STRATEGY RESEARCH PROJECT

EDUCATING OUR BULLETS; A ROADMAP TO MUNITIONS CENTRALITY

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ABSTRACT

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Smart munitions deliver warfighter advantages in effective defeat of critical targets, the reduction of logistics burdens, and total force survivability. Brilliant munitions, delivered by Army, Navy, Marine, and Air Force platforms offer further warfighter advantages and shifts some target attack processes from delivery platforms to the munition (munitions centrality). This paper addresses the basis for current smart and brilliant munitions programs. The spectrum of target recognition capabilities is presented as a roadmap towards munitions centrality. Based on key battlefield targets, the benefits of brilliant munitions are shown through selected computer scenarios. Finally, an approach to managing the technology is offered.

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ACKNOWLEDGMENTS

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Sincere thanks is also extended to those in the development community who have been addressing brilliant munitions, particularly Dr. Richard Sims of the Aviation and Missile Command at Redstone Arsenal, AL and Mr. Philip Jones of the TRADOC Analysis Command at White Sands Missile Range, NM who assisted in the review of the analysis presented here.

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INTRODUCTION.

BACKGROUND.

During his Senate Armed Services Committee confirmation hearing for selection as Under Secretary of Defense for Acquisition and Technology, Dr. Jacques S. Gansler identified five areas requiring particular attention. Two of the five addressed "The development and deployment of long-range, all-weather, low-cost, precise and 'smart' weapons to achieve maximum fire power with minimum loss of life;" and "Achievement of rapid force projection and global reach of military capability."[1]

The Air Force and Navy have employed "smart bombs" and the Army has fielded smart munitions such as Sense and Destroy Armor (SADARM) and is on the verge of fielding munitions with greater capabilities such as the brilliant antiarmor submunition (BAT).[2] While smart munitions bring distinct value to the battlefield, there is still greater potential ahead. The draft of the Field Artillery Vision for the 21st century coins the term "munitions centrality" to describe the transition from improved lethality derived from delivery platform technology to technologies that enable brilliant munitions to determine which targets to attack.[3]

Brilliant munitions promise to achieve the desired effects against the target with reduced expenditure of munitions, thus reducing the logistics burden and facilitating the rapid deployment of forces. "Few doubt that automatic target recognition (ATR) technology will be an essential element of 21st century warfighting, but many harbor suspicions that it is oversold. There is a perceived gap between the expectations of the warfighter and the efforts of developers."[4] So, given the emphasis on precision munitions, how might this capability be achieved?

PURPOSE.

The purpose of this paper is to present the battlefield trends of precision munitions in general, and brilliant munitions in particular in defeating high value targets. A roadmap for developers and warfighters is recommended to incrementally introduce capabilities that provide distinct battlefield advantages and allows technology growth—how to educate our bullets.

PRECISION GUIDED MUNITIONS

If you think education is expensive—try ignorance.[5]

—Derek Bok

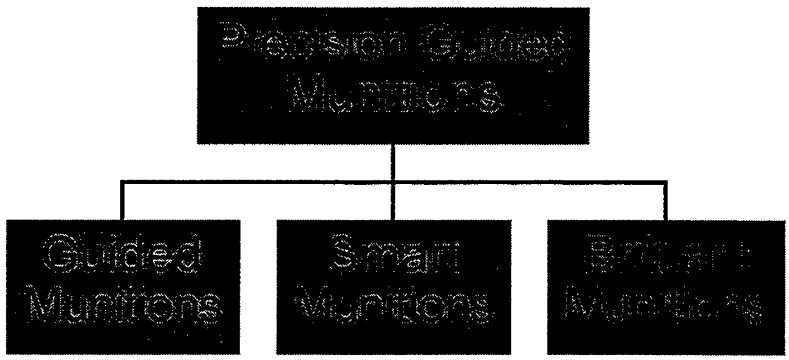

Figure 1. Classes of Precision Guided Munitions[6]

GUIDED MUNITIONS

The term "smart munition" is generally misused as the media broadcast the effects of "smart munitions" during Desert Storm. Systems such as the Air Force joint direct attack munition (JDAM) and joint air-to-surface standoff missile (JASSM) utilize inertial navigation systems and the global positioning system (GPS) to guide the munitions to the intended target. Other systems such as the Army's Copperhead cannon artillery round use external (to the munition) laser guidance techniques to direct the munition to the target. These munitions are certainly more precise than conventional munitions, but technically these are considered guided munitions. An operator is "in the loop" to select the target and assist in guidance (including entry of GPS coordinates).

SMART MUNITIONS

The correct designation of "smart" applies to those munitions that *autonomously* search, detect, and attack targets. No operator is involved in guiding the munition to the target. The Field Artillery has invested in delivery platforms such as the Paladin and Crusader howitzers to accurately deliver munitions such as SADARM to the target area. Once dispensed, the SADARM then attacks targets located within its footprint. The 1997 Division Advanced Warfighter Exercise (DAWE) showed dramatic advantages by employing SADARM by 155mm cannons (220 SADARM vs. 3600 dual purpose improved conventional munition (DPICM) rounds to defeat 100 armored fighting vehicles).[7] Programs such as the Multiple Launch Rocket System (MLRS) Smart Artillery Rocket (MSTAR) are evolving to deliver smart and brilliant munitions at greater ranges. Studies consistently indicate a reduction of MLRS rockets required to defeat hard targets by a factor of six when attacking with smart munitions (as compared to DPICM)[8].

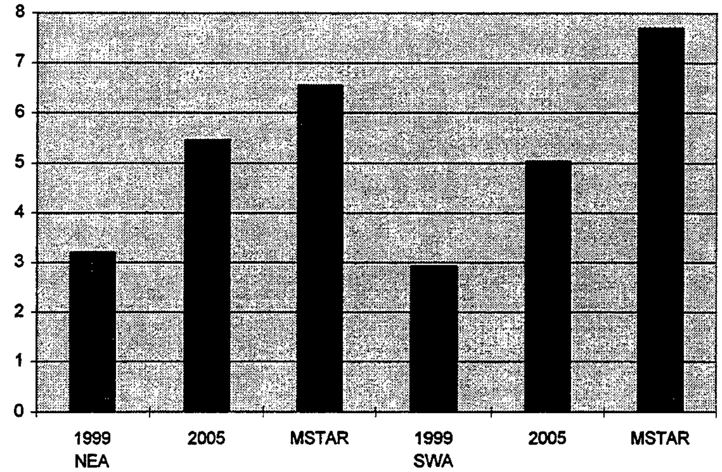

Chart 1. Changes in loss exchange ratios (LER)[9]

Chart 1 shows the loss exchange ratio (enemy systems killed divided by friendly systems killed) in Northeast Asia and Southwest Asia scenarios as portrayed in the 1996 Antiarmor Requirements and Resource (A2R2) Analysis. While the A2R2 study concentrated on direct fire systems, indirect fire systems (such as MSTAR) were also considered. Systems expected to be available in 1999 represented the base case in the study. The 2005 case represents the addition of selected friendly direct-fire systems to the force.[10] The addition of MSTAR suggests the aggregate benefits to the force at large by employing smart munitions.

BRILLIANT MUNITIONS

The Army is expected to begin production of BAT in FY99, followed by a preplanned product improvement (BAT P^3I) after the turn of the century. The Air Force is testing the low cost antiarmor submunition system (LOCAAS).[11] Brilliant munitions incorporate advanced decision-making algorithms to attack *specific* targets within their footprint. To maximize such a capability, the technology supporting brilliant munitions is being applied to munitions with large footprints and with a capability to maneuver to the desired target.

BENEFITS

Reductions in ammunition expenditures to defeat targets directly translate into reduced logistics burdens. Given the large volume of munitions delivered by Field Artillery systems, a reduction in ammunition requirements further translates into a more deployable force.

From a total system view, target acquisition sensors can be less precise and/or more timely in reporting a target. The weapon platform (e.g. Paladin or Crusader, MLRS, or Air Force fixed-wing) rapidly delivers munitions in the general target area and then either fires at another target or relocates for survivability reasons. The munition then assumes the responsibility for defeating the target. As critical targets are defeated, the force at large becomes more survivable. This is the essence of "munitions centrality".

With all this promise, where is the product? As the introduction suggests, is this technology oversold? What should the expectations really be? Benefits can be realized by all the services; the focus of this paper will be directed to Army delivery systems. To address these questions, an understanding of how the Army fights and how precision guided munitions can best be applied follows.

TACTICAL APPLICATIONS AND ROADMAP

> The enlightened ruler lays his plans well ahead; the good general cultivates his resources.
>
> —Sun Tzu

D^3A

The Field Artillery Center and School at Ft. Sill, OK has espoused the acronym D^3A (Decide, Detect, Deliver, and Assess) that affects targeting criteria and selection of weapons systems. The commander Decides what targets are important during each phase of the operation. Target acquisition resources are assigned search priorities to Detect and report those targets. Delivery systems (cannons, rockets, missiles, aviation, etc.) are identified to attack (Deliver munitions) targets according to criteria established in an attack guidance matrix.[12] Acquisition sensors are also assigned missions to Assess the effects on the target. If the target is not defeated according to the commander's desires, then the target may be attacked again.[13]

When Are Precision Munitions Not Needed?

A significant inventory of conventional munitions exists. These weapons are still relevant on current and future battlefields against targets such as dismounted infantry, towed artillery, logistics bases, command posts, and fixed installations that are vulnerable because of exposed soldiers, soft targets, and limited (or no) ability to rapidly relocate. Once a sensor detects these type targets, time is less critical and target location can be refined so that the conventional munitions can be more effectively delivered. Current rockets, missiles, and cannon artillery (including Navy, Marine, and Air Force systems) deliver ordnance that effectively covers large areas and effectively defeat these targets. In the case of fixed installations, gravity bombs may suffice. Certain weather conditions such as high winds can affect the performance of precision munitions.

"The high spin rate imparted to cannon projectiles provides a predictable ballistic path of flight. This advantage, the cannon system's fully integrated muzzle velocity measuring radar, and the digital updating of weather conditions along the trajectory of flight into the ballistic computer of each cannon on board make today's cannons more accurate than ever."[14] Until advanced munitions are developed and proven, conventional munitions, with observers controlling the fires, will remain the primary system of choice in a direct support role, close to friendly forces.

The message is that so-dubbed "dumb munitions" still have a role, are affordable, and are still effective, possibly more so than precision munitions depending on the target. Delivery systems have evolved to effectively attack certain targets.

When Should Precision Munitions Be Used?

Guided munitions have been effective where a precise location of the target is available such as fixed, non-mobile targets. The guidance is provided by external sources such as laser guidance or by inertial navigation and GPS-aided devices that attack a precise grid location. The Army's Copperhead munition can attack individual moving armored targets provided the observer can maintain line of sight to, and keep the laser designator on the target. These systems represent *aided* target recognition capabilities where there is a soldier in the loop making the decision to attack.

