

This solution involves firing the rifle-launched grapnel sequentially across the minefield. The same 170-meter by 5-meter area must be cleared of trip lines.

The grapnel works by hooking the trip line with one of its tines while being retrieved (pulled back by the operator pulling on the attached grapnel line). The project manager as a part of the source selection process extensively tested the rifle-launched grapnel against trip lines. Unfortunately, the test set-up involved taut trip lines, as the pulling force was measured as a part of the test. (The test trip lines were elevated 4" above the ground – scatterable mine trip lines lay on the ground.) Conversation with the project manager and with experts at ARDEC revealed it had never been tested against a loose trip line (the type employed with scatterable mines). Conversation with developers of the

US FASCAM system revealed that in the 1970s the loose trip line about to be fielded had been tested with grapnel hooks and had been highly breach resistant, however documentation has been lost.

In any event, the only data available is for taut trip lines. Loose trip lines should be much more difficult to hook with a grapnel.

The rifle-launched grapnel is required to travel 75 meters. Test data showed an average launch distance in excess of 85 meters. As the operator needs a 25-meter safe distance from any possible detonation, the effective clearing length is 60 meters. This means that three successive launches would be necessary to clear 170 meters. The grapnel drift must remain within 8 degrees. This means that the grapnel could miss the aim point by as much as 12 meters left or right – which means it would be difficult to launch successive grapnels along the same path. This ability has never been demonstrated.

Again, it is necessary to grapnel along both sides of the five-meter wide lane to be cleared of AT mines to ensure trip lines are snagged from mines on either side of the lane. Parallel launches (with a potential 12 meter drift for each of six launches) has also never been demonstrated.

Using the taut trip line data, the test report included data for 90 degree (perpendicular to the lane being cleared) and 45 degree trip lines. Taut trip lines (which are installed by hand) are typically used in a 90-degree configuration to maximize frontal coverage. Loose trip lines are shot out of the mine and are randomly oriented. The 45-degree orientation data better represents the average exposure to the grapnel – trip lines between 0 and 45 degrees are much harder to hook than those between 45 and 90 degrees, but 45 is a good overall average.

The lower 90% confidence limit for effectiveness at 45-degree orientation over all types of terrain was 55% success in tripping the trip line. This was better on grassy surfaces and poorer on rocky surfaces. Using this average, to have 98% success against trip lines requires 5 successive launches from the same position along the same path.

After the grapnel is launched (with the operator in a prone position in the event of mine detonation when the grapnel or attached line lands on the ground), the operator must pull the line back in a hand-over-hand retrieval. The test report stated that slow retrieval was necessary to maximize the probability of hooking trip lines. Basically, the hook is dragged along the ground where its tines catch on soil or vegetation, causing the hook to move in a series of small jumps. The size of each jump or hop is related to the speed that the hook is pulled. The elasticity of the retrieval line also contributes to the hook springing long distances if it should be hung up on an obstruction while being pulled. In some instances, the operator was forced to go to his knees in order to have sufficient pulling power to clear an obstruction. This is highly dangerous, as the line between the hook and the operator could put sufficient pull on a trip line to cause a mine to detonate between the hook and the operator.

A fast retrieval speed is two seconds/meter. This means that the operator requires almost three minutes to retrieve the grapnel. The test showed that operators could unstow and mount the grapnel (prepare to fire) in approximately 20 seconds. Including aiming and firing, the entire launch process requires about 30 seconds. Launch and retrieval thus requires 3.5 minutes. Grapnels cannot be reused.

