

Examining the Army's Future Warrior

Force-on-Force Simulation of
Candidate Technologies

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Candidate Technologies

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Preface

This report summarizes work performed during a quick-response analytic effort in support of the 2001 Army Science Board (ASB) Summer Study on Objective Force Soldier, along with subsequent efforts in related areas. The work used high-resolution constructive simulation to examine key aspects of “objective soldier,” with the modeling taking place in the 2015–2020 time frame. In conducting the study, the research team interacted with various members of the ASB and, in particular, with key members of the Analysis, Fightability, and Concepts panels, drawing extensively on their forward-looking ideas and ultimately integrating many of these ideas into the research. The primary scenario employed was a highly stressing mission involving a dismounted attack on an enemy position in complex terrain.

This work should be of interest to those involved in technology assessment, force structure, and examination of new tactical concepts.

This research was sponsored by the Assistant Secretary of the Army (Analysis, Logistics and Technology) and was conducted in the Force Development and Technology Program of RAND Arroyo Center. The Arroyo Center is a federally funded research and development center sponsored by the United States Army.

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Summary

Introduction

The U.S. Army is in the process of adapting to meet the needs of the new millennium. The vision for accomplishing this, as defined by the senior Army leadership, will ultimately lead to an increase in the Army's ability to quickly and effectively respond to situations across a full spectrum of contingencies. Much of this work has focused on examining alternative vehicle platforms and technologies for the Future Combat Systems (FCS) concept.¹ As a result, integrating the FCS concepts with future dismounted operations has not been given comparable levels of attention, although soldier systems occupy a prominent position in Army and Lead System Integrator (LSI) documents.² The Army Science Board (ASB) Summer Study attempted to balance the picture by focusing on the future soldier.³ The purpose of the work reported here is to provide an initial quantitative exploratory analysis of objective soldier options, within the context of several

¹ Matsumura et al., *Exploring Advanced Technologies for the Future Combat Systems Program*, Santa Monica, CA: RAND Corporation, MR-1332-A, 2002.

² Department of the Army, Army Materiel Systems Analysis Activity, *Army Future Combat Systems Unit of Action Systems Book*, Version 3.0, May 13, 2003.

³ This study and many other examinations of future soldier systems are reported in the ASB 2001 Summer Study on the Objective Force Soldier/Soldier Team. An electronic copy can be found at <https://webportal.saalt.army.mil/sard-asb/ASBDownloads/OFS-Vol-III-All.pdf>.

stressing scenarios. The effort focuses on a series of research questions, starting with How might a current-generation dismounted force perform in a challenging combat situation? and ending with What are the impacts of key, high-leverage technologies in combat? The report also references relevant research prior and subsequent to the ASB summer study.

Approach

Our approach entails a constructive simulation effort that centers on using Janus⁴ and a set of locally connected models to represent dismounted operations. Two scenarios were examined, the first a dismounted Blue force attack on a Red force defending inside a treeline, and the second a convoy operation through an urban area. A high-resolution terrain database describing Fort Hunter Liggett was modified with additional foliage to represent the treeline scenario, while data from Sarajevo were used to represent the urban convoy operation. The primary focus of this work was on the treeline scenario.

Before using Janus and associated models, we examined the benefits possible by changing to more sophisticated models: JCATS (Joint Conflict and Tactical Simulation) and OTB (OneSAF Test-bed). Each of these models offers advantages when representing urban terrain, including the modeling of noncombatants and presenting the results in the form of 3-D visualization.

Findings

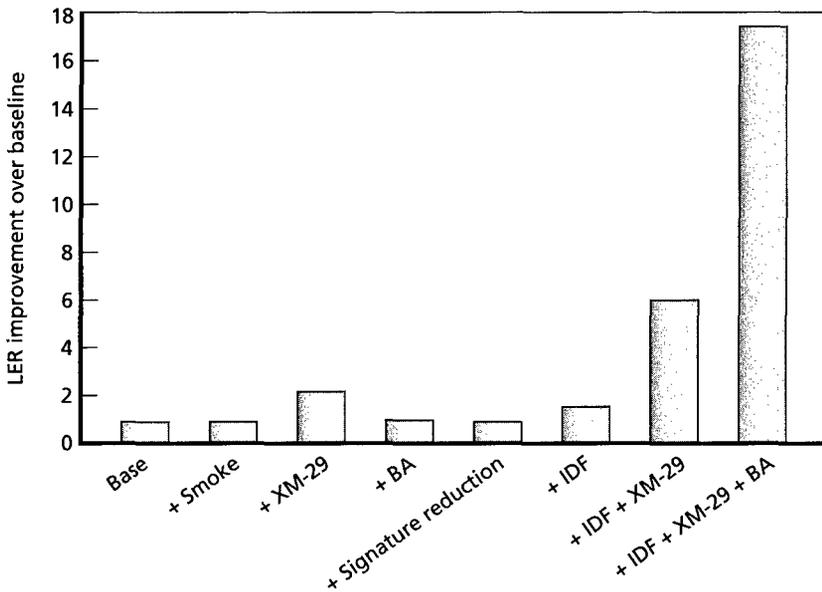
The bulk of our work focused on use of the treeline scenario. Here, a 40-soldier platoon of Blue dismounted soldiers attacked a 13-soldier squad of Red infantry dug into a treeline. The attack was made under covering fire by machine guns, with the force advancing in alternat-

⁴ Janus is a system-level force-on-force simulation originally developed by Lawrence Livermore National Laboratory.

ing sprints. We started with a current-generation force, with riflemen with M-16s, M-240 machine gunners, and grenadiers, facing an enemy squad with AK-74s and machine guns. The current Blue force was basically unsuccessful, losing half of its number while the enemy also lost half of its force.

Improvements to the force were tested one at a time and then in combination, and the results (stated as a ratio of improvement to the baseline) are shown in Figure S.1. Adding stealth and smoke to Blue did not improve the outcome, instead simply reducing the typical range of detections, shots, and kills. Adding body armor, the OICW

Figure S.1
LER Improvements as Individual Changes and Then
Combinations of Changes Are Made to the Blue Force
(Base given value of 1 in chart, actual base case LER = 0.38)



NOTE: BA = Body Armor
 IDF = Indirect fires.

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weapon (Objective Individual Combat Weapon—a rifle and precision explosive round combination—now designated the XM-29), and its forward-looking infrared (FLIR) sensor⁵ each helped, but none achieved more than a moderate improvement to the outcome. Linking the force to indirect fires (we used precision cannon fire and missile-based area fires with dual-purpose improved conventional munition—DPICM) attrited some 25 percent of the enemy force and suppressed another portion of it for a short period.

The real differences in outcome came when combinations of improvements were made. When indirect fire and the OICW weapon and FLIR were used, the loss-exchange ratio (LER, here the number of enemy dismounts killed divided by the number of Blue dismounts killed) improved fivefold. When body armor was then added to this mix (able to stop most small arms fire), the LER improvement reached seventeen times the original level. This synergy appeared to result from the indirect fire attriting the part of the enemy force (machine gun teams) that was the main threat to body armor, thus enabling massed Blue fires to be more effective.

Some additional excursions were also revealing. Additional speed of movement by Blue did not help, again just reducing the range of engagement, but slower movement actually hurt. A high level of body armor protection (90 percent against the 7.62 machine gun) made a substantial difference, but there is some question whether this level of body armor protection may be achievable. Surprisingly, equipping only one-sixth of the force with OICW resulted in roughly half the benefits of equipping the entire force. Alternatively, adding six armed unmanned ground vehicles (small UGVs about 1 meter tall) to the Blue force increased survivability of manned systems and improved lethality against the enemy. In fact, the combination of adding six armed UGVs and equipping six soldiers with OICW resulted in performance equivalent to equipping all the Blue force with OICW.

⁵ In the study we assumed the basic room-temperature FLIR planned for the OICW (similar to Javelin FLIR performance), but we also examined the use of a cooled second-generation FLIR.

The second, convoy scenario showed that smoke and UGVs can make a difference, if Blue is not attacking a fixed position. Use of smoke and addition of unmanned vehicles gave much greater survivability in the urban passage, especially when the UGVs were armed.

Conclusions

We found that even in a very stressing attack scenario, a Blue dismounted force with a combination of technologies could defeat an entrenched Red force. The key improvements in this scenario were the OICW weapon and FLIR, links to indirect fires, and capable body armor. In other scenarios, use of obscurants and UGVs may also make significant contributions to survivability. The importance of synergies between systems was especially evident in the studies we made.

Tradeoffs were evident in many runs. Equipping only a portion of the force resulted in a more than proportional improvement in outcome, indicating decreasing marginal returns. Reachback fires were useful, but they required substantial firepower to achieve a limited number of kills of dug-in forces.

This quick-reaction study relied on Janus for most of the analytic findings. Our parallel examinations of JCATS and OTB showed that these simulation tools had great potential for modeling interior fighting, representing noncombatant interactions and collateral damage, and visualizing event chains.⁶ At the same time, more needs to be done using man-in-the-loop simulation (especially for command and control issues) and field experiments. The scale of the analysis also needs to increase, with studies devoted to such questions as how closely linked the dismounts should be to the FCS vehicles, the linkages needed for controlling air and ground robotics, and development of new MOEs and MOPs (measures of effectiveness and perform-

⁶ While we did not directly compare Janus, JCATS, and OTB across the same scenarios, we found that Janus and JCATS had roughly similar outcomes in similar situations. A full determination of consistency between these models needs to be made.

ance) for operations in complex terrain. All these aspects should be explored in upcoming analytic efforts.

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The authors would like to thank the numerous individuals who generously contributed their time to this research effort. The authors must first acknowledge the key contributions provided by the various members and affiliates of the ASB. Outstanding guidance and, in some cases, support were provided by Dr. Robert Douglas, GEN(R) David Maddox, LTG(R) Charles Otstott, GEN(R) Wayne Downing, Dr. Anthony Tether, Dr. Stuart Starr, Dr. Michael Macedonia, Mr. Dan Rondeau, and Mr. Ed Brady. Additionally, we thank the following individuals for their insights and comments during the spring and summer period of the study: Dr. Joseph Braddock, Ms. Karen Williams, and Dr. Warren Morrison.

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List of Acronyms

AK-74	5.45mm Russian automatic rifle
APS	Active Protection System
ASB	Army Science Board
ATR	Automatic Target Recognition
BA	Body Armor
BCT	Brigade Combat Team
C2	Command and Control
CAGIS	Cartographic Analysis and Geographic Information System
DARPA	Defense Advanced Research Projects Agency
DPICM	Dual-Purpose Improved Conventional Munition
FCS	Future Combat Systems
FLIR	Forward-Looking Infrared
GPS	Global Positioning System
HE	High Explosive
HMMWV	High-Mobility Multipurpose Wheeled Vehicle

IDF	Indirect Fire
JCATS	Joint Combat and Tactical Simulation
Janus	Two-Sided Force-on-Force Ground Combat Model
LER	Loss-Exchange Ratio
LSI	Lead System Integrator
MADAM	Model to Assess Damage to Armor with Munitions
MG	Machine Gun
MLRS	Multiple Launch Rocket System
MOUT	Military Operations on Urbanized Terrain
Netfires	Missile launcher system being developed for the FCS
OICW	Objective Individual Combat Weapon
OTB	OneSAF (Semi-Automated Forces) Test-bed
PKM	7.62mm Russian machine gun
SASO	Stability and Support Operations
TLE	Target Location Error
TRADOC	Training and Doctrine Command
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensor
UGV	Unmanned Ground Vehicle

Introduction

Background

The U.S. Army is in the process of adapting to meet the needs of the new millennium. This vision, or “transformation,” as defined by the senior Army leadership, will ultimately lead to an increase in the Army’s ability to develop a force that can quickly and effectively respond to situations across a full spectrum of contingencies. More specifically, in addition to providing the force that can fight and win major theater wars (MTWs), the Army has embarked on a path to try to create a force that is more relevant to all kinds of potential conflict, including humanitarian and peacekeeping missions, stability and support operations (SASO), counterterrorism operations, and the widening numbers and kinds of small-scale contingencies (SSCs). To meet these needs, the Army’s force, including its operational concepts and its equipment, must change.

At the heart of this change lies the future combat systems (FCS) program. The FCS program is a collaborative effort between the U.S. Army and the Defense Advanced Research Projects Agency (DARPA), and it represents a new and distinct major program of the Army’s transformation plan. In coordination with the lead system in-

tegrator (LSI),¹ the Army and DARPA are now assessing the shape of this future force, what it will look like, and how it will operate. This force is intended to be network-centric, relying on rapid processing and dissemination of information, and it will operate much less with brute force and much more with surgical precision than current forces. This force is also designed to be much more deployable than current Army mechanized forces. To achieve this, the platforms themselves will weigh less, have much less armor, and thus rely more heavily on information, speed, and remote operation for protection.

Much of the attention so far has focused on examining alternative vehicle platforms and technologies for the FCS concept, and indeed that was the focus of the effort by the Army Science Board (ASB) in its 2000 Summer Study.² In its 2001 Summer Study, the ASB sought to balance the picture by focusing on the future soldier, examining the integration of the FCS concepts with future dismounted operations that are a key part of the concept. Subsequent definition of the FCS and umbrella Objective Force Concepts by the U.S. Army Training and Doctrine Command (TRADOC), DARPA, and the LSI reinforce the role of dismounted operations.³

Objective

As part of the ASB's Summer Study, RAND Arroyo Center was asked to provide analytic support. The purpose of this document is to provide and discuss the results of that analytic support—an initial quantitative exploratory analysis of objective soldier options using force-

¹ Team Boeing/SAIC is the lead system integrator for FCS; this group is responsible for the overall FCS development program.

² See ASB's website for electronic copy of the report, *Technical and Tactical Opportunities for Revolutionary Advances, Operations Panel*, <https://webportal.saalt.army.mil/sard-asb/ASBDownloads/T2O-Ops.pdf>.