Smart munitions search large footprints and extract targets from natural backgrounds. Various programs are exploiting sensor technologies such as infrared (IR), millimeter wave (MMW), laser radar (LADAR), and acoustics. As acquisition sensors locate high priority , short-dwell time targets, the targeting information must eventually be fused and passed through command and control (C^2) networks to a weapon delivery platform. The timeliness of this information determines the nature of the target once the weapon arrives in the target area. Will the munition see the same scene as the acquisition sensor reported moments, minutes, or longer ago? Has the target moved or otherwise changed its disposition (camouflaged, engine stopped and cooled, etc.)? The attack guidance matrix recognizes the uncertainty of the target location and disposition and recommends attack by smart munitions.

So, one aspect of munition selection involves target location error (TLE). Large TLEs can be a function of the target acquisition sensor capabilities or the tactics used by the target (e.g. shoot-and-scoot).[15] If a target is precisely located, conventional munitions may be employed according to the joint munitions effects manual (JMEM) that recommends the number of munitions required to achieve the effects desired by the commander. In some circumstances (such as attack of hard, armored targets), a smart munition may still be preferred even with a small TLE as demonstrated by 155mm SADARM defeat of armored artillery and fighting vehicles during the DAWE.

Another aspect of munition selection is the notion of high payoff targets. Chart 2 shows the contribution of enemy indirect fire systems in Northeast Asia and Southwest Asia scenarios as portrayed in the A2R2 analysis.[16] This chart complements chart 1, loss exchange ratios, and suggests (and studies have shown) that if more enemy artillery can be defeated, then an improvement in loss exchange ratios will be realized. Enemy indirect fire systems represent high payoff targets.

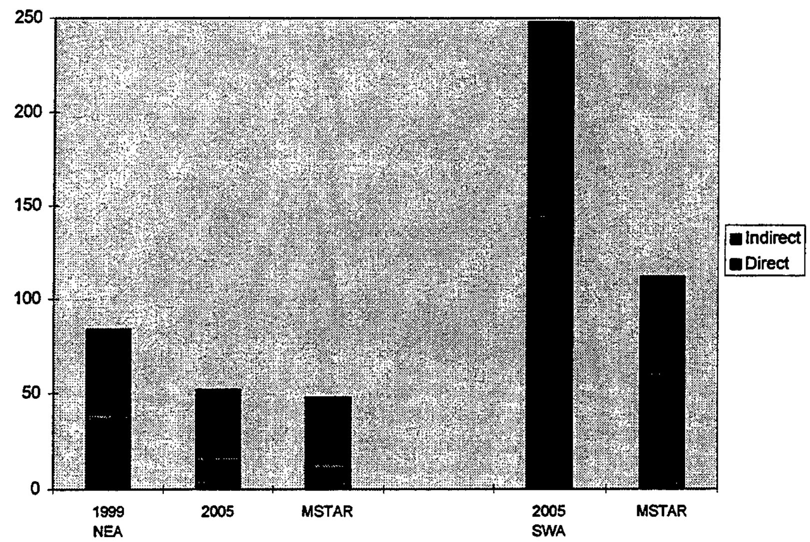

Chart 2. Friendly losses due to Threat systems[17]

A critical indirect fire system is heavy multiple rocket launchers (MRL). The performance of the US and UK MLRS units during Desert Storm revalidated the utility of heavy MRLs on modern battlefields. Improvements in rocket range and munition options are found in research and development programs in many nations.[18] A brilliant munition should possess the capability to find and attack heavy MRLs. This is where the roadmap for munitions centrality begins.

TARGET RECOGNITION

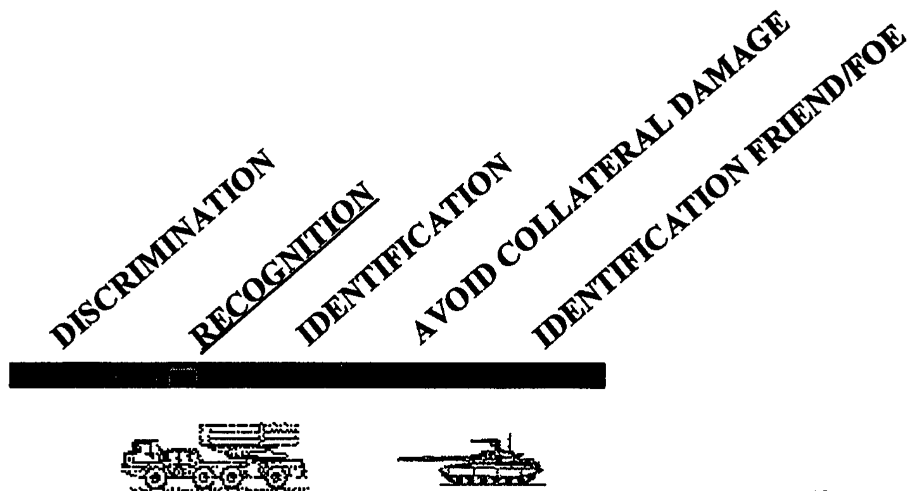

Figure 2. Roadmap; Target Recognition[19]

The sensors and supporting decision algorithms of smart munitions currently operate on the left of the roadmap and discriminate between targets and non-targets (e.g. natural features such as rocks and bushes, or large man-made objects such as buildings). While a smart munition may indeed attack a military target (e.g. armor in an assembly area) which could influence the outcome of the battle *later*, additional munitions may have to be expended to defeat the intended targets (e.g. heavy MRL) that are *currently* causing harm to the force. In this context, the first "education upgrade" should be *target recognition*. The physical features of MRLs can be exploited. Sensor resolution and decision algorithms can enable a smart munition to distinguish between armor and launchers.

The following scenarios assume a generic smart and brilliant munition with a large footprint and a capability to maneuver to the intended target. The munitions can be delivered by "busses" such as the Air Force tactical munitions dispenser (TMD), the Navy Tomahawk, or Army systems such as Multiple Launch Rocket System (MLRS) rockets or the Army Tactical Missile System (ATACMS).[20] The scenarios are focused on Army systems. The Illinois Institute of Technology Research Institute (IITRI) at Huntsville, AL graciously agreed to conduct some pro-bono simulations for this paper as they were preparing the GENEric Smart Indirect fire Simulation (GENESIS) model for an MSTAR (MLRS Smart Artillery Rocket) study for Ft. Sill, OK. Appendix A provides more detail on how the munitions work. Note that only 500 repetitions of each of these scenarios were conducted for this report; the associated trends warrant additional study.

Scenario 1; Attack of MRLs.

This scenario involves the attack of heavy MRLs located in the vicinity of armor. Six rockets, each carrying two smart munitions, attack the target. The target area includes eight MRLs and 34 armor and support vehicles. Current Field Artillery C^2 systems provide the capability to transmit the fact that a "launcher" is the target to be attacked. This information would be passed through the C^2 network to the MLRS launcher. The MLRS then passes the mission to the rockets that then download information to the munition. As the munition searches the target area, it may indeed encounter other military targets; those may be ignored. The launcher is the primary target of interest and the munition has been instructed to kill it.

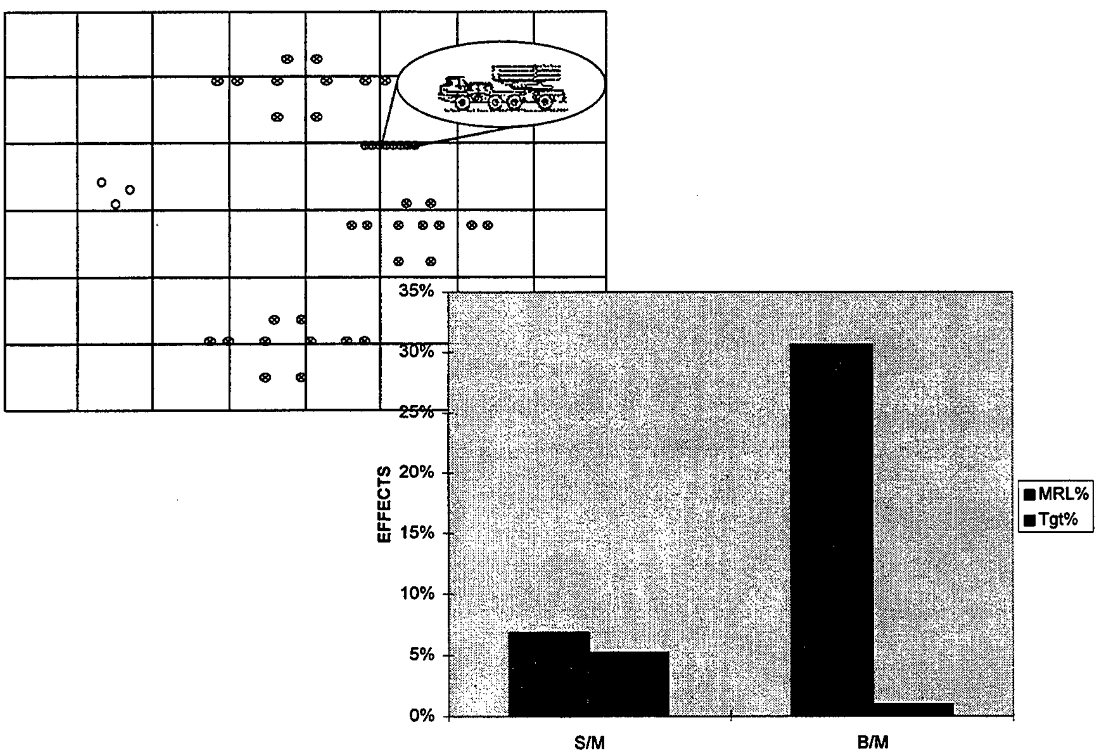

Figure 3. Target area; MRL vic armor; results

Figure 3 presents a scenario where real estate is at a premium (e.g. Korea, Western Europe) or in a wedge formation as was employed during Desert Storm by coalition forces.[21] MRL%

represents the effects against the MRL unit; TGT% represents the effects against the remaining targets. It suggests that brilliant munitions (B/M) with a *target recognition* capability increases the number of Threat indirect fire systems killed (MRLs) as compared to smart munitions (S/M). Attacking MRLs with conventional munitions requires a greater expenditure of ammunition; and if the MRLs are employing "shoot and scoot" tactics, the conventional munitions will impact where the MRLs *were*. Smart and brilliant munitions with large search footprints increase the probability of defeating the target with a reduction in ammunition required.

Note that this comparison is *not* an indictment of smart munitions; rather, this is an enhanced capability as the technology growth is applied (educating smart munitions—making them brilliant). The results should then reduce the number of friendly systems killed by indirect fire (Chart 2) with a subsequent ripple effect on the associated LER (Chart 1).

Scenario 2; Attack of SAM site.

The commander decides to attack a column of advancing armor with air assets. A surface to air missile (SAM) site has been detected in the vicinity of the armor convoy route, but time does not permit refinement of the SAM location; so this mission will be conducted with a large TLE. The commander decides to use precision munitions to locate and defeat the SAM site as a SEAD (suppression of enemy air defenses) mission. One missile carrying six munitions attacks the target. The resulting aimpoint causes the munitions to encounter the armor. This stressing scenario forces the implementation of the target recognition algorithm. It also demonstrates the benefit of large footprint munitions by their ability to compensate for targeting and delivery errors, thus allowing the commander a rapid attack of a target without waiting for refined target details (munitions centrality).