To clear a 5-meter lane of trip lines for later clearing of AT mines requires an operator with fifteen rifle-launched grapnels to assume a prone position 25 meters before the minefield and launch and retrieve five in succession. This requires 17.5 minutes. He then must move forward 85 meters (60 meters into the cleared path), which requires 1.5 minutes. Then he repeats the process to clear the next 60 meters, taking another 17.5 minutes. He then moves forward 85 meters to his final firing position taking another 1.5 minutes and does it all over again for another 17.5 minutes. The total time for him to clear the 170-meter path is 57 minutes. A second path must be cleared 5 meters to the side. If this is done as a second operation, the total time is 104 minutes. If two operators clear the two lanes in a parallel operation it would take 57 minutes plus some extra time for coordination as they shoot and retrieve lines simultaneously. The AT mine clearing team then requires 10 minutes to move through and clear the AT mines.

Clearing with a rifle-launched grapnel will require between one and two hours. Assuming grapnels all work perfectly, fly straight where aimed, and parallel – and that the grapnel is as effective against loose trip lines as it has been measured to be against taut. None of this has been tested.

The rifle-launched grapnel was designed for a different mission, and is not effective against the APL component of the mixed minefield in a breach situation.

The APOBS Solution

The APOBS (antipersonnel obstacle breaching system) is a two-man carry rocket propelled line charge designed to produce a footpath through wire and APL minefields. It destroys through fragmentation, not blast, as it incorporates a number of grenades strung along a length of detonating cord.

The APOBS consists of two backpacks weighing 55-65 pounds each. It is assembled at the launch location in about two minutes and after a short firing delay launches a 45-meter line charge with a 25-meter standoff. The detonation clears a path 45 meters long by 0.6-2.0 meters wide.

This system has never been tested against the loose trip lines on the scattered APL, so the exact behavior of the trip line exposed to the APOBS fragments is unknown. They should be far more survivable than a taut trip line as found on the M16 mine.

To breach a path through the 120-meter deep minefield requires firing multiple APOBS in sequence as the clearing team moves through the minefield. As the exact forward and rear edges of the minefield are not known, normally a breach team starts 25 meters (minimum) before reaching the nearest known edge of the minefield and continues 25 meters past the expected far edge. The actual breach lane, thus, is 170 meters.

The first APOBS produces a 45-meter lane beginning 25 meters from the launch point (there is a 25 meter non-explosive cable joining the line charge to the launcher to allow safe stand-off). The next APOB team must enter the lane and proceed along it 20 meters to assemble the second APOBS (to account for the 25 meter stand-off). There is no guarantee that the APOBS will clear a straight path, or that the second APOBS will lay precisely along the path laid by the first. In fact, the 25-meter standoff cable must overlay a potentially 0.6 meter wide lane for its full length. This has never been demonstrated. This must be successfully repeated four times in succession to get a clear lane the full length through the minefield.

The team must construct three parallel 0.6 meter wide breach lanes 170 meters long to ensure a reasonable probability of no trip lines within the 5 meters which will be cleared of antitank mines (one lane at each edge and one down the center of a five meter wide lane). No one has successfully demonstrated the ability to fire two APOBS and produce parallel lanes – let alone three in parallel repeated four times in succession.

Given everything works, it should take two minutes to setup the first APOBS (PM provided time) and 30 seconds for the firing delay so that the launch crew can take shelter. The time to fire the first APOBS is 2.5 minutes. The second team must leave shelter and carry their APOBS 45 meters to the new launch point – which takes approximately one minute. Thus the time to fire their APOBS is 3.5 minutes. The third team must travel 90 meters, which takes 1.75 minutes. The total time to fire their APOBS is 4.25 minutes. The fourth team must travel 135 meters, so their travel time is 2.5 minutes plus 2.5 minutes to fire their APOBS for a total of 5 minutes. Summing, the time for one lane is 15.25 minutes. To clear a five meter wide path so that the AT mines can be breached requires this action to take place three times, followed by 10 minutes to clear the AT mines with explosive charges. Clearing a mixed minefield using APOBS against the AP mines takes 55.75 minutes. This assumes all 12 rockets fly straight and parallel and precisely where aimed – which strains credibility.

The APOBS system was designed for a different mission, and is not an effective solution against the APL component of the mixed minefield in a breach situation.