³ See AMSAA (U.S. Army Materiel Systems Analysis Activity), *Army Future Combat Systems Unit of Action Systems Book, Version 3.0*, 22 May 2003. (For government use only; not available to the public.)

on-force simulation. Additionally, we describe relevant findings from previous and subsequent studies on future dismounted operations.

This work builds directly on previous studies of FCS platforms that revealed issues with dismounted operations. One such study centered around a stressing Kosovo II scenario, in which a Blue force was inserted through Albania, fought its way into Kosovo, and had to evict Serb forces from locations in treelines and cover. Additional Serb battle groups were moving from the north to support the defense. Many different excursions were run with different technologies and tactics.

The findings of that study showed that with a combination of remote fires, new technologies for the brigade combat team (BCT), and aggressive maneuver, the Blue force could prevail against an entrenched opponent. Robotics, active protection system (APS), and special sensors were all essential to the force.⁴

Even with such capabilities, the BCT encountered strong resistance from enemy forces in the treelines. These forces were difficult to detect and could lie in ambush. A special set of excursions examined the viability of using dismounts for engaging these forces. This preliminary look showed a system-exchange ratio (SER) of one or less for the dismounts, an outcome that helped motivate the ASB study.

Methodology

An overview of the research plan for this effort entailed a multistep process involving close cooperation with the ASB, ASA(ALT), TRADOC, and other agencies. It started by shifting from the Kosovo II scenario used in the previous study to a pair of higher-resolution scenarios that more accurately depict dismounted operations in complex terrain. We then decided which future concepts and technologies to assess in simulation. The Army is considering many concepts and technologies for future rapid-reaction forces, ranging from advanced

⁴Matsumura et al., 2002.

sensors, to new command and control (C2) systems, to manned and robotic weapons platforms. We wanted to determine which of these concepts and technologies could be modeled explicitly and which had to be represented by parametric effects modeling. We then assessed force-on-force effectiveness in simulation, which was intended to determine what advances the technologies were likely to yield. Below, we discuss in more detail the scenarios chosen and the simulation environment used.

Scenarios Chosen

In the work carried out for the earlier FCS study, we determined that level 2 terrain (30-meter horizontal resolution) was too coarse for representing dismounted infantry operations. The finding was substantiated in a 1995 study of data from scout operations using terrain at Twenty-Nine Palms.⁵ In that effort, Janus data sets were created from the base's Range 400 1-meter data set, with added dismounted forces and militarily sound routes. Detection of a squad of soldiers showed major discrepancies between 100- and 30-meter resolution, but little difference below 5- to 10-meter resolution levels.

As a result, we changed from the Kosovo data set to a more detailed Fort Hunter Liggett terrain, as shown in Figure 1.1. This terrain was generated by adding foliage to the database and sampling the 1-meter resolution original terrain data to achieve an approximately 9-meter resolution.⁶

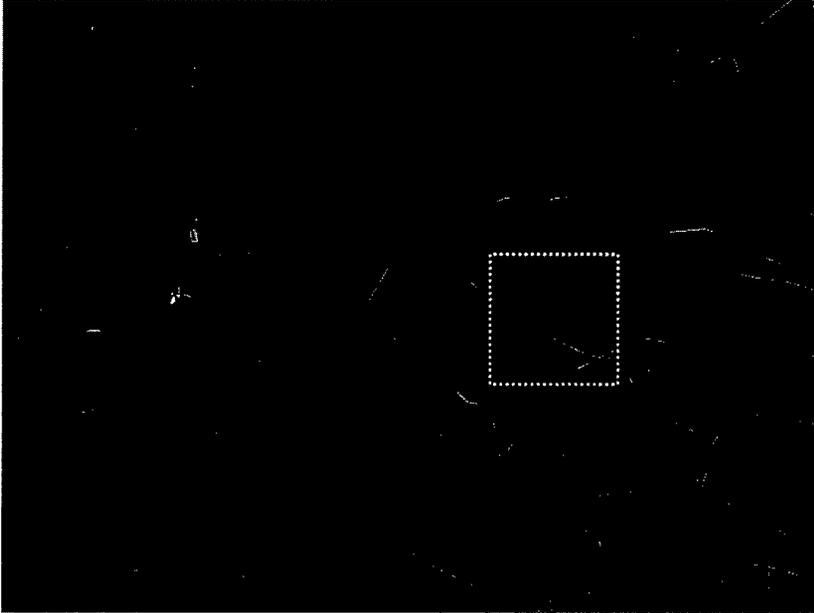
From that, we created two scenarios. The first, shown in Figure 1.2, employs the high-resolution digital terrain from Fort Hunter Liggett, overlaid with vegetation and trees to represent a rolling, forested area such as Kosovo.

Three squads of Blue dismounted soldiers attack a squad of Red soldiers hidden in a treeline. The Blue force includes two teams with M-240 machine guns, infantry with M-16s, and grenadiers. The Red

⁵ Personal communication with Dr. Al Zobrist, consultant to the RAND Corporation, and JPL.

⁶ We could not retain the original 1-meter data for this work due to the huge data files for this size scenario. The 9-meter sampled data were estimated to be sufficient for the study.

Figure 1.1
Modification of High-Resolution Fort Hunter Liggett Terrain
to Represent Kosovo Engagement

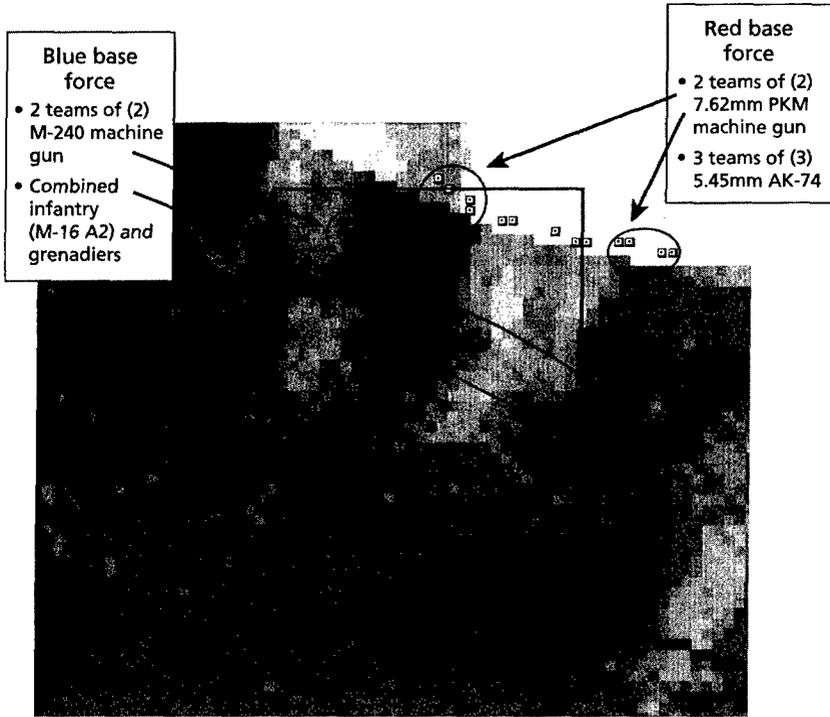


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force includes two teams of the Red force in defilade with AK-74s (5.45mm) and three teams with PKM machine guns (7.62mm). Red holds the treeline, and Blue has initial intelligence on their general location and strength. Blue probes the area, runs into resistance, and quickly returns fire. Movement is by echelon, with machine gun fire for cover. Blue must cross 300 meters of relatively open terrain and does so in sprints with the covering fire. Depending on equipment, tactics, weather, enemy fires, and attrition on both sides, the outcome varies widely.

In this scenario, there are many bunkers and defilade positions in the woods. A typical bunker might be something in front of a tree and behind low-lying foliage, where the enemy sets up sandbags and logs. He has somewhat constricted fields of fire, but at the same time

Figure 1.2
Details of Scenario 1



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he can be hit by direct fire from only a limited number of directions. Blue must use an integrated fireplan to suppress and attack the dug-in positions. The resulting bunkers are similar in many ways to an urban fighting position in a building. Again there is the use of sandbags and camouflage, and the enemy has a constrained firing area. Although the complex terrain is located in a treeline, the analysis of the scenario should produce insights relevant to urban combat.⁷

The second scenario is located in a portion of Sarajevo and involves a movement by a mounted convoy through an urban area with

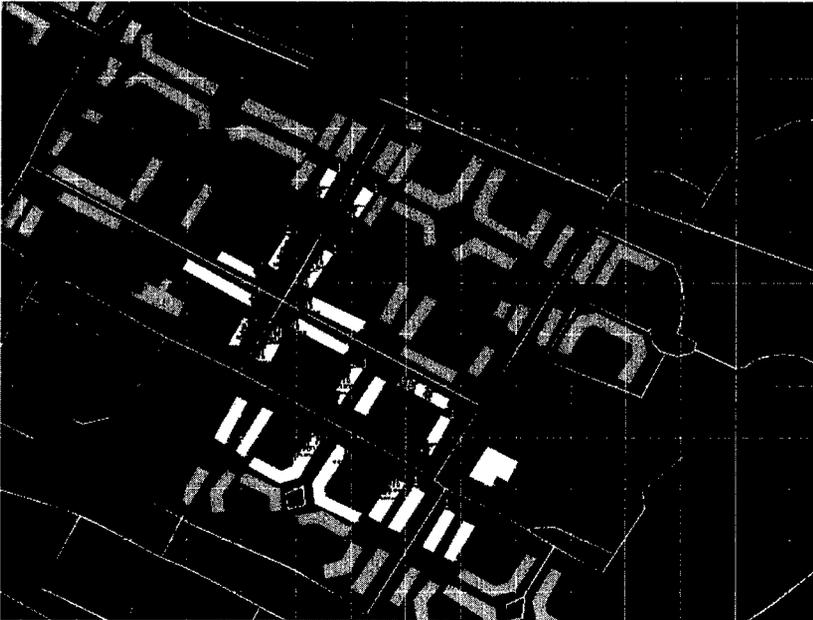
⁷ However, in many urban scenarios the Red force would have better protection and overhead cover than in this treeline vignette, and the Blue force would be more constrained by the terrain.

multistory buildings defended by Red snipers with AK-47s and rocket-propelled grenades (RPGs). It is shown in Figure 1.3. The scenario is a dangerous movement through an urban area, past buildings with armed enemy dismounts. The enemy soldiers are located in many different buildings, firing from different elevations. The Blue force is exposed to fire from both sides, from front and back, and from above. Red holds fire until the ambush is initiated.

Simulation Tools Used for the Analysis

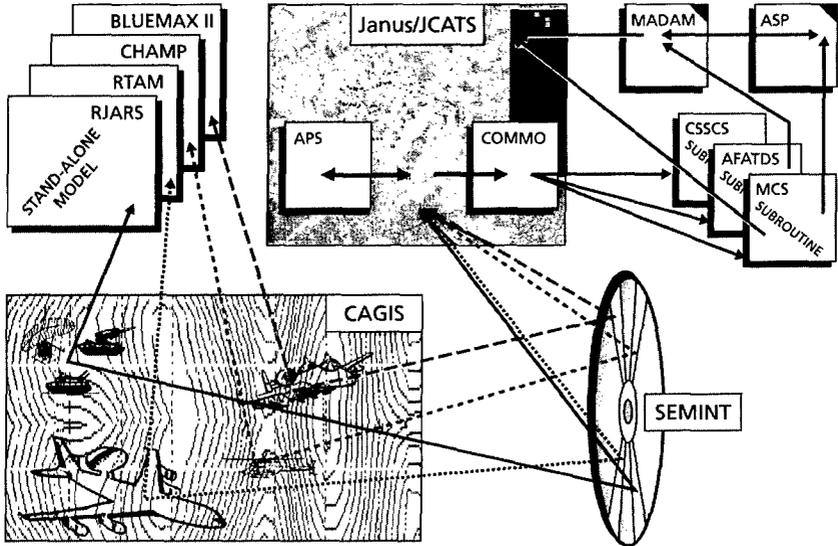
We used two simulation tools for examining the force options in the two scenarios: Janus (a two-sided, force-on-force ground combat model) and the Joint Combat and Tactical Simulation (JCATS). Figure 1.4 shows the constituent models of the Janus-based simulation environment. The models are linked together using the Seamless

Figure 1.3
Details of Scenario 2



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Figure 1.4
Simulation Environment Used for This Analysis



▼ Stand-alone models in CAGIS that also exist as subroutines in Janus

RANDMG140-1.4

Model Interface (SEMINT), a form of locally distributed network. The individual models center on the force-on-force Janus wargaming simulation and comprise a wide range of capabilities. Janus itself has been modified for analysis from its original form by increasing the size and scope of engagements, adding automated operations, and allowing special digital terrain representations.

The other models surrounding Janus are primarily for modeling advanced systems. The RAND Jamming and Radar Model (RJARS) dynamically simulates infrared (IR) and radio frequency (RF) air defense engagements against helicopters, unmanned aerial vehicles (UAVs), and fixed-wing aircraft. The Model to Assess Damage to Armor with Munitions (MADAM) models the flyout, encounter, detection, and endgame with smart and brilliant munitions. The RAND Target Acquisition Model (RTAM) represents low-observability vehicles, the Acoustic Sensor Program (ASP) models acoustic sensor phenomenology, and the APS program simulates the

effectiveness of vehicle protection systems against a variety of incoming weapons. The set of models are linked and coordinated in a local-area network using our Cartographic Analysis and Geographic System (CAGIS). Other models noted in the figure were not called in this analysis.

The system is normally first used interactively by Red and Blue gamers, setting up movements, firing missions, coordinating lines, etc. Once the dynamics are set, the model is run autonomously for many iterations to arrive at a statistically converging ensemble of runs for each excursion.