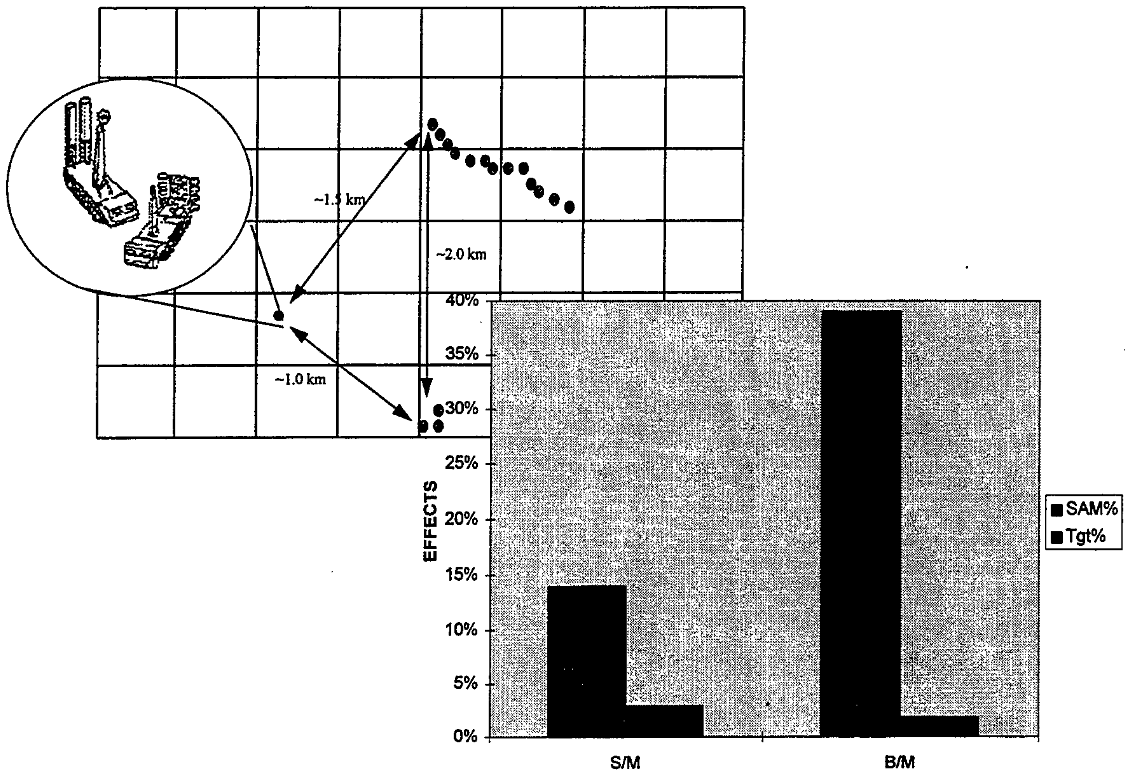

Figure 4. Target area; SAM vic armor; results

Figure 4 suggests an increase in the probability of killing the SAM launcher from 14% to 39%; but this is with poor targeting. The purpose of this scenario is to introduce a stressing case of large TLE and instructing the munition to find a single launcher among other military targets. "Better" targeting could have provided an attack guidance matrix recommendation to attack by conventional munitions (e.g. ATACMS or MLRS DPICM rockets).

Scenario 3; Attack of SSM launchers.

A commander has been ordered to deploy where a conflict is developing and has identified seaports and airfields for entry operations. No enemy close combat forces are within the vicinity of the entry point, but the enemy does have long range surface to surface missile (SSM) launchers. These SSMs are a high priority; target acquisition resources are focused on locating these targets based on the intelligence preparation of the battlefield (IPB) that was conducted.

Since this is a decision made prior to deployment, the commander ensured air defense systems (e.g. Patriot) and long range, responsive delivery systems (e.g. MLRS/HIMARS; the High Mobility Artillery Rocket System, the lightweight version of MLRS) were deployed early. Now in theater, the acquisition sensor has located (very accurately, near-zero TLE) an SSM launcher. The MLRS launcher was using a "stay hot, shoot fast" methodology[22] and has launched a missile to attack the SSM launcher.

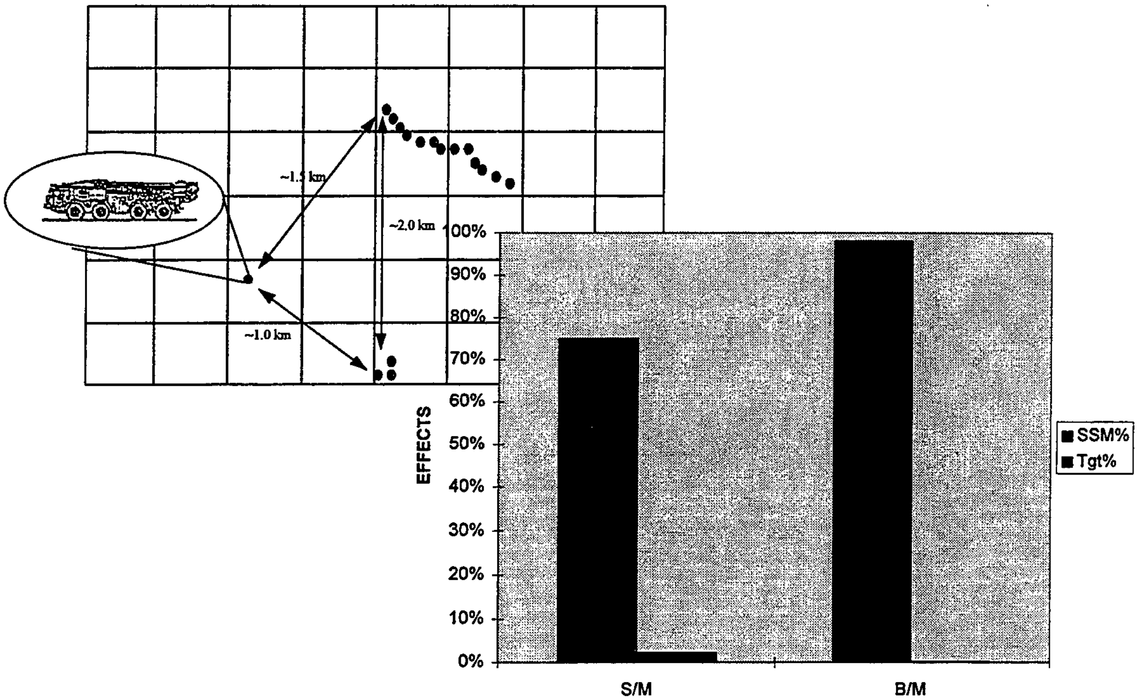

Figure 5. Target area; SSM vic armor; results

Armored vehicles could be protecting the launcher; there could be armor passing through that area towards the front lines. Figure 5 shows the benefit (98% vs. 75% chance of killing the SSM) of a brilliant munition searching the target area for the intended target. Similar scenarios apply to mobile inter-continental ballistic missile launchers (ICBMs) that can be attacked by brilliant munitions delivered by tactical munitions dispensers and Tomahawk cruise missiles.

TARGET IDENTIFICATION

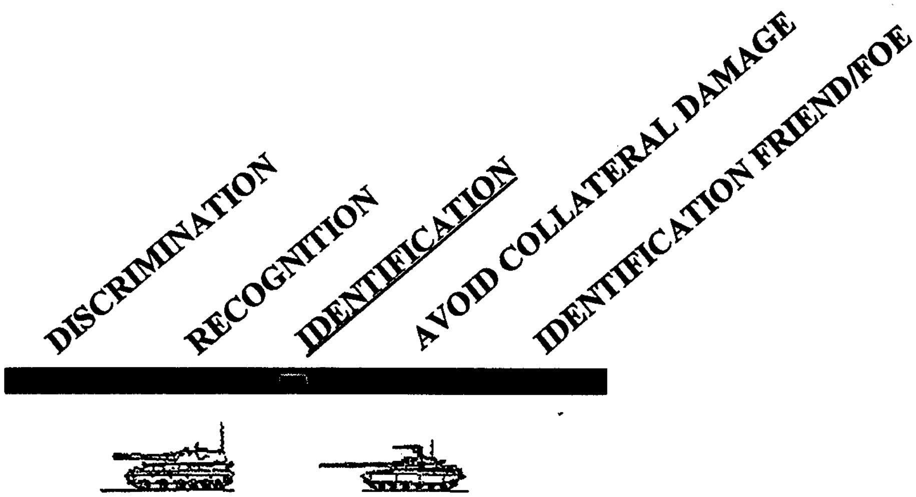

Figure 6. Roadmap; Target Identification

The previous three scenarios indicate the benefits of brilliant munitions with a target recognition capability. Recall chart 2 that shows the effects of enemy indirect fire on friendly forces. Indirect fire systems include cannon artillery as well as heavy MRLs. Self-propelled howitzers (SPH) have similar characteristics as armored vehicles, but differences do exist that can be exploited. Extraction of these features is a more difficult problem and it represents the next step towards munitions centrality—*target identification*.

Scenario 4; Attack of SPHs.

A battery of eight howitzers is located among 34 other vehicles. With their range and munition capabilities, these SPHs are inflicting damage to friendly forces at extended ranges while the armor (with reduced range and not in contact) is positioned nearby. Six rockets carrying two precision munitions each attack the target.

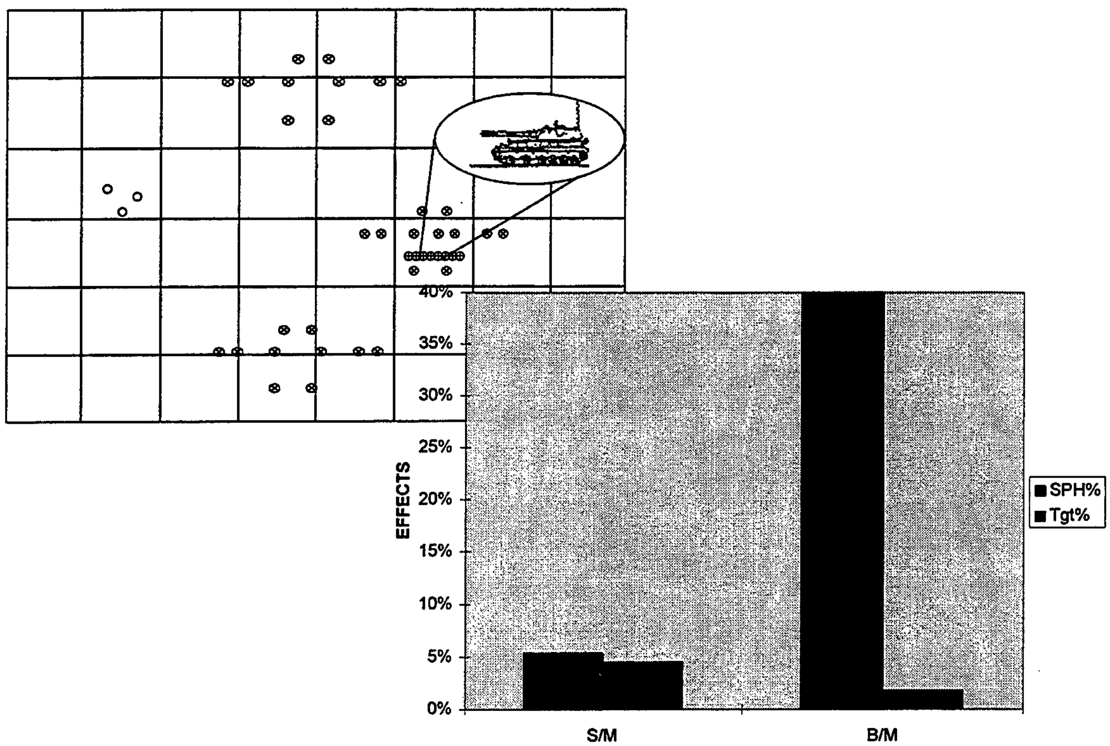

Figure 7. Target area; SPH vic armor; results

Again, the munition is instructed to search for the SPHs based on information passed through the C^2 network to the weapons platform and on to the munition. Figure 7 shows that with just six MSTAR rockets, 40% of the SPH unit is defeated. The classified JMEM requires many more conventional rockets for equivalent effects.[23]

Scenario 5; Acoustic sensors

The Brilliant Antiarmor Submunition (BAT) utilizes an acoustic sensor to locate moving armored formations and an infrared (IR) sensor to locate and attack specific targets within those formations. A pre-planned product improvement (BAT P^3I) replaces the infrared sensor with a dual mode (imaging IR and millimeter wave) seeker. BAT P^3I retains the acoustic sensors as well. While this report addresses generic, large footprint, smart munitions, an excursion was made to assess performance by a munition that also employs acoustic sensors.