Organization of This Document

The remainder of this document is organized around answering a set of four research questions. Chapter Two sets a baseline for the analyses that follow by answering the question, "How might a current-generation soldier unit perform in a challenging combat operation?" Chapter Three further sets the stage for the analyses by answering the question, "What are some key, high-leverage technologies for the objective soldier?" Chapter Four is the core of the document, providing the results of the analyses by answering the question, "What is the impact of such technologies (separately and in concert) in combat, using high-resolution simulation?" Finally, we mine previous work to answer the question, "What are some alternatives (non-soldier-based) for accomplishing the same mission?" Chapter Five offers some observations and conclusions based on the analyses.

How Might a Current-Generation Soldier Unit Perform in a Challenging Combat Operation?

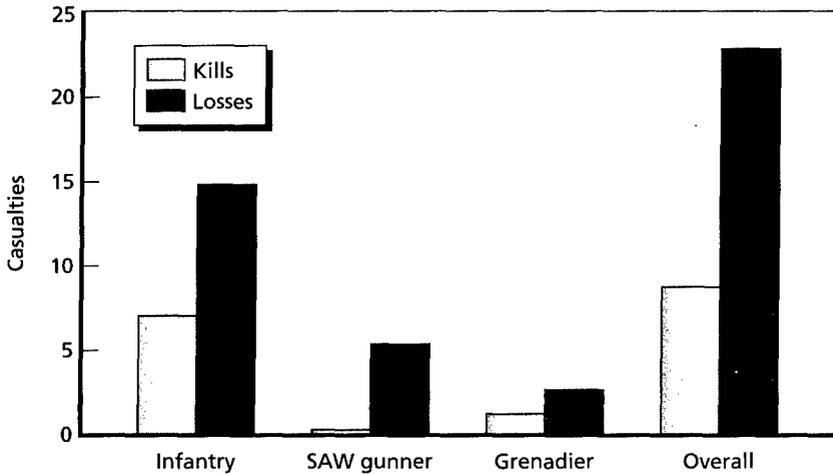
Before we can understand how to improve soldier performance, we need to understand how soldiers would currently perform in the stressing scenarios created for this analysis. Doing such an analysis provides us with a “baseline” against which to compare the results of the analyses shown in Chapter Four. The baseline analysis also suggests some of the technologies shown in Chapter Three that might be appropriate to simulate in conducting that analysis.

When we examine how a current-generation soldier unit—which is made up primarily of dismounted soldiers with M-16s and M-240 machine guns—might perform in a challenging combat operation (in this case, the treeline attack scenario), we find that *because of the strong defensive advantage afforded Red in this situation, the Blue force takes substantial losses during an intense direct-fire fight*. In the remainder of this chapter, we discuss this finding in more detail.

How Does the Current-Generation Soldier Unit Fare?

As Figure 2.1 shows, the current-generation force was unable to accomplish its objective in the mission. The figure, which shows the number of Blue and Red losses by force components, shows that all

Figure 2.1
Results of Baseline Case for Current-Generation Soldier Unit



*Based on 30 runs, 50% weather condition, e.g., average visibility for region.

RANDMG140-2.1

the Blue force components sustained similar loss levels—losses that are substantially higher than those for the Red force (shown as “kills”). And while both Red and Blue suffered roughly 50 percent losses, these losses are certainly unacceptable for the attacking Blue force.

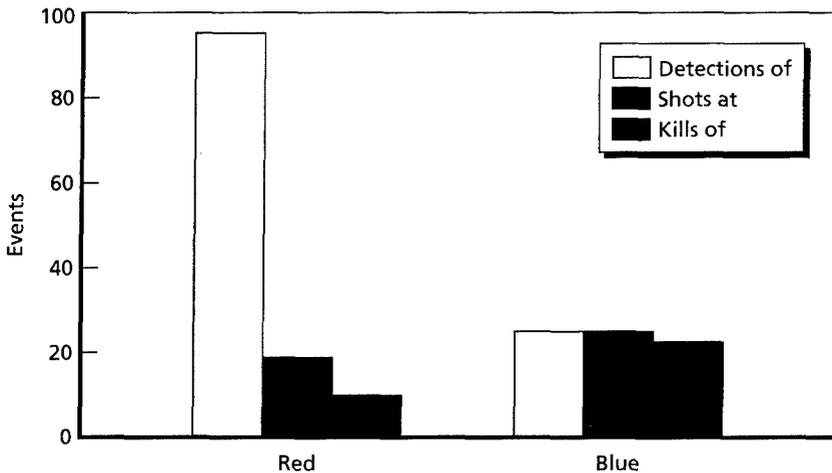
Why Do We See the Results We Do?

Figures 2.2 and 2.3 show the primary reasons for the results described above. The former, a Janus screen, shows that one of the features favoring the Red force is its good lines of sight. Thus, the Red force is able to spot moving Blue forces out to several hundred meters. The second figure, a JCATS screen, shows the overlapping lines of sight, making it apparent that the Red force has very good visibility and the tactical advantage.

Figure 2.4 shows another interesting insight from the analysis. It looks at individual detections, shots, and kills for the Red and Blue forces. What is clear from the figure is that even though the Blue force had better surveillance than the Red force (more than 90 detections versus more than 20, apparently due to detections of muzzle flashes by many Blue systems), the Red force shot more times than the Blue force (more than 20 versus fewer than 20) and had more suppressions and kills (around 20 versus fewer than 10). This would be expected against an opponent moving in relatively open terrain.

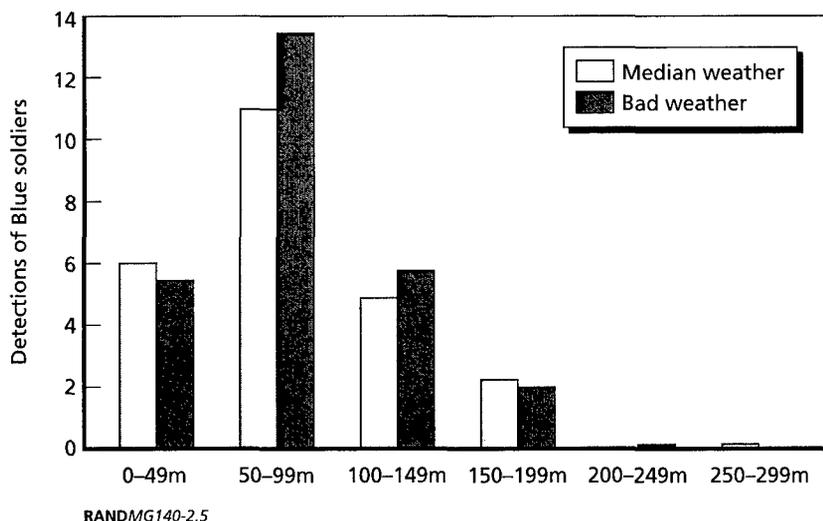
Finally, we analyzed what effect weather would have on the outcome of the battle, speculating that poorer visibility might help the attacking Blue force given its edge in surveillance and open terrain. Figure 2.5 shows the results of a run in which the weather in the region is that of the worst 10 percent of time, compared to median weather (here historical levels are worse 50 percent of the time).

Figure 2.4
Detections, Shots, and Kills for the Blue and Red Forces



RANDMG140-2.4

Figure 2.5
The Effects of Poor Weather on Detections of Blue Forces



However, the figure, which shows detections of the Blue force by the Red force by 50-meter range intervals, reveals that poor weather and the resulting decreased visibility actually hurt the Blue attack slightly. The attacker closes, increasing the probability of hit and kill in the ambush, and Blue is unable to effectively return fire. The forward-looking infrared sensors (FLIRs) of the Blue force do not provide sufficient advantage to overcome the problems of defiladed, tree-covered, and stationary targets. As a result, but not shown on the figure, kills of Red are roughly constant, but losses of Blue increase from around 23 to around 25.

It may appear that this baseline scenario is unrealistic and too demanding. A platoon leader or force commander would not risk these losses. However, this mission, attacking an uncertain, high-value target concealed in cover, is an important one for our forces. It might occur in treelines in Kosovo, urban areas in Iraq, or the rocky slopes of Afghanistan. In the next two chapters we will explore possi-

ble technologies and tactics to reduce risks and improve chances of mission success.

What Are Some Key, High-Leverage Technologies for the Objective Soldier?

The baseline analysis described above highlights some areas where the current-generation force needs help if it is to accomplish its mission in a stressing scenario like the one being used here. When we answer the question of what are the key technologies to address those needs, we find that *new sensor, weapon, protection, and information systems are envisioned for the future soldier*. We discuss this finding in more detail below.

What Technologies Are Examined?

The technologies that directly equip the dismounted soldier can be roughly grouped into weapons (both personal and remote), sensors, information (i.e., links to other systems), and protection, as shown in Figure 3.1. Some of these technologies have been specified in detail, while others are still preliminary or conceptual in nature. We will be modeling the effects of all of these. Some of the excursions were of specific systems, while others, such as stealth level, were parametric. The degree of situational awareness (for indirect fire) was varied by assuming different levels of knowledge of enemy positions.

Weapon systems include the Objective Individual Combat Weapon (OICW; now called the XM-29) and the future 5mm agile

Figure 3.1
Various Technologies to Improve Soldier Operations



Weapon systems



Information systems



Sensor systems



Protection systems

RANDMG140-3.1

SOURCE: Courtesy of Natick Labs, Objective Force Soldier program.

missile with seeker. We have received preliminary data on the XM-29 indicating that the 20mm round is expected to have a probability of kill (Pk) of 0.35 out to 300 meters. Other sources state that a 0.5 Pk is anticipated to this range, with effects out to 1,000 meters.

Information systems (or extent of situational awareness) are played parametrically. We assume that enemy status and position are known accurately (10-meter target location accuracy), or that an enemy force is located in a treeline several hundred meters long.

For the sensor systems, the FLIR being modeled here is a room-temperature 480×640-pixel sensor said to have at least 90 percent of the sensitivity of the current Javelin FLIR. We are using the Javelin characteristics as a surrogate.

The protection systems include body armor of the future warrior, which is supposed to stop small arms and fragments. We are modeling full protection against 5.45mm AK-74 rifles and partial (50–90 percent) against 7.62mm PKM machine guns.¹

What Are Some Other Potential Excursions?

Our initial excursion set examined the options available to the dismounted force, comparing the results if they carried out the same attack plan. Additional, more time-intensive excursions should provide insights on how the units may alter their fighting tactics, how they might use more sophisticated protection systems and weapons, and how the enemy might in turn respond to these.

If the unit was able to access real-time surveillance from additional sensors, such as UAVs, integrated unattended ground sensors (IUGS), unmanned ground vehicles (UGVs), robotic remote sentry, or other means, they might attempt to carry out a substantially different attack procedure. Knowing the danger areas, time available, and enemy vulnerability, the unit commander might use maneuver and shock to beat down the enemy, while avoiding losses to ambush and harassment.

Energy weapons such as microwave and acoustic weapons have the ability to incapacitate and disable. Modeling such effects requires system augmentations to better represent the performance. It also requires additional data sets to specify range, impact, and duration of these weapons.

The package of equipment is necessarily heavy, and we need to determine the impact on speed, endurance, and performance. This may require the use of special models, such as Integrated Unit Soldier Simulation (IUSS).

¹ Lightweight body armor is an area of active research. It is possible that future versions of the Objective Force Soldier suite may stiffen when a bullet hits the fabric, using magnets suspended in fluid. ABC news release, Cheri Preston, May 30, 2003.

Enemy countermeasures, finally, can run the gamut of jamming, E-bombs,² decoys, dispersion, hugging up to noncombatants, and use of area weapons. These, in combination with the possible breakthroughs noted above, will require extensive further analysis.

² E-bombs are radio frequency burst weapons that can incapacitate unprotected electronic systems over a wide area.

What Is the Impact of Such Technologies in Combat, Using High-Resolution Simulation?

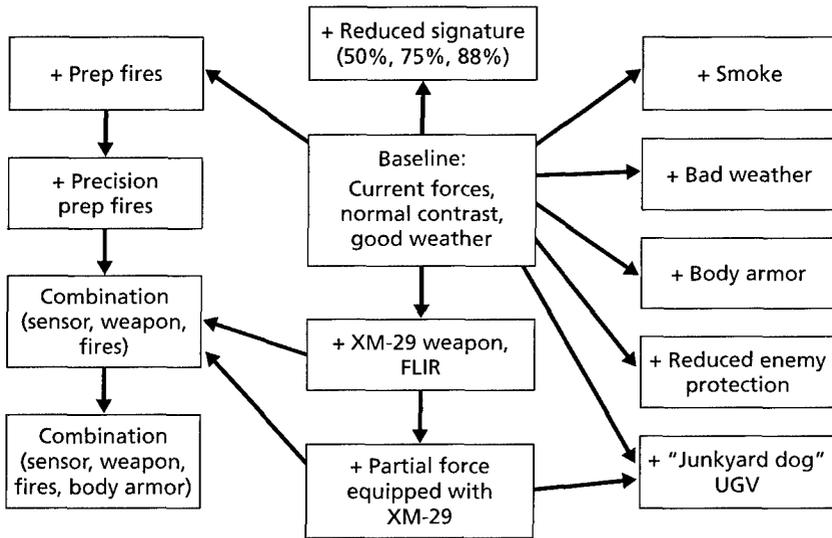
What happens to the outcomes of the mission when the technologies discussed above are incorporated forms the core of the analysis conducted for this study. When we answer this question using high-resolution modeling, we find that *major improvements appear to be possible, especially when the impacts of such technologies are viewed synergistically*. We explore this finding in more detail in the remainder of this chapter.

What Effect Do Future Technologies Have on the Performance of Future Objective Soldier?

Figure 4.1 shows conceptually how we went about answering the question. Our excursion set in the treeline attack case (Scenario 1) was fairly extensive. The baseline condition, shown in the center of the diagram, is the situation described in Chapter Two: current-generation troops, without body armor, attacking under good weather against enemy forces defending in bunkers. The bad-weather excursion, also described in Chapter Two, is shown to the right of the baseline.