This scenario presents an armor convoy of 27 vehicles containing six SPHs. The scenario does not assume any enhanced capability by the acoustic sensor; all enhancements are applied to the primary seeker.

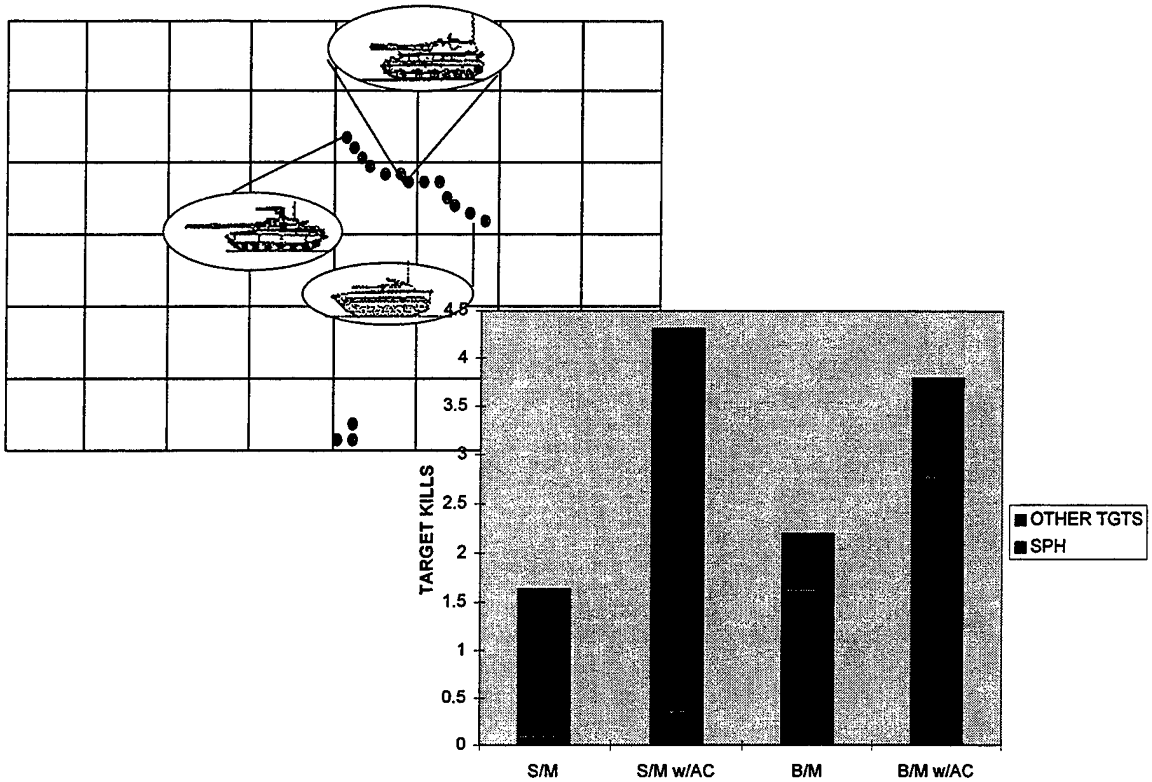

Figure 8. Target area; SPH in Armor Convoy; acoustics

With acoustics, the total number of targets killed by the smart munition increases as compared to munitions not using an acoustic sensor. The intended target is the artillery that is the current concern to the commander. Coupled with acoustics, the simulation indicates 47% defeat of the artillery battery by a single pod of MLRS ammunition; six rockets, each delivering 2 BAT P^3I munitions. The decrease in total performance (total number of targets defeated) between a smart munition with acoustics versus a brilliant munition with acoustics may be addressed with a "dynamic logic" algorithm that is described in Appendix A.

Again, further study is warranted.

AVOIDANCE OF COLLATERAL DAMAGE

> ..de-massified destruction, customized to minimize collateral damage, will increasingly dominate the zones of battle...[24]

Avoidance of collateral damage is addressed in the Field Artillery vision and is part of the roadmap.

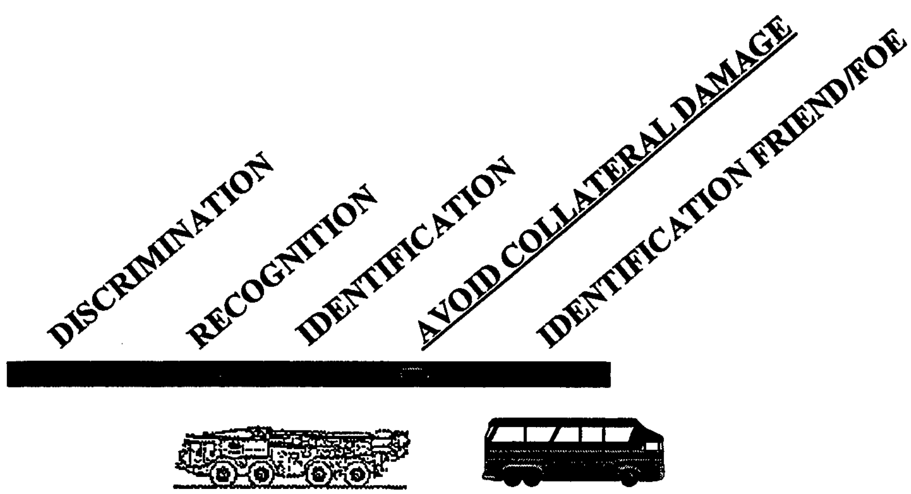

Figure 9. Roadmap; Avoidance of Collateral Damage

Scenario 6; Attack of SSM vic. civilian vehicles.

Future adversaries may utilize the power of the media to undermine US resolve in a conflict. For example, some SSM launchers (large, wheeled vehicles) may look similar to some commercial vehicles such as school busses. A smart, but unscrupulous leader may position his SSM launchers in the vicinity of a school and conduct attacks. What better way to affect public opinion than to show videos of counter-attacking munitions destroying school busses!

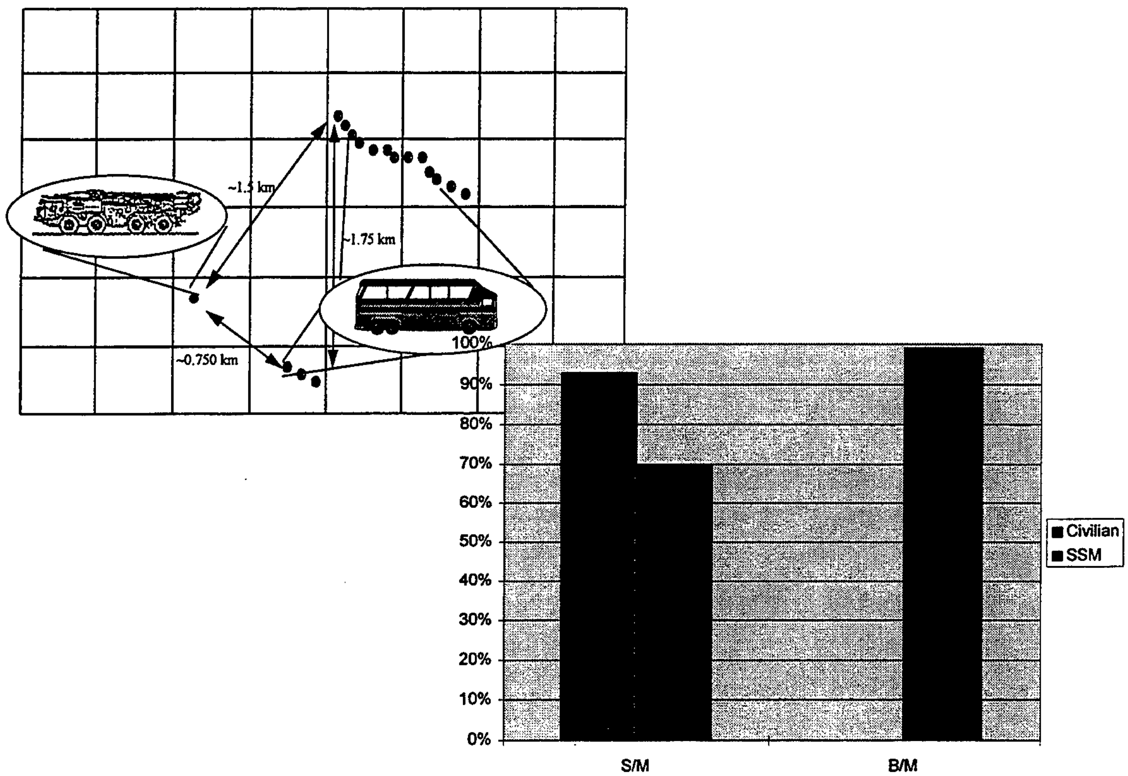

Figure 10. Target area; Avoidance of collateral damage; results

Figure 10 indicates potential performance of six brilliant munitions in a mode where only the desired target is attacked. The left bars indicate the SSM was killed 70% of the time by smart munitions, but there was a 93% chance of civilian vehicles also being hit. The brilliant munition searches for a launcher; however, as other vehicles come into view, the munition would decide to intentionally miss or self-destruct. At least two approaches are feasible. Either the munition recognizes civilian vehicles (incorporated as a target description in the munition memory), or (as was assumed to generate this chart) a perfect confusion matrix (see Appendix A) is adapted. Unless the detected target met *all* SSM feature requirements, it was not attacked. All other targets are avoided.

Obviously, a great deal of work is necessary to resolve this problem. DTLOMS still applies.[25] If the enemy is taking such an approach, other means can be considered to locate and attack the SSM rather than by an inanimate object. In this scenario, the enemy has elected to limit the range of options to position SSMs. That allows the commander to focus search efforts and a very precise attack by a Special Operations soldier may be feasible.

IDENTIFICATION FRIEND OR FOE

> Don't use a hatchet to remove a fly from a friend's forehead.
>
> —Chinese proverb

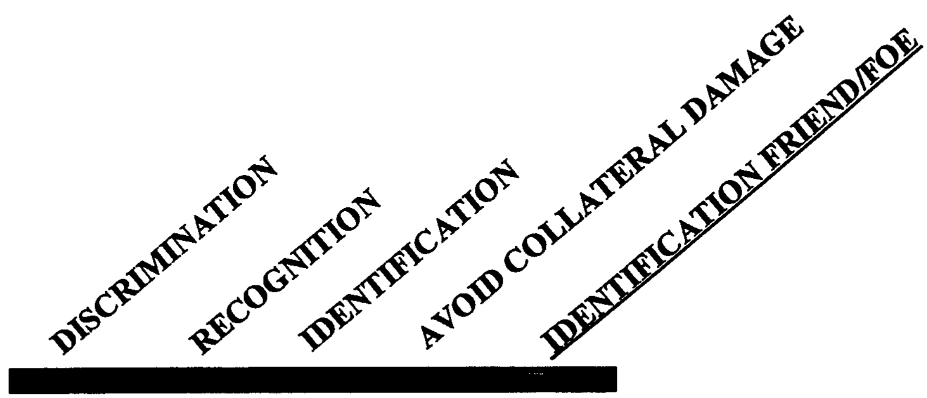

Figure 11. Roadmap; IFF

These models and scenarios focused on smart and brilliant munitions delivered by indirect fire systems against target sets that are *not* in the proximity (direct fire range) of friendly forces. Tactics, techniques, and procedures have evolved to reduce fratricide on the battlefield. Programs such as the Battlefield Combat Identification System (BCIS) build on the Air Force IFF systems and address ground combat forces. The Army is also pursuing "battlefield awareness" techniques to further reduce fratricide. *Aided* target recognition (with a soldier making the final attack decision) provides soldiers the ability to quickly identify targets for attack. Aided targeting should further reduce fratricide particularly after extended periods of combat when the soldier is fatigued.

Brilliant munitions with *automatic* target recognition (with the munition making the attack decision) may offer an IFF solution. The sophistication of the algorithms and the detailed understanding of the exploitable differences of systems will take time to develop before an inanimate object is tasked to determine friendly versus enemy forces. In the meantime, BCIS, DTLOMS, and current initiatives in battlefield awareness are providing adequate time to develop these algorithms.

How close can friendly forces be to the target area without introducing fratricide by smart or brilliant munitions? Each munition has a footprint—the ground area covered as a result of the munition flight path and sensor capability. The munitions are projected to be delivered accurately by systems such as ATACMS and guided MLRS rockets. Targets may be identified by scouts and observers located forward of the main body of friendly forces. These observers maintain "eyes-on" the target and generally engage targets early, at ranges that exceed the footprint sizes of current munitions under development. Based on a knowledge of the munitions capabilities (including footprint) and the range to the target, the observer can determine if the target can be attacked by precision or conventional munitions.

OTHER TRENDS

Appendix A describes how the munitions were modeled and presents more details of the scenario results. The appendix also presents how munition efficiency is enhanced through the reduction of false alarm effects and consideration of dynamic logic to further improve munition efficiency.

COST

Discussion of precision munitions is not complete without addressing costs. As the epigraph indicated at the beginning of this paper, education is expensive, but ignorance is potentially more so. Prior studies have investigated validated cost estimates of various precision munition programs. The costs associated with precision munitions are offset by the number of conventional munitions otherwise required to defeat the targets and the increased number of friendly systems surviving the fight.[26] Furthermore, the ability to deliver these munitions by various Army, Navy, Air Force, and Marine Corps systems introduces an economy of scale that can dramatically reduce the cost of these munitions.

IMPLICATIONS TO ARMY AFTER NEXT; RECOMMENDATIONS AND CONCLUSIONS.

RECOMMENDATIONS, MANAGEMENT OF THE TECHNOLOGY.

Well begun is half done.

—Horace

Significant advances have been made in sensor technologies and the application to target acquisition systems and precision munitions. Brilliant munitions show great promise and can be incrementally evolved. Weapons developers must remain cognizant of how the forces communicate and fight. By understanding how the commanders operate in battle (D^3A, attack guidance matrix, target type in fire mission processing, etc.), the roadmap to munitions centrality defines technological growth and is directed to solving problems that pay greater tactical advantages.

Stay the course on current programs

Munitions developers must first and foremost ensure the key performance parameters (KPP) are satisfied. Current developer models utilize target templates approved by intelligence sources, and are used as stand-alone targets (addressed in Appendix A). This is an appropriate approach to assess the required munition performance dictated by the requirements document. Smart munitions offer significant benefits. We must get these capabilities fielded.

As the programs progress, developers and warfighters must remain cognizant that conventional munitions still have a role. Precision guided munitions should not be expected to defeat all targets on the battlefield. While this might be technically feasible, it is not fiscally realistic nor cost effective.

Manage the test program

The journey towards munitions centrality should *not* be identified as a critical operational issue and concern (COIC). The description of the target template is the primary issue. Brilliant munitions represent an added capability on the battlefield when the "approved target templates" used for munition development are affected by the realities of available real estate and the enemy's approach to the fight. Testing against the innumerable combinations of battlefield positioning of forces is not reasonable and the likelihood of gaining consensus on target arrays will remain a challenge. Seeker simulations such as hardware-in-the-loop facilities and integrated flight simulators can be used to confirm the capability prior to fielding.[27] The Advanced Warfighting Experiments (AWE) may offer a forum to describe target templates to be reconstructed in models.

Ensure munition hardware and software offer growth

The definition of "growth capabilities" has been difficult to capture in a development contract and to subsequently cost-out by a contractor. The roadmap offers a definition. Given the required munition sensor resolution and on-board processing power, the journey towards munitions centrality can be implemented as software changes or otherwise cut into production where economically feasible. The MLRS software architecture supports the capability for updating target information through the launcher.

Easy problems first

Lower fidelity enhancements should be introduced first. Targets such as SSMs, SAMs, and MRLs tend to be high on priority lists. These target design characteristics, the associated tactical utilization of these targets, and our means of attacking these targets offer a favorable environment to implement and experiment with *automatic* target recognition by an inanimate munition; specifically, *target recognition*—the difference between armor and launchers.

As we gain familiarity with brilliant munitions and integrate those into warfighting skills, the next step should then be *target identification*—the difference between armor and SPHs. Tactical payoffs can be derived by efficiently defeating these systems in support of the close fight. After that, consideration should be given to special situations such as avoidance of collateral damage. That certainly requires extensive thought involving the specific scenario and options in addition to launching precision munitions.

Don't get overly focused

With regard to the algorithms incorporated into a smart munition, the notion of "dynamic logic" (to ensure the munitions contribute in some fashion to the battle should the intended target not be found) should be implemented. The munition must remain capable of finding all types of targets. Directing the munition to find *only* the intended target (and purging all other targets from memory) can reduce the efficiency of the munitions. Appendix A addresses these trends.

Concurrently develop TTPs

Munition performance is affected by fly-out patterns, search logic, and aiming techniques to name a few. The tactics, techniques, and procedures need to be assessed as the journey continues.

Understand who/what is making an attack decision

Aided Target Recognition is viable and appropriate now for direct fire systems. A soldier making the final decision to attack a target reduces fratricide. An inanimate object making decisions (automatic target recognition) is best employed where friendly forces are not at risk. Current technologies and techniques to reduce fratricide are appropriate until the technology evolves to allow IFF by a munition.

Sensor resolution can be different

Target acquisition systems developers and users should apply IPB and attack guidance principles when implementing target recognition capabilities. When employing precision munitions, the acquisition sensors may shorten target analysis time and initiate fire missions sooner. Details of the target (and the time to establish those details) may be desired for order of battle, but not necessarily required for targeting.

CONCLUSIONS.

Field Current Smart Munitions

Studies consistently indicate that smart munitions bring distinct advantages on the battlefield in terms of improved LERs and reduced logistics burdens. Smart munitions should be fielded according to the requirement documents driving their respective designs so that such benefits may be reaped.

Establish a Roadmap Supported by Technology and Tactical Utility

The journey towards munitions centrality is facilitated based on a knowledge of the battlefield and the targets of interest. Certain targets are more critical to the commander during various phases of the operation. Many of these weapon designs have exploitable characteristics that, when viewed in a battlefield context, define munition capabilities growth and produce definite combat benefits.

Each element of the DTLOMS equation will be affected by the AAN debate. While forces will tend to be lighter, lethality requirements must increase to provide an appropriate level of deterrence and to offer survivability to the force should the shooting begin. Precision guided munitions can bring significant benefits to future battlefields; the evolution of brilliant munitions indicate even more benefits; but precision guided munitions will never be the panacea to future conflicts.

> In the movie trilogy "Star Wars", the Ewoks, with their rocks and sticks, played a major role in defeating the high-tech Evil Empire.

Forces

Time and computer resources were not available to generate loss exchange ratios (LER) specifically for this paper. Based on previous studies and the type targets defeated by brilliant munitions, one can speculate that the LERs will favor the friendly forces as critical targets (SPH, MRL, etc.) are defeated at critical times during the battle.

Training

The technology that "educates" our bullets can be transparent to the soldier. Data fields exist in current C^2 formats that will allow information to trigger the munition to search for intended targets. The brilliant munition can earn its title by performing with minimal information (location and target type). As progress is achieved towards munitions centrality, commanders and soldiers can also evolve to effects management.[28]

Procurement

Legacy systems delivering smart and brilliant munitions, particularly MLRS and the lighter version, HIMARS, offer great flexibility in range capabilities, rapid massing of fires, and deployment into the theater (HIMARS). The evolution of MLRS rockets and ATACMS missiles provide the lethal solution to information dominance. Once located, the target can be defeated. Nothing disrupts enemy communications with greater certainty than blasting it over several acres of real estate.

Consideration of IFF capabilities are best accomplished first by BCIS, battlefield awareness, and TTPs. As lighter direct fire systems are designed, consideration of *automatic* target recognition in direct fire systems may provide lethality and survivability advantages in the close fight. In the meantime, *aided* target recognition is a more appropriate and near term solution. The IFF aspect of munitions centrality requires time to develop; near term efforts in target recognition and target identification offer battlefield advantages within technological reach.

The ability to deliver these munitions by various Army, Navy, Air Force, and Marine Corps systems introduces an economy of scale that can dramatically reduce the cost of these munitions.

Logistics

A detailed model to assess logistics benefits was also not available in the short period of this report. Again, based on MSTAR study trends, further munition efficiencies should translate into a reduced logistics burden. This reduction further translates to more deployable forces.

Wrap-up

This paper introduced Dr. Gansler's priorities, two of which are precision munitions and rapid deployment. As the November 1997 Automatic Target Recognition Transition Conference recognized, there has been promising work, but the product is slow in coming. By viewing this challenge in a battlefield context, a roadmap to munitions centrality is recommended for developers and warfighters. This approach incrementally introduces capabilities that provide distinct battlefield advantages and allows technology growth—how to educate our bullets. The benefits provided by precision guided munitions facilitates the deployment of forces.