Technology options include reduced signature, smoke, body armor, sensor, personal weapon, UGVs, and indirect fire links. A

Figure 4.1
Different Conditions Examined in the Analyses



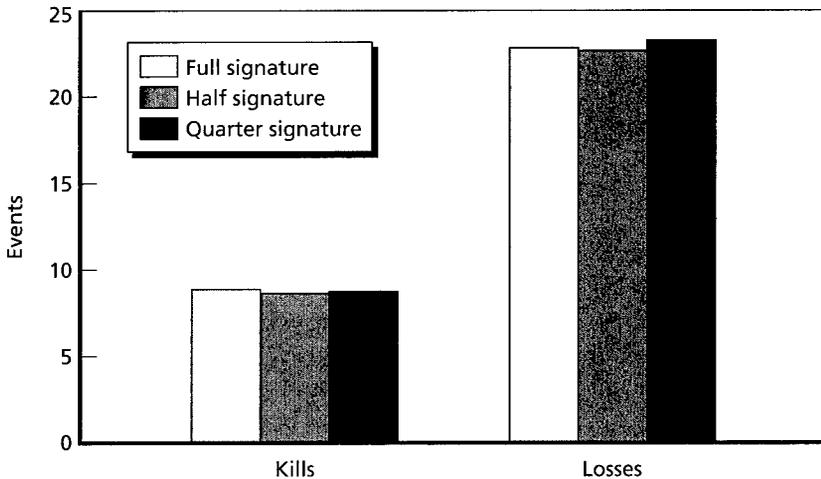
RANDMG140-4.1

variant of enemy posture is shown as enemy protection, in which the bunker is removed and the soldiers simply fire from defilade. Combinations of conditions then look at the synergistic effects of multiple technology options.

Excursions on Individual Technology Options

We start by examining what happens when we introduce technology options in isolation, beginning with technologies that reduce signature. Figure 4.2 shows what happens when we reduce the visible and thermal signatures for the Blue forces by 50 percent (half signature) and 75 percent (quarter signature) compared to the full signature in the baseline case. Unfortunately, doing this had little effect because of the short ranges of engagement. At less than 150 meters, even a stealthy moving soldier is relatively visible. As a result, as seen by the similar level of the bars, outcomes in terms of losses and kills were relatively unchanged, while the typical engagement range shortened.

Figure 4.2
Effect of Reducing Signature

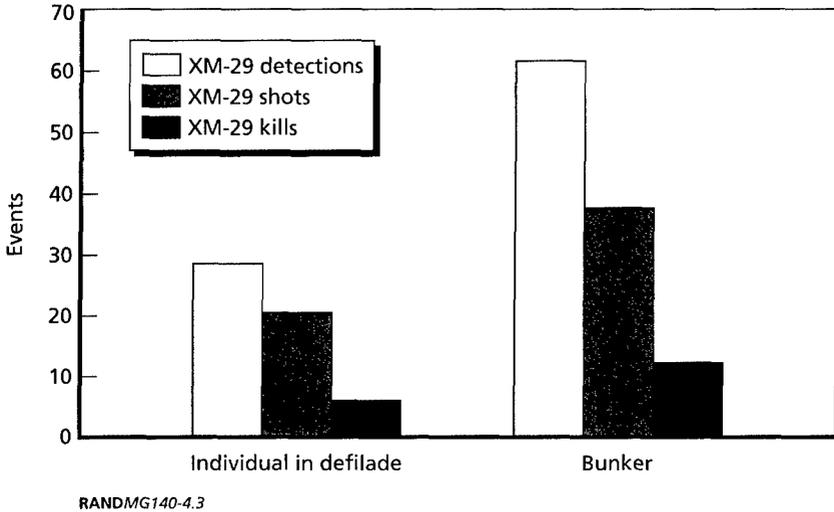


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Returning to clear weather and no obscurants, we examined the use of the XM-29 with different sensors and target conditions. The enemy soldiers are in defilade and have limited fields of fire. Spotting and engaging them, even with muzzle flash detection, is very difficult. With eyeballs alone, few shots and kills result from the weapon. With the basic uncooled XM-29 FLIR (similar to a Javelin FLIR), more kills are attained (roughly double). With a highly capable, cooled second-generation FLIR, additional shots and kills occur (roughly double again).

When the dismounted enemy is in a bunker, this provides the XM-29 laser with a reasonably sized target to discriminate, even though the bunker affords camouflage and overprotection. The weapon can be shot over or by the target and explode near it. As shown in Figure 4.3, spotting and hitting a dismounted soldier in simple defilade in the treeline is more difficult compared to spotting and hitting him in a bunker.

Figure 4.3
Performance of XM-29 by Target Characteristics

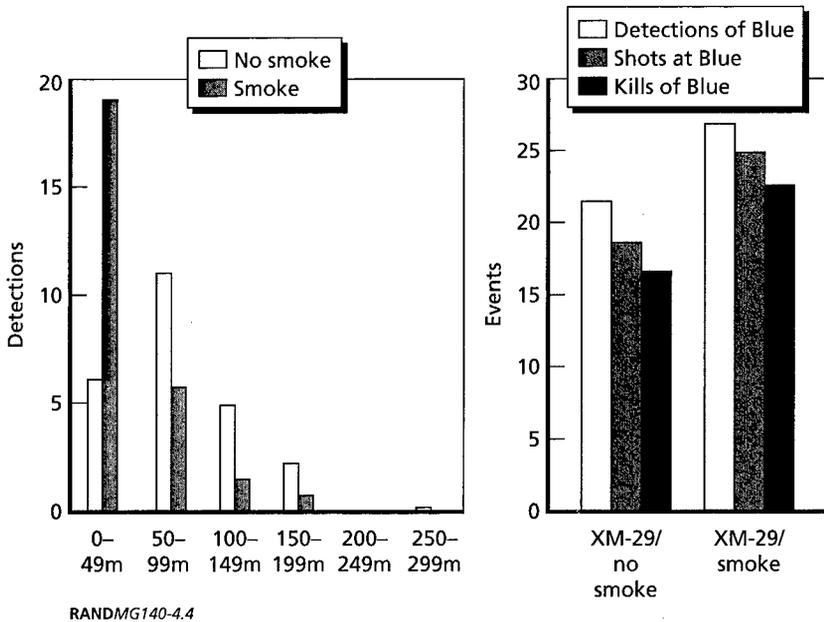


Smoke was used, in the form of smokepots emitting hydrocarbon smoke placed between the Blue and Red force, with a favorable wind direction. This might be expected to aid the Blue force, since their sensors would be less affected by the obscurant than those of the Red force. However, this advantage was not seen.

As shown in the left graph in Figure 4.4, the range at which detection of the moving Blue forces occurred was significantly decreased when smoke was used, which (as shown in the right graph) raised the Red probability of hit and kill. The number of detections, shots, and kills of Blue subsequently increased, and the overall loss-exchange ratio (LER) dropped to almost half of the baseline case. Blue losses increase and Red losses decrease, because surviving Red forces are able to fire more frequently and accurately at closer range.

By itself, the addition of body armor, with the ability to stop small arms fire up to machine gun level, had little effect. Specifically, kills by Blue are similar to what they are in the baseline, with losses

Figure 4.4
Effects of Smoke



reducing slightly from around 23 to 21. Shots and kills by Red infantry (using 5.45mm AK-74) decrease markedly compared to the baseline, where 10 percent of the kills are attributed to AK-74s. Most losses (90 percent) are attributable to PKM machine guns, and two machine gun teams had many available targets when the Blue force was given no other improvements than enhanced body armor. Ranges of engagement (detections, shots, and kills) are similar to what they are in the baseline case.

One of the benefits of the XM-29 is that it can be fired while holding it around a corner or above the head. In this mode, the hands are the only vulnerable part and constitute a small area compared to the body (80–90 percent) or even the portion of a soldier unprotected by defilade (30–40 percent). No lethality data are available for this posture, but there should be a significant advantage in survivability with this feature, at least when the soldiers are stationary.

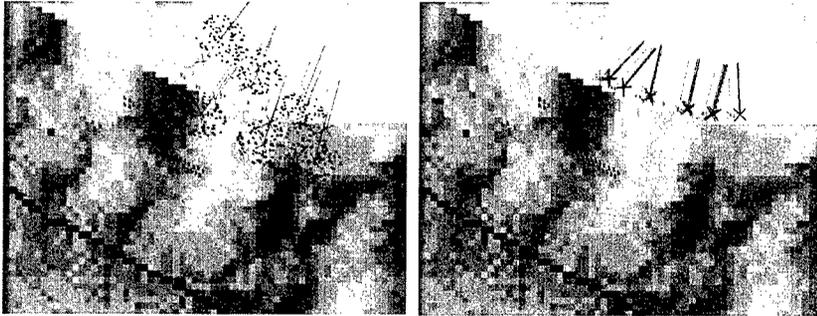
Unfortunately, we examined several of our excursions in detail, and found that most kills of Blue soldiers occurred during the short times they were running over open ground. Most of these were attributable to the machine gun teams. As a result, it would make it very difficult to protect these forces with body armor, cloak them in stealth, or take advantage of firing behind cover with the XM-29.

Before launching the attack, the dismounted force can soften the enemy by using indirect fires—either wide-area anti-personnel bomblets or more powerful high-explosive (HE) rounds. Using MADAM, we modeled several current options that would most likely have effects similar to the tube and missile options being considered as organic fire support for the FCS force. In particular, we modeled a 155mm battery firing dual-purpose improved conventional munition (DPICM) and HE (five volleys from six tubes, serving as a surrogate for the FCS 155mm cannon and 120mm mortar) and the high-mobility artillery rocket system (HIMARS) firing multiple-launch rocket system (MLRS) rockets with DPICM (one 12-tube volley from one launcher, serving as a surrogate for Netfires loaded with anti-personnel weapons).¹ These excursions have different delivery accuracies, payloads, and target location errors (TLEs). They result in different lethalties and secondary effects, and give some idea of the possible contributions of indirect fires to this mission.

Some options make significant impacts on the battle, as seen in the next few figures. Figure 4.5 shows that if Blue does not know the exact location of the enemy teams but has an idea of the region of treeline they are operating in, we can call in fires (recon by fire). Unfortunately, if only cannon fire is available, the beaten areas are not sufficient to do more than suppress a few of the enemy troops. The figure shows the intended target locations as X's and the actual munition splashes as red dots. In the case of DPICM without global positioning system (GPS)-guided rounds, even some friendly forces are attrited in this scenario.

¹ Netfires is a missile-launching system envisioned for the Future Combat Systems program. It is planned to contain both loitering and direct attack missiles.

Figure 4.5
Effect of Cannon Fire Without Good Knowledge of Enemy Positions



- 155mm battery, 5 volleys DPICM, 50 m TLE
- Killed 0.39 Red, 0.19 Blue

- 155mm battery, 5 volleys HE, 50 m TLE
- Killed 0.53 Red

Results averaged over 200 runs

RANDMG140-4.5

However, as shown in Figure 4.6, even without good knowledge of enemy positions, MLRS with DPICM is effective. The larger payload of MLRS rockets (644 M-42 bomblets versus 88 in a 155) results in a much larger beaten area. In fact, over the roughly 300×100 meter area, a bomblet falls about every three meters. The large overlapping areas reduce the need for good intelligence. However, if non-combatants are present, there will be extensive casualties. There are also friendly losses if GPS guidance is not used.

If we have very good knowledge of enemy positions, attained from unattended ground sensors (UGS), overhead sensors, hovering UAVs, or other sources, the result is better outcomes, as shown in Figure 4.7. GPS-guided cannon fire and MLRS both result in loss of roughly one-quarter of the enemy force and suppression of the remainder. Up to 40 percent of the highly lethal machine gun teams are taken out in this way.

While such indirect-fire systems can clearly be effective, the secondary effects of these weapons must be considered. In Kosovo, the complex terrain areas contained an average of about 1,500 noncom-

Figure 4.6
Effect of MLRS with DPICM Without Good Knowledge of Enemy Positions



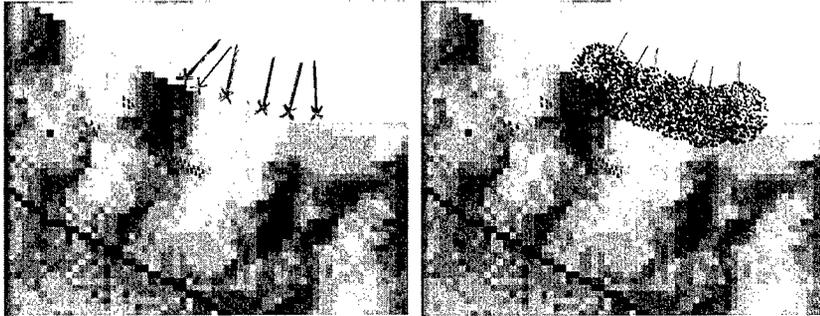
- GPS-guided MLRS w/DPICM, 50 m TLE
- Killed 3.3 Red soldiers, including 1.4 MG (23% of Red force)

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batants per kilometer. In this scenario, that might mean there were as many noncombatants as enemy in the MLRS/DPICM beaten zone. An MLRS/DPICM volley also produces collateral damage to the infrastructure over 30,000 square meters. Inaccurately delivered DPICM and HE both produce friendly casualties in this scenario. In addition, supporting fires cannot be used once the forces are in contact.

GPS-guided HE rounds should have significantly less collateral damage, although this is specific to the use of small warheads. Our previous studies of the use of the U.S. Air Force 250-pound small

Figure 4.7
Effect of Fires with Good Knowledge of Enemy Positions



- 155mm battery, 5 volleys DPICM, 0 m TLE
- Killed 3.1 Red, including 1.1 MG

- GPS-guided MLRS w/DPICM, 0 m TLE
- Killed 3.5 Red, including 1.6 MG

RANDMG140-4.7

smart bomb showed substantial damage and injuries.² However, with smaller Netfires rockets, spacing of submunitions is unlikely to be greater than with an MLRS volley (2–3 meters).³

For future applications, there may be a compromise that is effective. A guided 155mm cannon round or Netfires missile could carry anti-personnel or dual-purpose submunitions, and these could be released at low altitude over a very small spread area. This should kill a large percentage of infantry in the treelines or in bunkers, but it would have limited effects on noncombatants 50–100 meters away.