APPENDIX A

SIMULATION DETAILS

MODEL TYPES

Performance Models.

Precision munition maturity is assessed by performance models that incorporate target templates approved by intelligence sources. Each mission conducted in these models present the munition against the target template as well as some value of false targets, countermeasures, and weather effects. This approach addresses the mandated requirement document metric (e.g. kills vs. a particular target). These models adequately support design trades and major acquisition decisions.

These target templates do not account for other military units that may indeed be in the proximity of the intended target on a real battlefield. The number of battlefield combinations of adjacent units and individual vehicle alignments preclude a complete set of analyses in the time and resources available to developers, not to mention the difficulty in gaining consensus over which battlefield alignments should be used to demonstrate a munition should be fielded. To that end, the journey towards munitions centrality should *not* be identified as a critical operational issue and concern (COIC).

Warfighting Models.

Force-on-force models use loss exchange ratios (LER) as one metric to define benefits of emerging systems. Ft. Sill's Target Acquisition and Fire Support Model (TAFSM) is a fire support force on force model with scripted direct fire attrition.[29] Within TAFSM, each individual mission poses the munition against a performance model-based target template for the initial engagement. Subsequent attacks against that target accounts for elements previously defeated, and the model changes the template accordingly.

Hybrid Target Templates.

To support this paper, IITRI modified approved templates to offer preliminary trends that might be realized by brilliant munitions. Notional templates were used that combine the intended uses of performance and warfighting models. These templates were supported by the TRADOC System Manager for Rockets and Missiles (TSM-RAM) and the Depth and Simultaneous Attack Battle Lab at Ft. Sill, OK. As Advanced Warfighting Experiments

(AWE) are conducted, modelers should attempt to capture selected enemy formations and replicate those in appropriate simulations.

MUNITION ASSUMPTIONS

Targeting.

Munition aimpoints represent errors associated with certain targeting systems. System delivery errors were also incorporated. Since this study is not intended to address any one particular smart munition, typical fly-out patterns of gliding munitions were used. Against the MRL and SPH targets, the MSTAR rockets were aimed with 50 meters between rockets in the target area; perpendicular to the gun-target line. This TTP warrants further study.

Attack Logic.

The scenarios utilized a "first target" logic. As each target is encountered, it is processed. Furthermore, when a target recognition capability is applied, it is applied as "ATR-only". For example, in scenario 1, the munition is instructed to attack only MRLs. If a target does not look like an MRL, it is bypassed (see confusion matrix). See also "dynamic logic" in this appendix.

Confusion Matrix.

Table 1 represents a summarized version of the confusion matrix utilized in this study; GENESIS can track the history of all vehicles in the simulation. When the munition encounters an MRL (intended target), it will correctly recognize that vehicle as a launcher 80% of the time; however, the rest of the time the munition will think the MRL is something else. Other targets are defeated because the munition incorrectly thought it was attacking an MRL. For example, there is a 16.7% chance that another vehicle will be misinterpreted as being an MRL. Those non-MRL targets that were killed by the brilliant munition in scenario 1 represent the "confusion matrix" in action. A particular munition thought it found a launcher; it was wrong. This table has been supported by Army Materiel Systems Analysis Agency (AMSAA) as a reasonable, achievable capability for a brilliant munition.[30]

	Other Targets	**Intended Target**	**False Alarms**
Other Targets	0.934	0.033	0.033
Intended Target*	0.167	0.8	0.033
False Alarms	0.084	0.016	0.9

* MRL, SAM, SSM, or SPH

Table 1. Confusion matrix

Munition Logic.

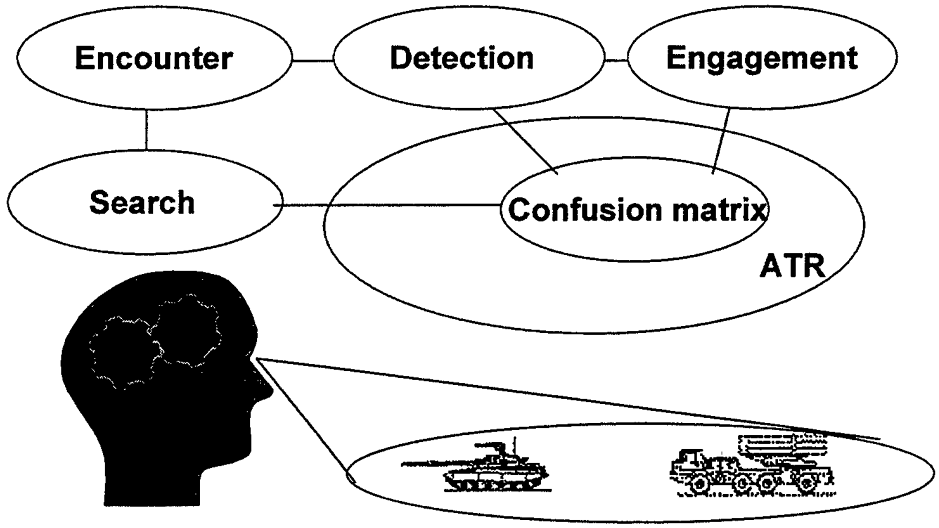

Figure 12. How the munitions worked

The munition is dispensed over the target area and begins to search for targets. An encounter is recorded (by the simulation) every time the footprint passes over a target. Given this encounter occurred, did the munition detect that a target was there? If the simulation was modeling a smart munition, and a target was detected, then the munition engaged that target. If a brilliant munition detected a target, it applied the confusion matrix to determine if that was the target of interest. If it is, the target is engaged; if not, the brilliant munition resumed searching the target area. Given the target was engaged, did the munition hit it; and if so, did the munition hit a vulnerable area and kill the target? These values are recorded in the simulation and presented in the following charts. Note that only

500 repetitions were conducted for each of the scenarios; further study is warranted.

Distinct Value. The number of targets recorded during the flight of the munitions from the target point of view. More than one munition could possibly hit a target. Distinct values eliminate multiple counting; if 3 munitions hit a target, either of which could have killed it, only credit for one kill is given.

Scenario 1; Detailed results

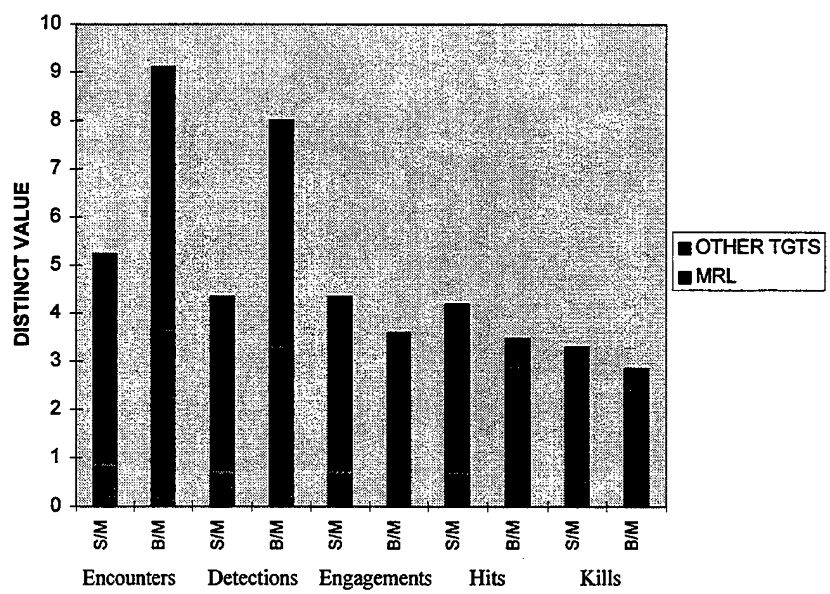

Chart 3. Performance against MRLs vic Armor

Chart 3 compares the performance of a smart munition (S/M) and a brilliant munition (B/M) from encounters through killing the targets. A brilliant munition encounters a target; it then detects it. The munition applies the confusion matrix and decides the target it has detected is not the intended target (MRL), so it continues to search; thus increasing the number of encounters and detections, sorting through the array to find an MRL. The total number of kills in the target area is slightly greater for the smart munition as compared to the brilliant munition, but the brilliant munition killed more of the intended targets (MRLs).

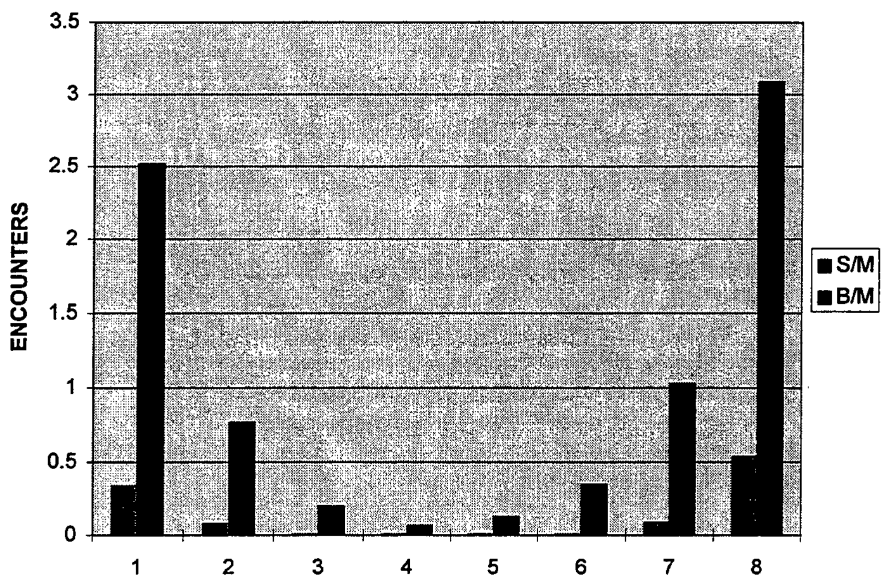

Chart 4. MRL Encounters

Chart 4 shows the effect of the encounter-detection-resume search cycle as the brilliant munition sorts through the target array. The increased searches cause an increase in encounters of the eight MRLs by the munitions. Remember, these charts are the result of 500 replications under the targeting and munition assumptions (flying patterns, attack logic, etc.) applied. Additional study is warranted to determine the optimal approach to covering the target area.