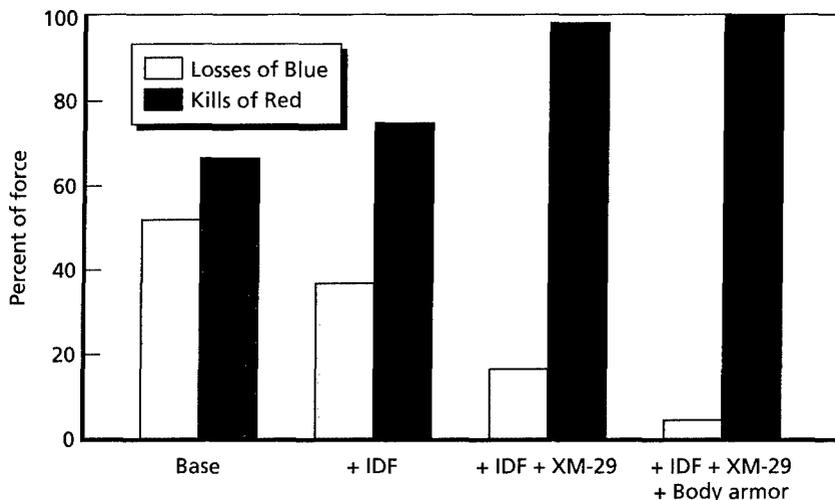
Excursions on Synergistic Effect of Multiple Options

What happens when the effects of the options are combined synergistically? We found that combinations of the improvements to the Blue dismounts have much greater performance than might be expected from the additive effects alone, as shown in Figure 4.8.

² Matsumura et al., 2002.

³ The Netfires system envisioned for the Future Combat Systems program incorporates precision-guided missiles, but there are no current plans for submunitions.

Figure 4.8
Effect of Synergies of Indirect Fire, XM-29, and Body Armor



NOTE: IDF = Indirect fires.

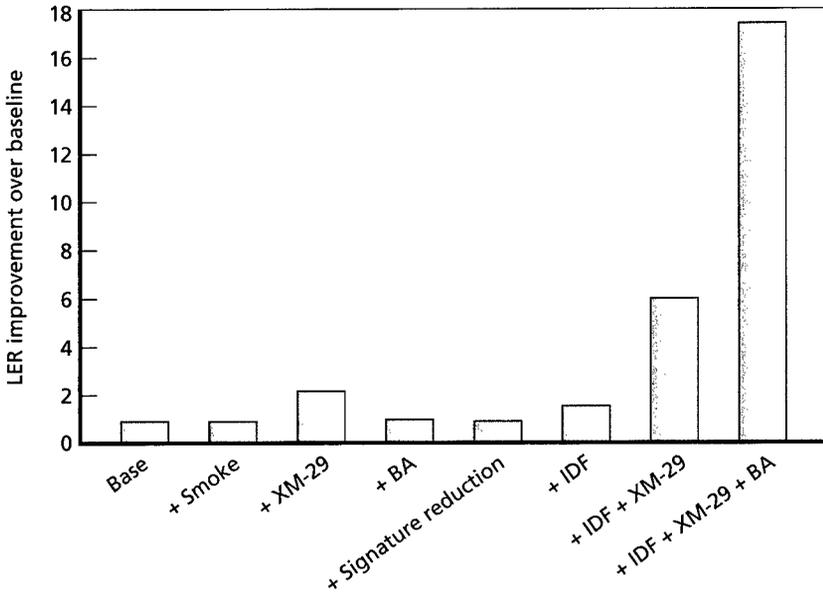
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Alone, indirect fire resulted in a rough doubling of effectiveness of the force (in terms of kills and losses), the use of the XM-29 weapon and associated FLIR improved effectiveness by about 60 percent, and body armor had a negligible effect. When used together, however, indirect fire and XM-29 increased effectiveness by over five times, while the same combination with body armor improved the outcome over 15 times.⁴ In the last case, only two Blue soldiers were lost and all the enemy were killed. The synergies seem to arise from the ability to start the direct-fire battle with a better force ratio after attrition from long-range fires, to withstand a round from the enemy without casualty, and to return fire with first-round lethality.

Another way to look at the cumulative effects of adding options to the force is shown in Figure 4.9. The chart starts with the base

⁴ Note that we did not try stealth in the mix of technologies because in this scenario, the ranges appeared to be too short to have an effect.

Figure 4.9
Effect of Synergies of Indirect Fire, XM-29, and Body Armor on LERs



NOTE: BA = Body Armor
 IDF = Indirect fires.

RANDMG140-4.9

LER as a calibration point, assigned a value of one, and presents all the other cases as a ratio of that value. Minor improvements are seen with individual options, but very large changes occur with combinations.

What Effect Do “Far Future” Technologies Have on the Performance of the Future Objective Soldier?

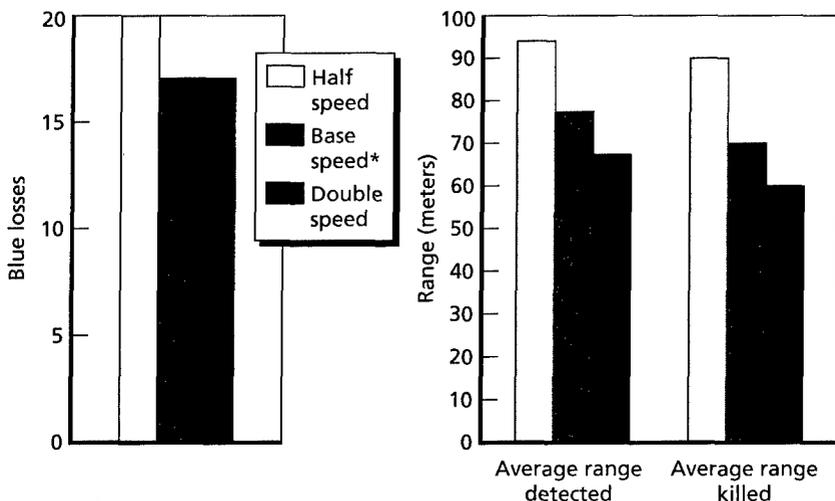
Beyond the technologies proposed above, we also examined some “far future” technologies in a set of excursions. Specifically, we made the soldier faster (doubling sprint speed from 10 miles per hour to 20 miles per hour) through exoskeletal thrust and, conversely, we looked

at slowing him to 5 miles per hour under a heavy load. We also made him better protected with body armor (to 90 percent assurance against a 7.62mm PKM machine gun and 100 percent against 5.45mm AK-74) and stealthier (reducing his signature to one-eighth of the baseline level). All these changes were at levels that do not appear to be possible with technologies currently in development. Finally, we examined the value of adding a small number of armed UGVs to the force (so-called "Junkyard Dogs").

Looking first at the impact of faster sprint speed, we found that because the Blue infantry were assaulting a dug-in defensive position with good cover, greater speed did not materially improve the outcome, as shown in Figure 4.10. The soldiers made it closer to the enemy, but this simply increased the Pk of opposing force weapons. Slower sprint speed (caused by, e.g., a heavy ruck), increased the exposure time and increased Blue casualties.

Very-high-quality body armor did make a difference, as shown in Figure 4.11. Here, we increased the protection of Blue machine

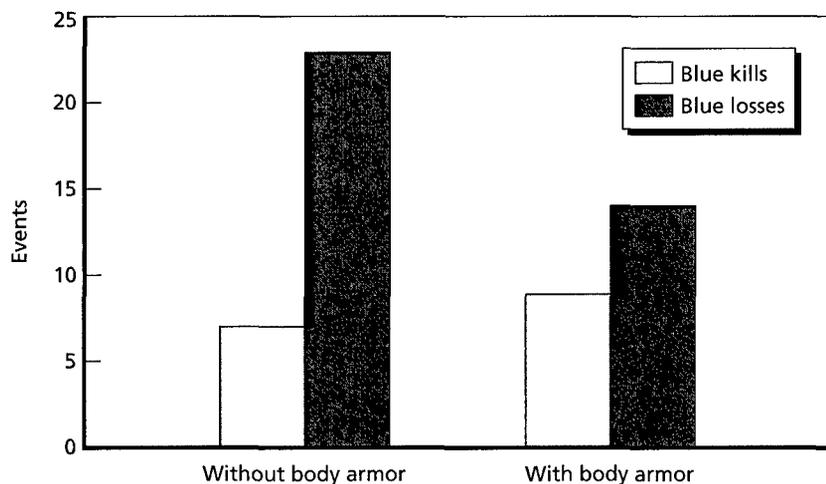
Figure 4.10
Effects of Faster and Slower Sprint Speed Under Heavier Load



*10 mph running speed.

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Figure 4.11
Effects of Adding Very-High-Quality Body Armor



RANDMG140-4.11

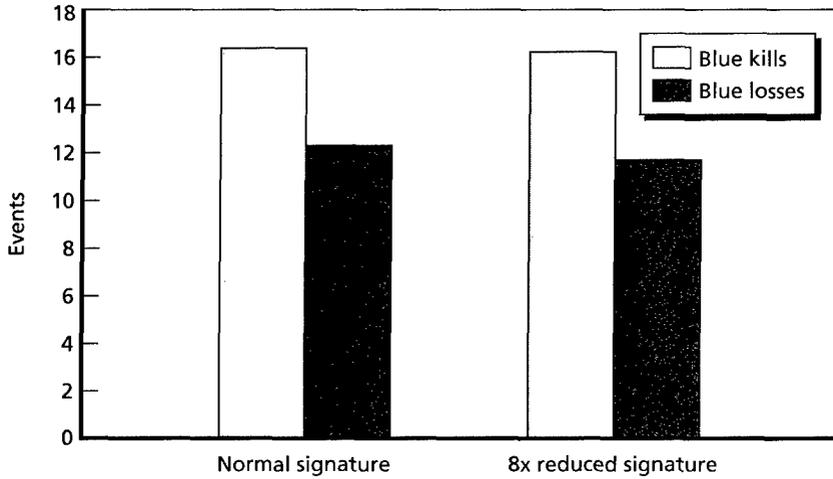
gunners against enemy machine guns to 90 percent. The few soldiers given this protection (only four machine gunners were assumed) made a large difference in the overall battle, more than doubling the overall LER.

Reducing signature down to one-eighth of the baseline level still did not change the outcome in this scenario, as shown in Figure 4.12. As we saw with speed and smoke, the ensuing engagement occurred at shorter ranges, but the Red force was still typically able to fire first and inflict substantial damage on the Blue force.

Interestingly, much of the benefit from XM-29 (the weapon with FLIR) seems to be achievable by outfitting only a small portion of the force with the system, as shown in Figure 4.13. Here, only 6 of the 40 Blue dismounts are given the equipment, compared to equipping 36 of the 40 in the “full XM-29” case.⁵ The performance of this

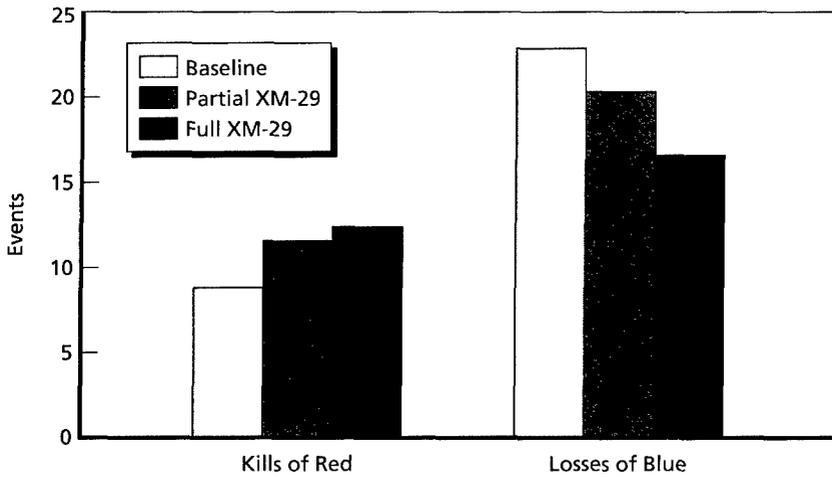
⁵ Four members of the force (Javelin team and machine gunners) were not equipped with OICW in any case.

Figure 4.12
Effects of Further Reducing Signature



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Figure 4.13
Effects of Outfitting Only a Portion of Force with XM-29



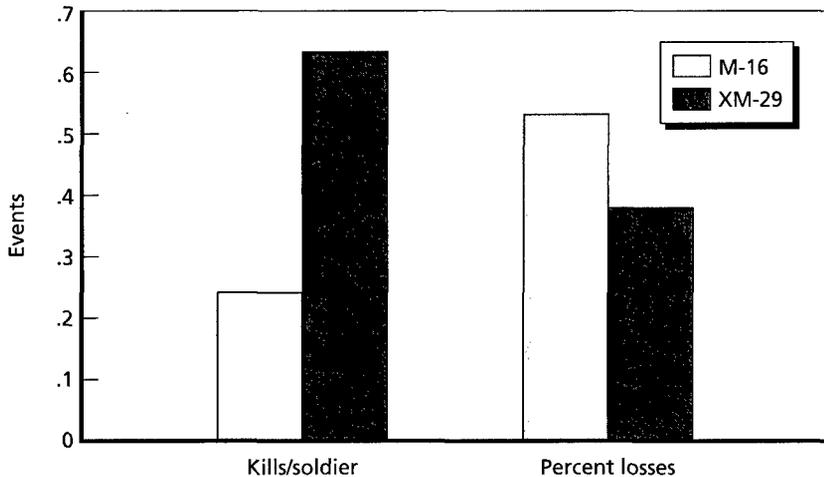
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sparsely equipped force is roughly midway between that of the baseline and the expensive, fully equipped force.