Scenario 2; Detailed results

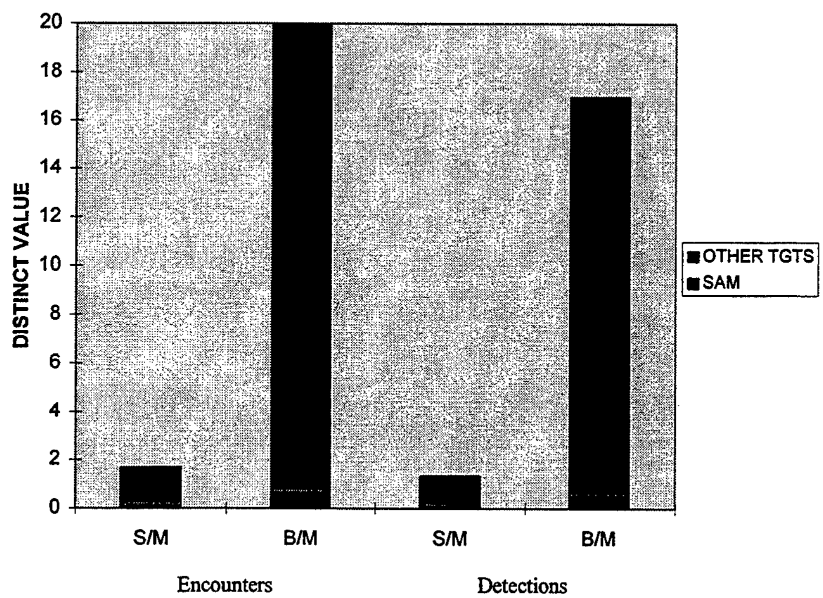

Chart 5. SAM launcher vic armor; Encounters and Detections

Chart 5 also shows the effect of a brilliant munition as it searches the target area. Scenario 2 included a large TLE and the munitions were tasked to find a single SAM launcher among 26 other targets. As the brilliant munition encountered various targets, it had to determine if it had detected the SAM. When it did not, it resumed searching and sorting through the target area.

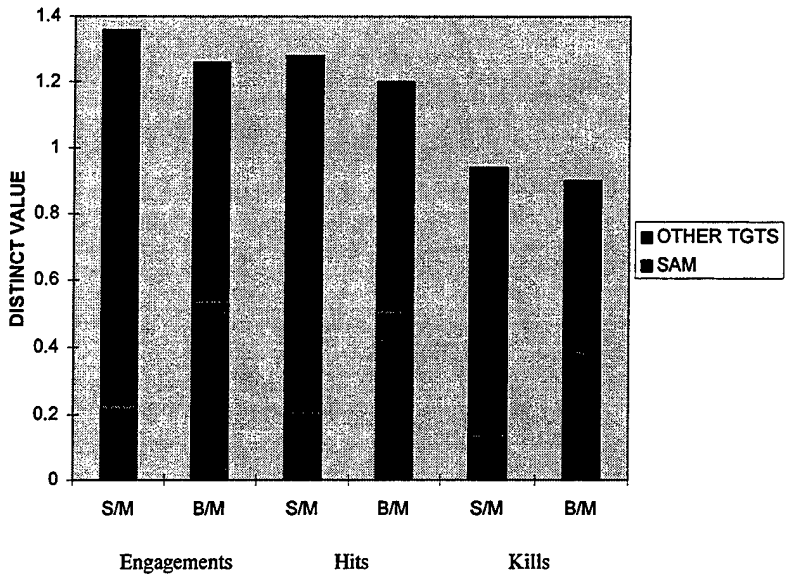

Chart 6. Performance against SAM vic armor

Chart 6 also shows roughly the same performance from the smart and brilliant munitions relative to the number of targets killed over 500 repetitions and with poor targeting. With a brilliant munition, the probability of killing the SAM launcher increased from 14% to 39%.

Scenario 3; Detailed results

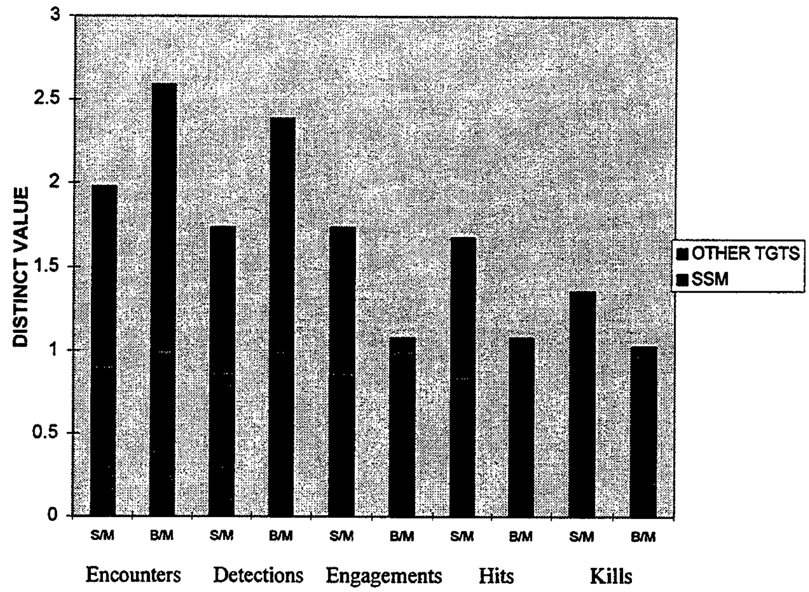

Chart 7. Performance against SSM vic armor; Zero TLE

Chart 7 suggests the performance of munitions searching for the SSM in scenario 3. Zero TLE is unrealistic operationally, but analytically it is used to establish an effects ceiling. Again, the brilliant munition has an increase in encounters and detections as it detects non-SSM targets and resumes its search. The smart munition defeats the SSM 75% of the time—which is impressive—but the brilliant munition defeats it 98% of the time.

Scenario 4; Detailed results

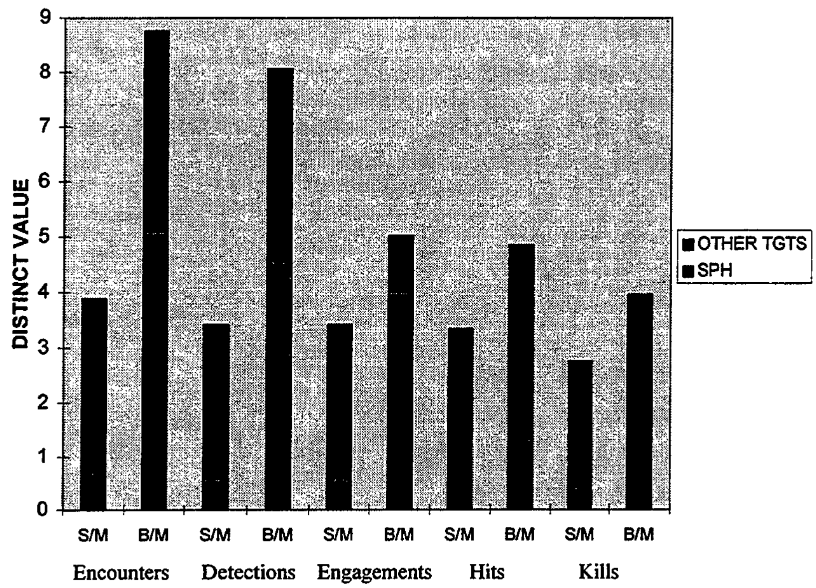

Chart 8. Performance against SPH vic armor

Chart 8 continues to show the increase in encounters and detections by the brilliant munition and defeat of the intended target (SPH; scenario 4). With a single pod of MSTAR rockets delivering brilliant munitions, 40% of that SPH unit is defeated. Historically, a 30% effects against an SPH unit has been desired by a commander.

FALSE ALARMS.

Smart munitions developers have been designing seekers to extract targets from battlefield backgrounds. Developers are challenged to ensure the seekers are not distracted by nature as certain features such as rocks, ice, and foliage could appear as a target to the munition. Various techniques such as multiple sensors and multiple looks at the target area are used to counter this phenomenon.

During the course of this brief study, a trend developed that indicates brilliant munitions may be less susceptible to the effects of false alarms. A portion of this may be attributed to the fact that false alarms, as an entity, were included in the confusion matrix. As developers capture empirical data on their respective systems and brilliant munitions are introduced, then false alarm rejection provides the opportunity for more munitions to attack real targets. Chart 9 shows the percentage of munitions that were affected by false alarms within the target templates.

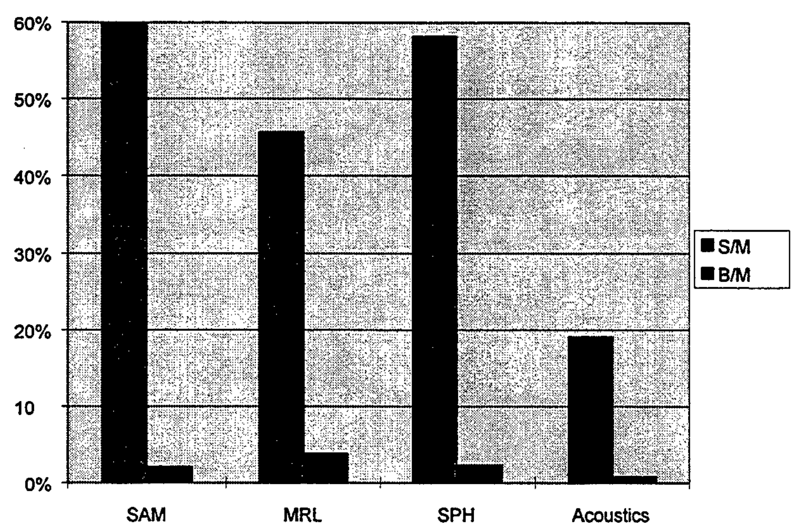

Chart 9. False Alarm effects.

DYNAMIC LOGIC

There are reasons an individual munition might not find the intended target. In these scenarios, one missile carrying 6 munitions (vs. SSM or SAM) or 6 rockets, each carrying 2 munitions (12 munitions total vs. MRL or SPH) were assumed. One of the other munitions may have killed the target or the intended target may have successfully escaped the area. This phenomena partly explains why (after 500 repetitions; more repetitions may bring the results closer; maybe worse) a smart munition may kill more targets in the target area as compared to the brilliant munition.

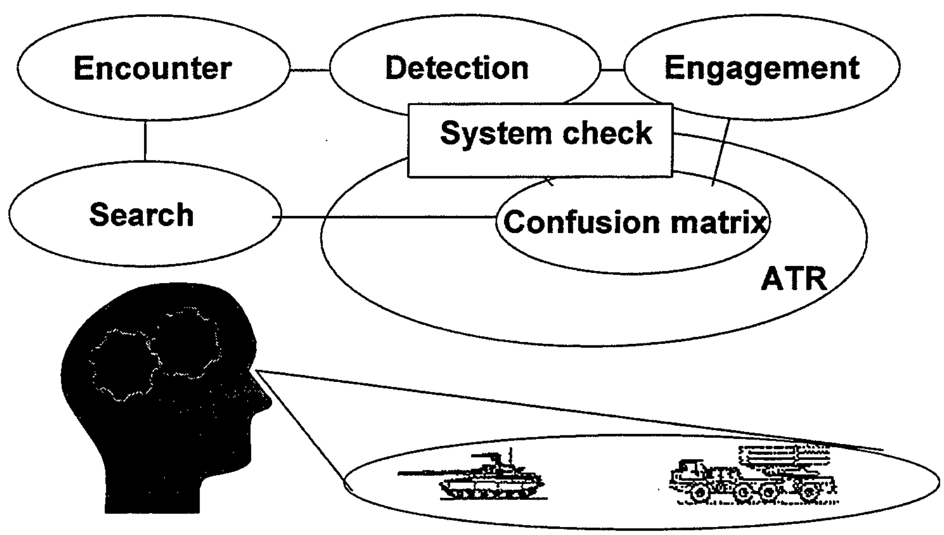

Figure 13. Munition logic; Dynamic logic

A dynamic logic algorithm is an attempt to account for times the intended target is not located. Based on a predetermined condition (e.g. munition altitude or battery power), the munition ignores the confusion matrix and attacks the next target it detects. The MRL scenario was modified and re-run.