Looking at individual system exchange ratios in Figure 4.14, we found that the six team members equipped with XM-29 were much more lethal and somewhat more survivable than team members with current equipment (M-16s). The chart is normalized to the force size, because there are 24 soldiers in the force with M-16s and only six with XM-29. The moderate improvement in survivability for the XM-29-equipped force would probably be much more if body armor were also added.

In a last set of far-future excursions, we defined a robotic element to aid in the attack. Termed "Junkyard Dog," this is a small unmanned ground vehicle (UGV) with a Javelin-quality sensor, an XM-29 weapon, and the ability to move at up to 10 miles per hour on good terrain. The UGV is assumed to send back images to the manned scout or C2 vehicles, and so it does not have to rely on

Figure 4.14
Effects of XM-29 and M-16 on LER



automatic target recognition (ATR)-level resolution for acquisition.⁶ Vulnerability was assumed to be less than that of an infantryman. Only six were added to the force, since this was thought to tax the span of control possible for an attacking infantry unit.

We tried several variations of the system before finding one that would help the force. If the UGVs were pushed well out in front of the force (several minutes before the attack), they moved too far ahead and had little impact on the outcome. The associated following manned reconnaissance vehicles could not interact well when the UGVs took fire. Large (one-meter) UGVs with chassis-mounted sensors (no mast) also suffered quick losses to the enemy with few kills.

The best option was a small UGV with a mast-mounted sensor (two meters high) that stayed on-leash with the force. This constitutes the system we report on below.

Despite their small numbers (only 6 UGVs in the 40-man force), the unmanned systems made substantial impacts on the outcome, as shown in the first row of Table 4.1.

The UGVs increased kills (the overall LER increased by 37 percent), decreased manned system losses (survivability of manned systems increased by 20 percent), improved infantry efficiency (the system exchange ratio of infantry increased by 10 percent), and contributed their share of detections (detections were fairly evenly spread among infantry, grenadiers, M-240 machine gunners, and UGVs), even though most of them survived only a short period. All told, the UGVs contributed 23 percent of the kills but constituted only 13 percent of the force.

The impact of Junkyard Dog was even more evident when a portion (six) of the manned force was equipped with XM-29, as shown in the second row of Table 4.1. The UGVs improved performance to a level similar to a force that was entirely equipped with the expensive XM-29 weapon and FLIR. Most notably, the XM-29-equipped soldiers themselves became much more efficient, as did the other infantry (up from 10 percent to 35 percent).

⁶ ATRs often require 100 pixels or roughly ten lines across the target for recognition, versus only four lines or so for a human observer.

Table 4.1
Effects of Adding "Junkyard Dogs" to the Force

Case	PERCENT IMPROVEMENT RELATIVE TO BASE CASE			
	LER	Survivability	Detections	Infantry Efficiency
Adding UGVs to force	37%	20%	Spread evenly	10%
Adding UGVs to partial-XM-29 force	35%	20%	Spread evenly	35%

There is a tradeoff of UGVs lost for manned systems surviving and kills achieved. However, this seems to be an effective trade in this situation.

Additional excursions have been suggested by our team and by members of the panel. These include glint detection and response, measured response with nonlethal weapons, additional personal and reachback weapons, the use of smart smoke and penetrating sensors, and the use of additional scenarios. Some of these should be straightforward, while others, such as nonlethal weapons, may require substantial reprogramming.

What Are Some of the Alternatives (Non-Soldier-Based) for Accomplishing the Same Mission?

Although the focus of this study is on dismounted soldiers, we have also conducted other (non-soldier-based) studies that can be mined for relevant insights. In this chapter, we describe findings from some of these previous, related studies that provide insights about other options for accomplishing this mission. Many of these options are related to objective force systems and might augment the dismounted operation. They may also extend the applicability of this force to other scenarios, such as military operations in cities, SASO, and other nontraditional conflicts. In answering the question in the chapter title, we find that *recent, related studies indicate that the use of UAVs, UGVs, and UGSs (unattended ground sensors), special weapons, and fast C2 systems can also strongly improve outcomes.* We examine this finding in more detail below.

What Can We Learn from Other Relevant Studies About Fighting in Complex Terrain as in Scenario 1?

Our previous work with scenarios in forested areas such as Kosovo indicated that comprehensive situational awareness is not guaranteed by future technology improvements.¹ Large and small vehicles can be

¹J. Matsumura et al., 2002.

spotted and tracked in woods, but even with expected improvements in foliage penetrating (FOPEN) radar, they will not likely be identified or discriminated from noncombatant vehicles or realistic decoys. The problem is even more difficult with dismounts. With very little signature and extensive clutter, dismounts can rarely be identified, tracked, or even detected in the woods, especially if they are stationary and in defilade.

Some future options for spotting enemy soldiers and equipment include UAVs searching treelines with laser radar/JIGSAW,² dispersal of unattended ground sensors (UGS) in suspected areas, and deploying UGVs with thermal sensors near treelines. Our Rapid Force Project Initiative (RFPI) study found that acoustic sensors are able to acquire loud moving vehicles with limited discrimination and tracking, but that dismounts are much more difficult to locate. Seismic sensors have limited range and can be spoofed by animals and noncombatants.³

If substantial situational awareness could be achieved, the Blue commander would undoubtedly change his tactics to outmaneuver the enemy, or he would try to precisely target those systems he could hit. The importance of flexible maneuver against a mounted and dismounted opponent was shown strikingly in our FCS study, in which airborne maneuver of Blue forces behind the enemy resulted in a rough tripling of force effectiveness.⁴

Time is important in other ways. Figure 5.1, which comes from our Small Unit Operations study performed for DARPA, shows the effects of time delays when several different types of indirect fire precision weapons were used to engage moving vehicles.⁵ The enemy vehicles could alter their direction and speed to avoid prediction of en-

² This DARPA program involves the use of a UAV-mounted laser-radar to "stitch together" still images taken from different aspects as the platform hovers in front of the treeline.

³ See J. Matsumura et al., *Rapid Force Projection Technologies: Assessing the Performance of Advanced Ground Sensors*, Santa Monica, CA: RAND Corporation, DB-262-A/OSD, 2000.

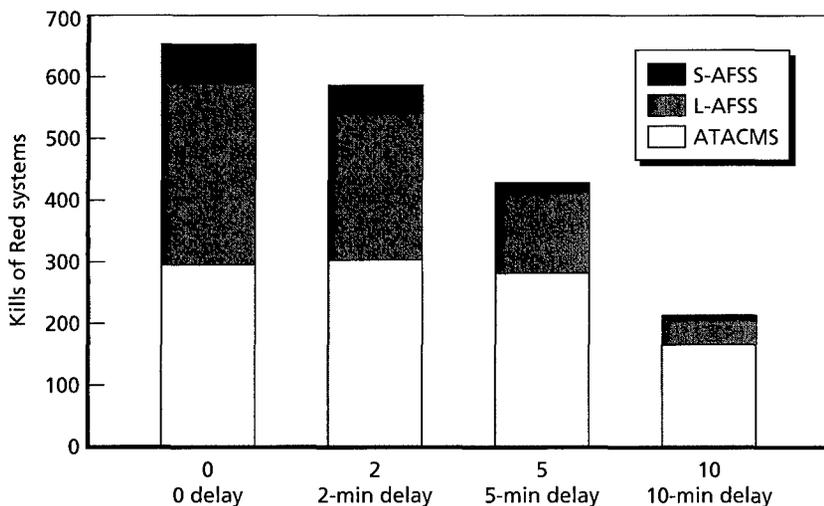
⁴ This effect is described in detail in Matsumura et al., 2002.

⁵ See R. Steeb et al., *Exploration of the DARPA Small Unit Operations Concept Using High Resolution Simulation*, Santa Monica, CA: RAND Corporation, DB-289-DARPA, 1999.

gement areas, and they were able to move between cover. It was found that command and control delays had the most impact on small-footprint weapons such as small and large advanced fire support systems (AFSSs) (variations of the Netfires concept of missiles in a box). Larger-footprint weapons such as ATACMS carrying brilliant anti-tank (BAT) were less affected by up to five-minute delays. Of course, dismounted forces would most likely require much faster timelines than the extremes shown in the figure.

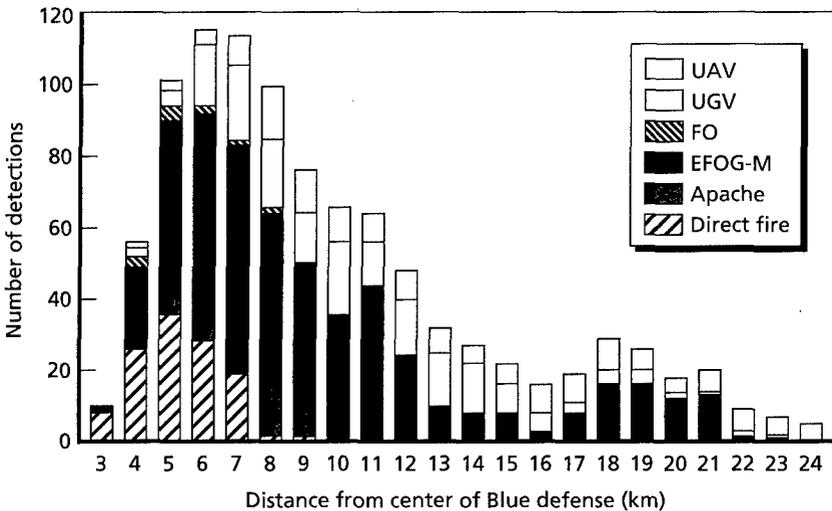
Situational awareness is especially critical to light forces. In an early, special study on robotics, we used many different forms of intelligence gathering by the light force. Human forward observers (18) were placed in front of the force, behind deeper-deployed UGVs (12) and UAVs (2). Enhanced fiber-optic guided missiles (EFOG-Ms) and Apache helicopters also relayed back images as they flew over enemy positions. As Figure 5.2 shows, the detections are complementary in nature, with UAVs providing the bulk of long-range detections and UGVs providing many of the mid-range ones.

Figure 5.1
Effects of C2 Delay on Indirect Fire Munitions



RANDMG140-5.1

Figure 5.2
Effects of Different Types of Intelligence Gathering by the Light Force



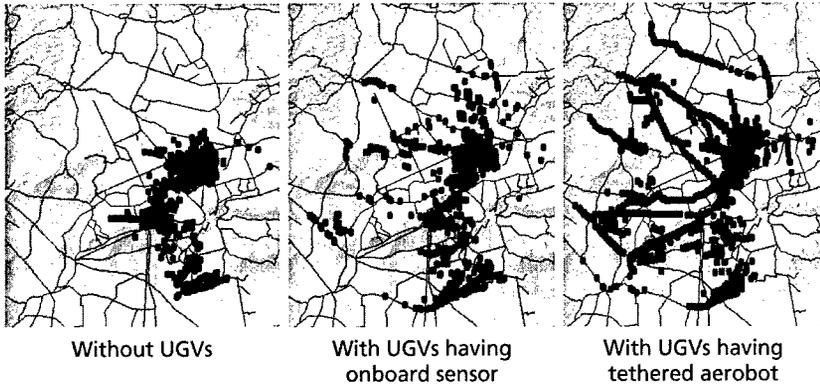
NOTE: The "number of detections" is unique acquisitions only. First sensor to acquire the target is credited with acquisition.

RANDMG140-5.2

Using a mixed-terrain Latin America–Atlantic Command (LANTCOM) defense scenario, we can see the cumulative "detection images" that accrue during the course of a simulated battle.⁶ The sequence in Figure 5.3 shows that the sensor height of the UGV can be critical. The leftmost image shows detections for the forward-observer (FO)-only case (some detections are from EFOG-Ms also), the middle one shows detections with UGVs and FOs present, and the right one shows the extreme case of UGVs with tethered aerobots at 200-foot altitude. As more reconnaissance, surveillance, and target acquisition (RSTA) assets are added, detections occur earlier, are deeper, and are more complete. Of course, the commander is not able to see the

⁶ See J. Matsumura et al., *Lightning Over Water: Sharpening America's Light Forces for Rapid Reaction Missions*, Santa Monica, CA: RAND Corporation, MR-1196-A/OSD, 2000.

Figure 5.3
Importance of Sensor Height on UGVs



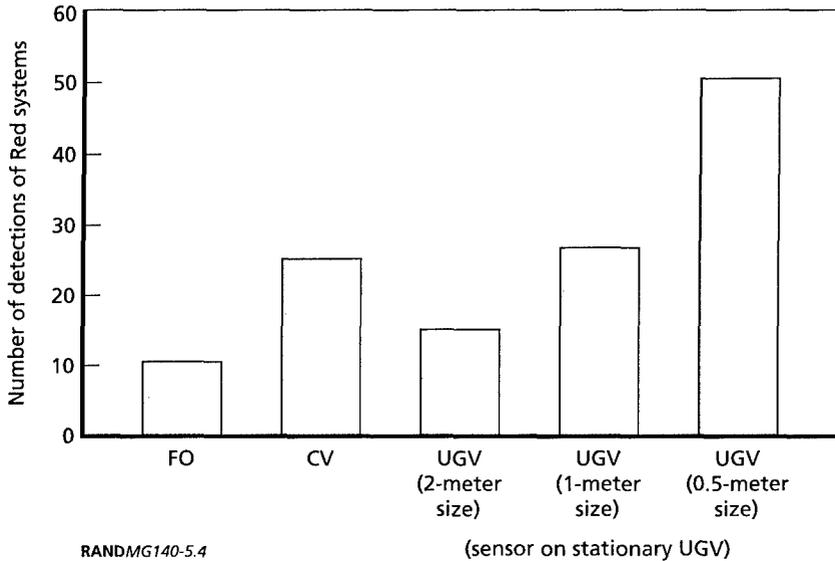
RAND/MG140-5.3

entire cumulative scene shown below; even in the UGV case, only a third or so of the enemy force is visible at any one time.