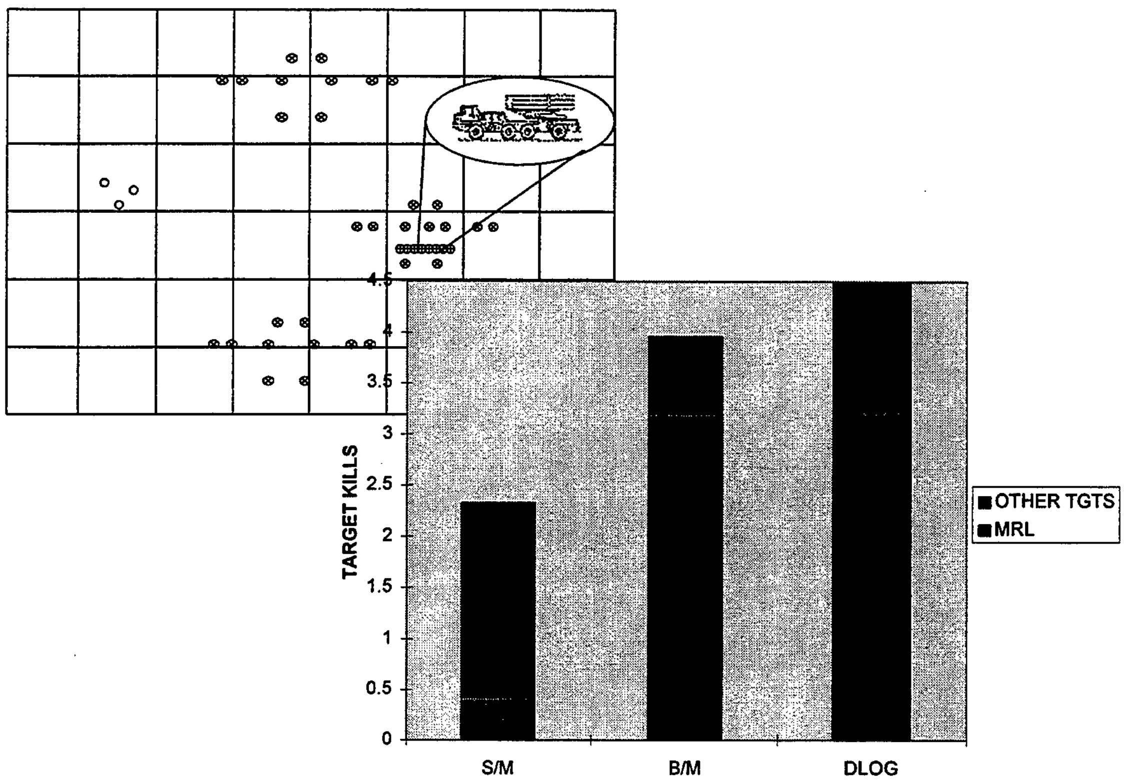

Figure 14. Target area; MRL vic armor, dynamic logic results

With a dynamic logic application to the brilliant munition, the number of total kills increased slightly; more munitions destroyed something of significance while the intended target was still being defeated. To further investigate this approach, scenario 3 was re-run; but this time, no SAM launcher was in the vicinity at all. Only the armored column was present.

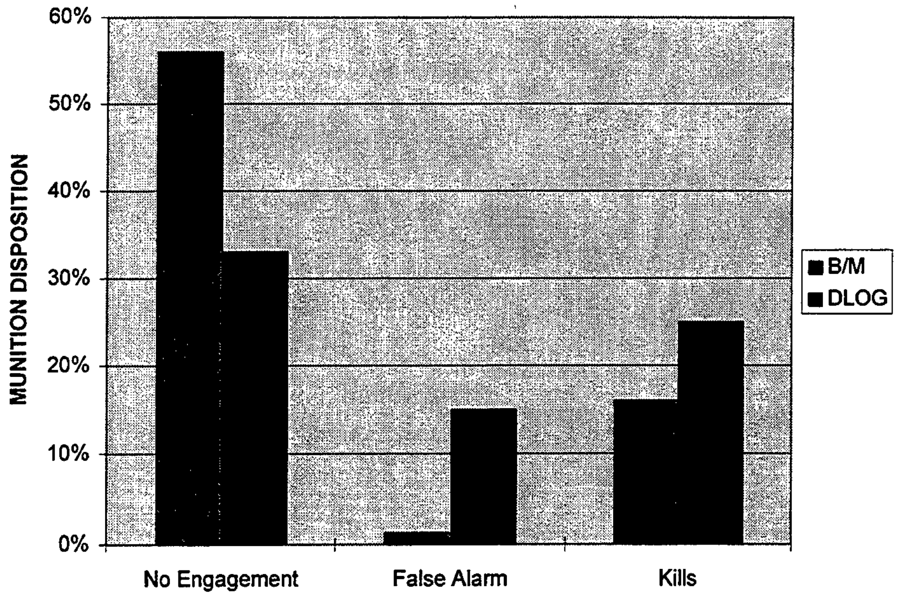

Chart 10. Munition performance with Dynamic Logic

The brilliant munition is instructed to sort through the target array until a SAM launcher is found, but no instructions are given if a launcher is *not* detected. The kills columns show 16% of the brilliant munitions misinterpreted other targets as a SAM launcher and defeated those, but 56% of the munitions contributed nothing to the fight (no engagement); a small percentage were victims to false alarms.

In this limited scenario of 500 repetitions, 33% of the six brilliant munitions with a dynamic logic made no contribution; but that was somewhat offset by the 15% that attacked some natural feature (false alarm). What is intriguing is that 25% of the munitions at least killed something.

In the aggregate, that may be good; an assessment is required to determine if a subsequent attack is warranted (remember D^3A; assess the results). Additional work and study is required in this area. It appears to be a correct approach to maximize the utility of the munitions delivered.

The message to munitions developers is twofold. First, the Army *can* provide apriori information regarding the target type, the design of which can be exploited. Second, the target descriptions carried onboard the munition should *not* exclude other military targets not considered a priority for that mission. While a munition may not have killed the intended target, it may have at least killed something that could pose a problem later.

ENDNOTES

[1] Senate, Committee on Armed Services, *Testimony by Under Secretary of Defense (A&T)-designate, Dr. Jacques S. Gansler,* 1 Oct 1997, Program Manager Magazine, January-February 1998, 3.

[2] The Sense and Destroy Armor (SADARM) munition is delivered by 155mm cannon artillery. The Brilliant Antiarmor Submunition (BAT) is to be delivered by the Army Tactical Missile System (ATACMS).

[3] Fires, The Cutting Edge for the 21st Century (Draft), p8.

[4] *Automatic Target Recognition Transition Conference*, 19-20 November, 1997, Lincoln Laboratory, Massachusetts Institute of Technology, Background information.

[5]Perry M. Smith, *Taking Charge, Making the Right Choices* (New York: Avery Publishing Group, Inc., 1993), 151.

[6] Guidance and Control Information Analysis Center, *Smart Munitions Training Course*

[7] DAWE discussion with COL Coffman, Director, Depth and Simultaneous Attack Battle Lab, Ft. Sill, OK, 27 Feb. 1998.

[8] IITRI, *Analysis Performed in Support of MLRS Smart Tactical Rocket (MSTAR) Study* (U), (Secret/NOFORN Report ATC-03-1652-94, 7 December, 1994).

[9] TRADOC Analysis Center-White Sands Missile Range (TRAC-WSMR), *Antiarmor Requirements and Resource Analysis (A2R2)* (U), (Secret/NOFORN Technical Report TR-96-022, July 1996), extracted from pages 30 and 48.

[10] *A2R2*, 30.

[11] LOCAAS is a gliding munition that uses a laser radar (LADAR) seeker. A powered version of LOCAAS is being tested to provide a loitering capability to the munition.

[12] The attack guidance matrix addresses target characteristics that include target location error, target size, stationary or moving targets, target window of vulnerability, time to attack the target, and the number of rounds (munitions) the commander is willing to expend on the target to achieve desired effects. ST 6-60-30, Army Tactical Missile System (Army TACMS) Family of Munitions (AFOM) Tactics, Techniques and Procedures (TTP), 5 January 1998, 10.

[13] Ibid.

[14] Whiteside, COL Daniel J. "Cannons, Rockets or Both?," *Army Magazine*, March 1998, 12.

[15] Shoot-and-scoot is a technique where an indirect fire system shoots from a particular location, but quickly moves

(scoots) from that location. Reactive acquisition sensors back-track the artillery rounds (or rockets) to the origin and submit a fire mission to attack that grid location. If the enemy target has relocated, the counterfire mission will be ineffective.

[16] *A2R2*, 30.

[17] Ibid., 34 and 161.

[18] Tereshchenko, General-Major Volodimir I., "Ukraine's Shield of Fire," *FA Journal* Volume III, No. 2 (March-April 1998): 6-8.

[19] The definitions associated with the roadmap are those of the author. Various sources use similar terms to describe lesser or greater capabilities.

[20] ATACMS is also being considered by the Navy as a potential system to be delivered by vertical launch systems (VLS).

[21] *Into the Storm*, 141.

[22] *III Corps TTP.* An MLRS launcher is laid (aimed) on a priority target (location where a target is expected to appear based on IPB).

[23] Della-Giustina, Major John E. "The Artillery S2 and Interpretive Counterfire BDA." *FA Journal* Volume III, No. 1 (January-February 1998): 37.

[24] Alvin and Heidi Toffler, *War and Anti-War, Survival at the Dawn of the 21st Century* (Boston: Little, Brown and Company,1993), 73.

[25] DTLOMS: Doctrine. A statement of how the Army intends to fight. It gives the Army a common language and a common reference point that allows shorthand professional communication. It's not a dogma; it's a guideline, a statement of principles that should prove helpful in solving battlefield problems.

Training. Doctrine gives you mission and focus. Training gives you the skills to carry out your mission.

Leader Development. The conviction, mental agility, morality, and confidence of officers and NCOs to perform in the absence of guidance and direction.

Organizations. Those formed during peacetime and those that are task organized (including coalitions) in times of crises.

Materiel. The hardware and software necessary (or available) to execute the mission.

Soldiers. The logistics and infrastructure necessary to recruit and develop soldiers and to sustain operations.

[26] *MSTAR Study*

[27] A hardware in the loop (HIL) facility, in this context, tests seeker hardware performance against simulated targets in a one-on-one mode. An integrated flight simulator (IFS) tests

seeker software and a representation of the seeker against simulated targets in a one-on-one or one-on-many scenario.

[28] *Fires*, 6.

[29] Scripted scenarios track the performance, actions, and events of individual friendly and enemy systems. As an example, enemy system "A" is designated to attack and defeat friendly system "B" at a defined moment in the battle. During the early stages of the fight, enemy system "A" is defeated by friendly artillery. When friendly system "B" is scripted to meet against enemy system "A", no engagement occurs because "A" no longer exists. A friendly system then survives and a positive change to the LER is realized.

[30] Mr. Marty Perry, AMSAA, in discussion with LTC Robert Arnone, Spring, 1997.

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