In the special study on robotics, we also examined the potential of increasingly smaller robotic systems to perform reconnaissance missions in a recon/counter-recon scenario in mixed terrain. As shown in Figure 5.4, we found that a UGV the same rough size (2 meters tall) as a cavalry fighting vehicle (CFV) tallied fewer detections, primarily because the UGV had more stringent requirements for acquisition (10 lines across the target for the ATR rather than 3–4 lines for human interpretation). As the size was reduced, this problem was overcome. By reducing the UGV to half its size, twice the number of detections occurred as with the 2-meter UGB, mainly because the UGV was harder to detect and to kill and, thus, penetrated deeper into the enemy area. More size reduction improved the detections yet again. The effect was greater than that seen when reducing vehicle signature by a similar proportion.⁷ That is, stealth did not seem to be as important as vehicle size for intelligence collection.

⁷ Stealth was modeled here as a simple average contrast reduction. More realistic dynamic contrast and thermal signature modeling may show different effects.

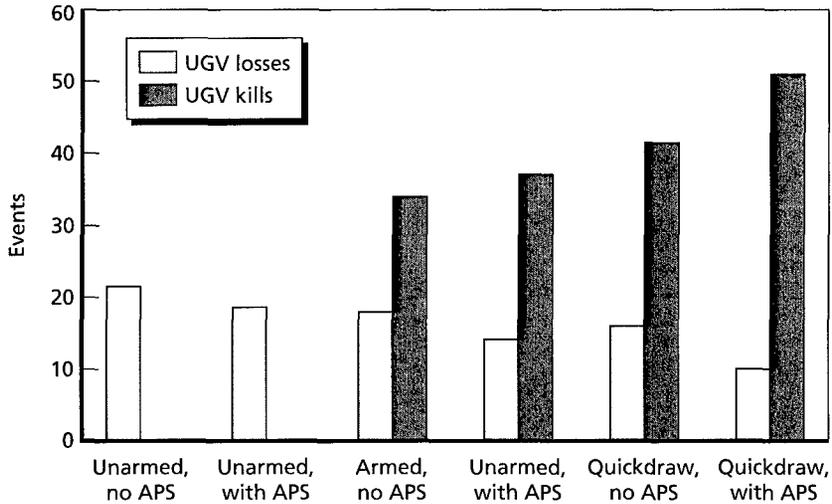
Figure 5.4
Effect of Reducing UGV Size on Detections



In general, UGVs were seen as an effective augmentation of the ground force. In our study of the Future Combat Systems concept, we found, as shown in Figure 5.5, that robotic scouts were effective in replacing larger manned scouts. Here, the kills and losses specific to the UGVs are broken out. Arming the UGVs and instituting a “Quickdraw” response made them much more effective than an unarmed variation that had to call for fires from other assets.

The UGVs were relatively effective against dismounts, but even in the best case, they killed only 14 percent (51 of 360) of those they faced. This finding is very rough because of the coarse (30-meter) terrain that was used in the simulation.

Figure 5.5
Effect of Using Armed UGVs for Recon



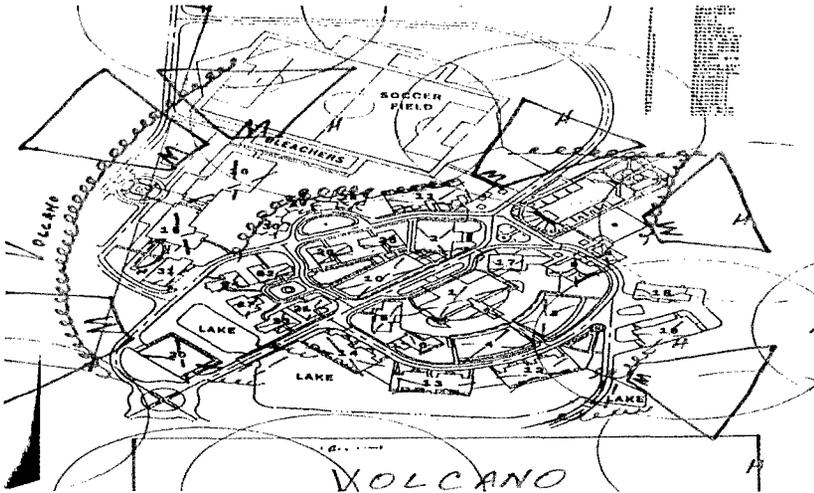
NOTE: APS is active protection system, able to stop most shoulder-fired missiles.

RANDMG140-5.5

What Can We Learn from Other Relevant Studies About Fighting in MOUT Situations as in Scenario 27

Some of our previous work has focused on the difficulties of fighting in MOUT (military operations on urbanized terrain) scenarios. The extreme case of such a scenario was diagrammed for us by the Engineer School at Fort Leonard Wood, as shown in Figure 5.6. Overlapping belts of smart mines, conventional mines, obstacles, and overwatching fires encircle the defended urban area. If necessary, the defenders can use explosives to drop the buildings on the attackers.

Figure 5.6
Difficulty of Attacking an Urban Area



RANDMG140-5.6

Figure 5.7
Modeling MOU "Pointman" Function Using Janus

Blue convoy:	Red ambush:
• 30 trucks	• 15 infantry with MGs
• 10 HMMWV scouts (.50 cal)	• 5 grenadiers
• 4/6 UGVs	• 30 infantry with RPGs

Janus screen image of MOU scenario (Sarejevo terrain)

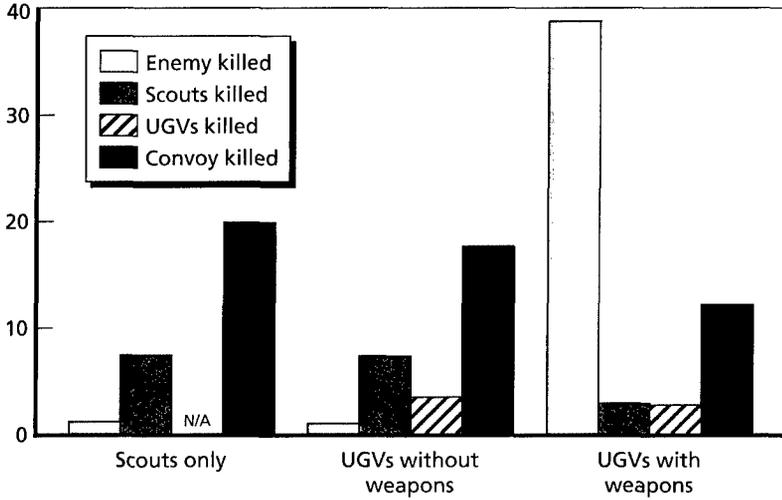
RANDMG140-5.7

Scenario 2 similarly showed the risks of urban operations. This MOUT vignette was adapted from a scenario based on a Sarajevo mission that highlighted a high-risk "pointman" function, as shown in Figure 5.7. Blue is escorting a resupply or humanitarian convoy of trucks through the downtown area. Blue leads with high-mobility multipurpose wheeled vehicle (HMMWV) scouts equipped with .50-caliber machine guns and changes routes if an enemy ambush is spotted in time. Red has prepared an ambush partway through the town, with cratering charges along the road and infantry in the nearby buildings. Red waits until most of the convoy is in the killing zone, initiates cratering charges, and opens fire. Often, the lead vehicles are hit and the convoy is halted. When Blue UGVs are present, these lead the convoy and periodically stop to scan the buildings and find Red units. Red does not use obstacles in the roads, but is able to effectively halt the convoy with mines and fires.

One of the key findings in the MOUT scenario described above was the effectiveness of including UGVs in the convoy, as shown in Figure 5.8. Configured to be indistinguishable from the manned vehicles, the UGVs sustained many losses, but the Red fires highlighted their positions and return fire was then effective. This process was especially effective when the UGVs themselves could fire back, since they had good line of sight (LOS) to the shooters and minimum delay times.

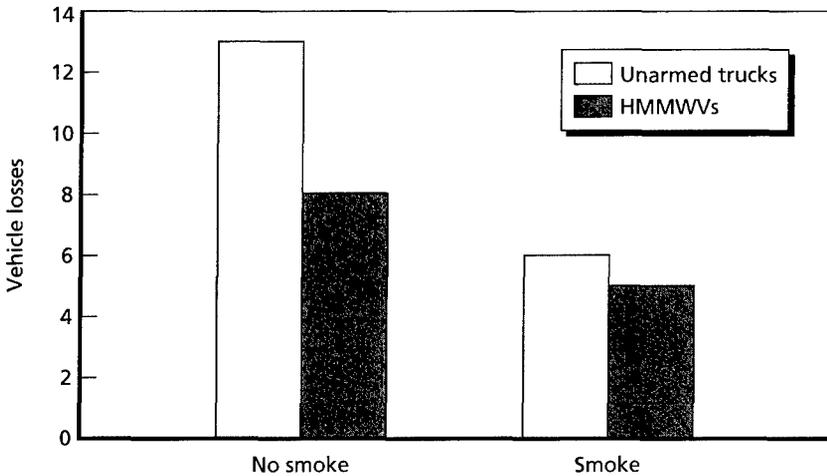
Finally, the Sarajevo scenario showed the effect of simple smoke generators on survivability in an ambush situation, as shown in Figure 5.9. Without smoke, almost half the trucks and most of the HMMWVs are killed. Many of the detections are at range (up to a kilometer), and the Blue force is able to kill only one of the Red infantry. With smoke generators, detections by Red are decreased strongly in number and range, and losses fall to almost half of those experienced in the open. The Blue HMMWVs detect more Red soldiers when smoke is present (Blue has FLIRs that are less affected by the smoke), and they kill more infantry.

Figure 5.8
Effects of Using UGVs in Convoys In MOUT Scenario



RANDMG140-5.8

Figure 5.9
Effect of Smoke on Convoy Survivability In MOUT Scenario



RANDMG140-5.9

We expect that survivability and lethality would further increase with a smart smoke (one that allows Blue to see and Red to be blinded), along with more responsive maneuvers and reactive fires.

What Improvements in Modeling and Simulation Are Needed for Representing Dismounted Infantry Operations and Complex Terrain?

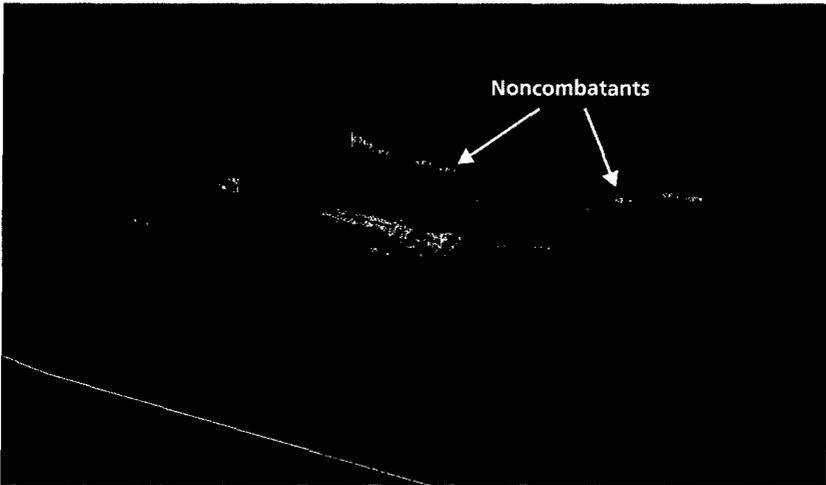
Janus was adequate to the task of modeling combined arms fighting exterior to buildings, but had limitations when representing non-combatants, interior fighting, dismounted infantry postures, special behaviors, and many other aspects of complex terrain. We explored the use of two recently developed modeling tools, JCATS (Joint Combat and Tactical Simulation) and OTB (OneSAF Testbed). For both of these models we were able to access source code and examine model capabilities.

Using JCATS (developed by Lawrence Livermore National Laboratory) allows us to add noncombatants to the modeling issues, as shown in Figure 5.10. Here, the Red squad is holding an equal number of noncombatants in the woods and forces them to run out during the attack. Discriminating these noncombatants from actual threats occupied the attention of the Blue force and resulted in delays and confusion.

We also obtained review copies of several visualization programs from commercial vendors and found them to be extremely useful in urban environments and other forms of complex terrain. One such image is shown in Figure 5.11. Vertical line-of-sight, visual clutter, posture of dismounts, exposure intervals, obscurant masking, and many other phenomena could be examined using these tools.

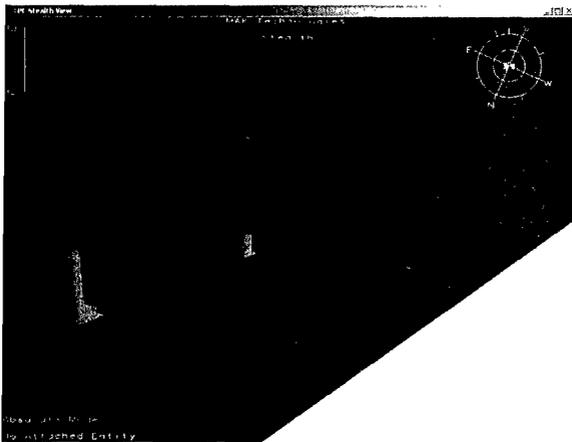
Terrain cross-section, line-of-sight fans, trafficability, weather effects and other phenomena could be checked on the OneSAF Testbed (OTB) map-type displays, such as the ones shown in Figure 5.12. JCATS provided similar tools.

Figure 5.10
An Illustration of the Problem of Noncombatants (White) Using JCATS



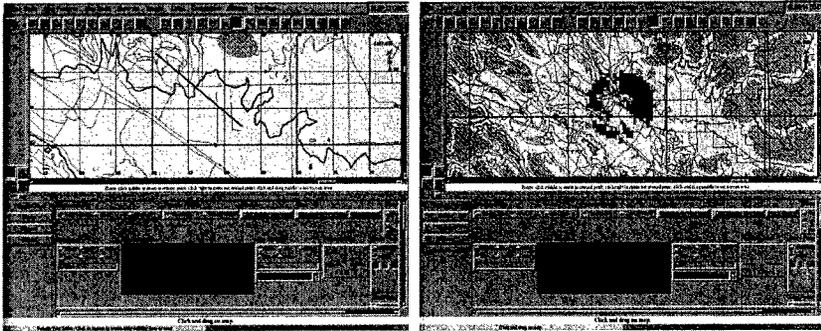
RANDMG140-5.10

Figure 5.11
Usefulness of Visualization Programs in MOUT Modeling Using OneSAF Testbed



RANDMG140-5.11

Figure 5.12
Usefulness of OTB Maps in Showing Terrain



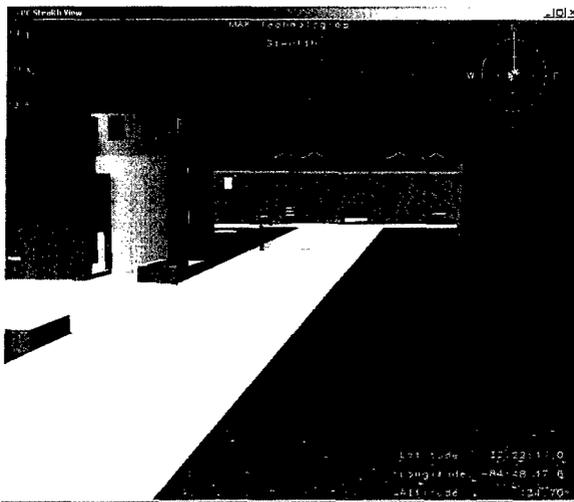
RANDMG140-5.12

Using terrain from the McKenna MOUT site at Fort Benning and the more open areas at Fort Hunter Liggett, we explored some of the functions provided by OTB. Illustrated in Figure 5.13 are three-dimensional buildings and squad movements.

One thing we were disappointed in with OTB was the unpredictability of some reactive behaviors in the model. It was very difficult to move and position soldiers exactly as needed in interiors and have them engage the enemy with precision. We are improving our capabilities for controlling forces through an increasing understanding of the rule sets, but this is still problematic.

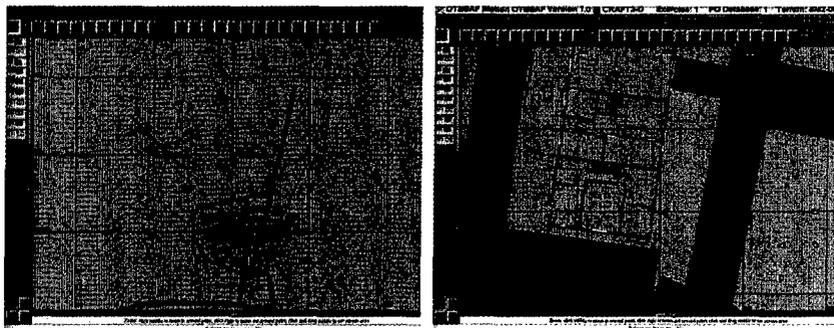
Our examination of both OneSAF and JCATS using MOUT scenarios showed that exterior and interior fighting could be represented successfully, as shown in Figures 5.14 and 5.15. In Figure 5.14 using OTB, three Blue squads attack from multiple directions, while two Red squads occupy the perimeter and one multiple elevation structure (a building). Small-squad operations did not tax the system, and the engagements could be logged easily and played back for analysis and modification. Figure 5.15 shows a different scenario developed in JCATS, with two Blue squads attacking a single Red squad defending a high-value target located in one of the buildings. This operation was also represented easily, in some ways more credibly than in OTB, but did not allow 3-D visualization of the process and was not as flexible in programming reactive behaviors.

Figure 5.13
Movement in Three-Dimensional Terrain Represented by OTB



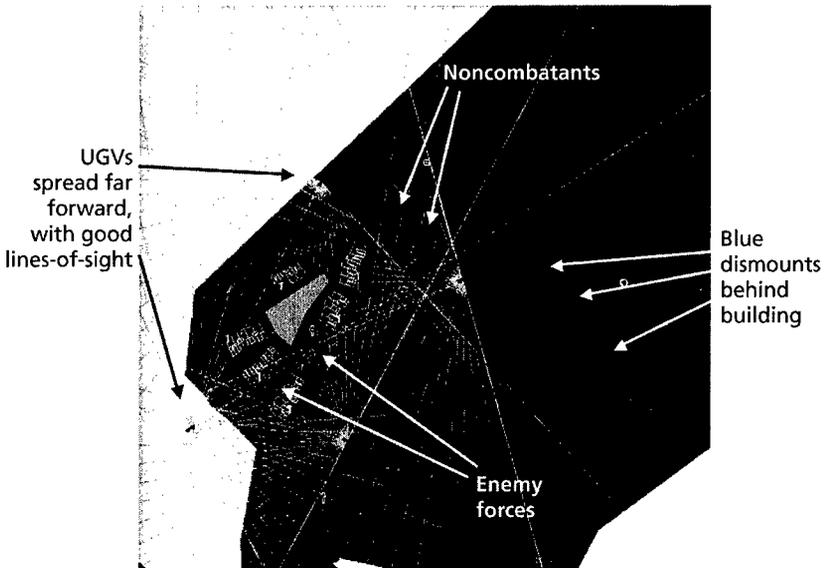
RANDMG140-5.13

Figure 5.14
A MOUT Scenario Represented Using OTB



RANDMG140-5.14

Figure 5.15
An Alternative MOUT Scenario Represented in JCATS



RANDMG140-5.15

In summary, JCATS and OneSAF provide many improvements for modeling urban and dismounted operations over the more traditional Janus simulation tool. These included representation of both exterior and interior engagements, modeling of building construction and details, discrimination of different types of noncombatants, invoking of automated behaviors, and improved illustration of plans and their implications. These models are also better able to scale up to larger scenarios and joint operations.⁸

⁸ For a larger review of plans for improving urban modeling, see J. Willis, T. Cioppa, N. Georger, and L. Brown, *Research Plan Development for Modeling and Simulation of Military Operations in Urban Terrain*, TRAC-Monterrey Technical Report TRAC-M-TR-03-012, March 2003.

Observations and Conclusions

In this chapter, we assemble some initial observations and conclusions from the analyses we conducted. These should be treated as insights specific to the scenario at hand rather than absolute and general findings. The technologies, tactics, and modeling approaches to improving the future soldier are evolving rapidly, with numerous implications for force structure, technology development, and system acquisition. It is hoped that the quantitative comparisons and insights collected here will help in those deliberations.

It should be noted that the mission of attacking an enemy force in complex and wooded terrain is extremely difficult. The enemy has advantages of terrain, cover, preparation, and surprise. In more benign situations, such as police actions, ambushes, or combined arms defensive screens, a moderately capable Objective Force Soldier ensemble of sensors, weapons, protection, and networking might perform well. Here, we were interested in providing the most stressing mission, in the hope that those technologies and tactics providing the most impact would stand out.

We quickly found that improvements such as XM-29, body armor, and indirect fires alone have only limited effect on the outcome. Each of these improves lethality or reduces the extent of losses, but does not change the course of battle. Each of these also has shortcomings. XM-29 is effective only after locating and identifying the enemy. This may require waiting for the enemy to fire or move. Its use as an area weapon is prohibitively expensive and would probably

result in noncombatant losses. Body armor helps survivability, but protecting all vulnerable areas from all directional aspects can make the armor excessively heavy and result in decreased mobility (and increased exposure). Links to indirect fires, even precision ones, can be problematic in treelines or urban areas. Even if the enemy location and identity are known, most munitions have limited effects under a tree canopy or against fortified bunkers. Specialized weapons such as fuel-air explosives may kill or incapacitate normally protected troops, but they may also injure or kill noncombatants and set massive fires.

Some individual measures were not found to have any advantage in the treeline scenario, but would be expected to be useful to the future soldier in other situations. Smoke and foot speed simply reduced the range of engagement in this situation, but in many other vignettes—crossing urban areas or extracting from a hot landing zone, for example—they would probably be more valuable. Stealth was similarly low value here, but it may be effective when attempting a covert assault on an enemy outpost or when performing long-range reconnaissance patrols.

Synergies between the future soldier options were found to be extremely important and led to much more effective and robust behaviors than the individual improvements. This appears to be a common theme for light, high-technology options: the system will not perform well unless all the component parts are contributing. For example, here indirect fires softened up the enemy and, in particular, attrited or suppressed the lethal machine gun teams. The addition of body armor was then more effective against the smaller-caliber rounds. Use of the XM-29, following detection of the enemy from their shots, was then highly effective against the dug-in enemy positions.

The future soldier systems must be viewed as part of a larger, combined arms FCS force. This includes intelligence gathering, insertion of the force, access to reachback fires, and use of the battle command network. These can set the conditions for a dismounted attack or other use of the future soldier. Unfortunately, the scenarios examined here had timelines too rapid for reliance on the larger combined

arms force. The dismounted soldiers had to depend on their own sensors and weapons to respond to enemy fires.

One organic system that did help the soldier was the small UGV. While this system does require oversight and control (depending on the level of autonomy assumed), it relieves the soldier of much of the risk of probing forward into the enemy position. We assumed UGVs with small dimensions, fast movement, and good payload capability (ones able to carry sensors and light weapons). These UGVs significantly improved the survivability of the infantry platoon, even when used in limited numbers. To further explore this option, extensive experimentation and simulation are needed. Key issues include span of control (how many can be controlled by an operator), bandwidth requirements, network architecture, and rules of engagement.

The MOUT scenarios we examined (both here and in other studies) showed the limitations of Janus in representing building interiors, noncombatants, command and control processes, and such specialized functions as nonlethal weapons and electronic warfare. We found that more sophisticated models such as JCATS and OTB were much more capable of modeling MOUT-related phenomena, producing reactive behaviors, and visualizing the engagement. These models should also be instrumental as we move from traditional evaluation of the outcomes using attrition-based measures of effectiveness, such as LERs, to more complex measures, such as shock, area control, collateral damage, and other factors. Even so, the models are limited by the digital terrain quality and resolution. Examination of dismount operations in concert with small UGVs requires collecting high-resolution terrain files for the areas of interest.

The future soldier program shows great potential for increasing the effectiveness of our ground forces, particularly with the heightened likelihood that they will be called upon to carry out urban and small-scale operations. As the services embrace new tactics and technologies for these operations—swarming, nodal warfare, noncombat-

ant control, etc.¹—the future soldier ensemble will have to become increasingly flexible and multifaceted. The Army will need to invest resources in all aspects of this effort: requirements, modeling, experimentation, development, implementation, and (as we see from this study), integration.

¹ See R. Glenn et al., *Corralling the Trojan Horse*, Santa Monica, CA: RAND Corporation, DB-322-A, 2001, for a discussion of some of these emerging tactics for urban and small-scale operations.

Bibliography

- AMSAA (U.S. Army Materiel Systems Analysis Activity), *Army Future Combat Systems Unit of Action Systems Book, Version 3.0*, 22 May 2003. (For government use only; not available to the public.)
- “Army Builds Future Combat Systems Around Information Technologies,” *Signal*, November 2002, pp. 39–42.
- Arquilla, John, and David Ronfeldt, *Swarming and the Future of Conflict*, Santa Monica, CA: RAND Corporation, DB-311-OSD, 2000.
- ASB 2001 Summer Study on the Objective Force Soldier/Soldier Team. Electronic copy available at <https://webportal.saalt.army.mil/sard-asb/ASBDownloads/OFS-Vol-III-All.pdf>.
- Glenn, Russell, Randall Steeb, and John Matsumura, *Corralling the Trojan Horse: A Proposal for Improving U.S. Urban Operations Preparedness in the Period 2000–2025*, Santa Monica, CA: RAND Corporation, DB-322-A, 2001.
- Grossman, J., J. Matsumura, R. Steeb, J. Gordon, T. Herbert, and W. Sollfrey, *Analysis of Air-Based Mechanization and Vertical Envelopment Concepts and Technologies*, Santa Monica, CA: RAND Corporation, DB-321-A, 2001.
- Hewish, Mark, “Little Brother is Watching You,” *International Defense Review*, June 2001, pp. 46–48.
- Matsumura, J., et al., *Lightning over Water: Sharpening America’s Light Forces for Rapid Reaction Missions*, Santa Monica, CA: RAND Corporation, MR-1196-A, 2000.
- Matsumura, J., et al., *Exploring Advanced Technologies for the Future Combat Systems Program*, Santa Monica, CA: RAND Corporation, MR-1332-A, 2002.

"Modeling to Thwart Terrorism: Virtual Scenarios Help Planners Identify, Deter Threats," *Signal*, October 2002, pp. 45–49.

Steeb, R., et al., *Exploration of the DARPA Small Unit Operations Concept Using High Resolution Simulation*, Santa Monica, CA: RAND Corporation, DB-289-DARPA, 1999.

Willis, J., T. Cioppa, N. Georger, and L. Brown, *Research Plan Development for Modeling and Simulation of Military Operations in Urban Terrain*, TRAC-Monterrey Technical Report TRAC-M-TR-03-012, March 2003.

This monograph summarizes a quick-response analysis done for the 2001 Army Science Board Summer Study on Objective Force Soldier. It assessed technology options for future dismounted soldiers that could improve mission effectiveness and reduce casualties. The central findings were that soldier effectiveness and survivability could be moderately improved by individual systems (such as the XM-29, body armor, and links to indirect fire), but significant improvements resulted only from applications of combined systems.

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