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THESIS

AN EXPLORATION OF EQUIPPING A FUTURE FORCE WARRIOR SMALL COMBAT UNIT WITH NON-LETHAL WEAPONS

by

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June 2006

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13. ABSTRACT (maximum 200 words)

The U.S. military has an increasing requirement to prepare for and conduct urban operations (UO). This UO requirement spreads across the spectrum of conflict, from high intensity combat to peacekeeping and humanitarian missions (Stability and Support Operations—SASO), often simultaneously. Regardless of which portion(s) of the warfare spectrum U.S. forces are involved in, urban engagements are inevitable and present major challenges. Superior standoff weapons ranges and combined arms tactics are quickly negated in the confined terrain of a complex and usually unfamiliar urban environment. Often considerably more challenging is the ability to differentiate the enemy from noncombatants—endangering our Soldiers and their mission. Conventional forces, armed only with traditional weapons, normally have two options: the threat of a violent response (passive) or the use of deadly force (active). These two extremes have virtually no middle ground. The reluctance of military and/or peacekeeping forces to employ deadly force on unconfirmed enemy targets creates a vulnerability. This vulnerability may be mitigated by equipping a small combat unit (SCU) with a viable alternative to deadly force—non-lethal weapons (NLWs).

Using an imperfect friend or foe identification modeling framework within an agent-based simulation (ABS), an NLW is essentially used to interrogate (determine the intent of the person in order to identify friend or foe) rather than attempt to incapacitate a target. To determine the impacts of employing NLWs in an urban combat environment (with civilians on the battlefield), three factors were varied across 15 design points: the ability of U.S. military forces to positively identify a target, the range of the selected NLW, and the distribution/number of NLWs in an SCU. By replicating each design point and analyzing the resulting output data, the following insights were determined: the use of NLWs does not degrade U.S. survivability; NLWs are essential to neutralizing suicide attacks; and NLWs decrease civilian casualties.

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ABSTRACT

The U.S. military has an increasing requirement to prepare for and conduct urban operations (UO). This UO requirement spreads across the spectrum of conflict, from high intensity combat to peacekeeping and humanitarian missions, often simultaneously. Regardless of which portion(s) of the warfare spectrum U.S. forces are involved in, urban engagements are inevitable and present significant challenges. Superior standoff weapons ranges and combined arms tactics are quickly negated in the confined terrain of the urban environment. Often considerably more challenging is differentiating the enemy from noncombatants. Conventional forces normally have two options: (1) the threat of a violent response (passive) or (2) the use of deadly force (active). These two extremes have virtually no middle ground. The reluctance of military and/or peacekeeping forces to employ deadly force on unconfirmed enemy targets can create a vulnerability. This vulnerability may be mitigated by equipping a small combat unit (SCU) with a viable alternative to deadly force—non-lethal weapons (NLWs).

Using an imperfect friend or foe identification modeling framework within an agent-based simulation (ABS), an NLW is used to interrogate (determine the intent of the person in order to identify friend or foe) rather than attempt to incapacitate a target. To determine the impacts of employing NLWs in an urban combat environment (with civilians on the battlefield), three factors were varied across 15 design points: the ability of U.S. military forces to positively identify a target, the range of the selected NLW, and the number of NLWs in an SCU. By replicating each design point and analyzing the resulting output data, the following insights were discovered: the use of NLWs does not degrade U.S. survivability; NLWs are essential to neutralizing suicide attacks; and NLWs decrease civilian casualties.

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THESIS DISCLAIMER

The reader is cautioned that the computer programs presented in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.[1]

[1] Charles A. Sulewski, "An Exploration of Unmanned Aerial Vehicles in the Army's Future Combat Systems Family of Systems," Masters Thesis, Naval Postgraduate School, Monterey, CA, December 2005, p. vii.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ABM	Agent-Based Models
ABS	Agent-Based Simulations
AIB	Azari Islamic Brotherhood
AMSAA	Army Materiel Analysis Activity
AO	Area of Operations
ARV	Armed Robotic Vehicle
ATD	Advanced Technology Demonstration
AWARS	Advanced Warfighting Simulation
BFT	Blue Force Tracking
CAEN	Close Action Environment
CASTFOREM	Combined Arms and Support Task Force Evaluation Model
CE	Combat Effectiveness
COE	Contemporary Operating Environment
COMBAT XXI	Combined Arms Analysis Tool for the 21st Century
DoD	Department of Defense
DOE	Design of Experiments
FCS	Future Combat Systems
FFW	Future Force Warrior
GPS	Global Positioning System
GSS	Ground Soldier System
GUI	Graphical User Interface
GWOT	Global War on Terrorism

IR	Infrared
IUSS	Integrated Unit Simulation System
JCATS	Joint Conflict and Tactical Simulation
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
M&S	Models and Simulations
MAS	Multi-Agent Simulations
MCO	Major Combat Operations
MHPCC	Maui High Performance Computing Center
MOE	Measures of Effectiveness
MOUT	Military Operations in Urbanized Terrain
MTC	Movement to Contact
NL	Non-Lethal
NLW	Non-Lethal Weapon
NOLH	Nearly Orthogonal Latin Hypercube
OC	Oleoresin Capsicum
OFW	Objective Force Warrior
OneSAF	One Semi-Autonomous Force
OPORD	Operations Order
Psy-Ops	Psychological Operations
RCA	Riot Control Agent
ROE	Rules of Engagement
SA	Situational Awareness
S-MAWG	Soldier Modeling and Analysis Working Group
SaaS	Soldier as a System

SSE	Squad Synthetic Environment
SCU	Small Combat Unit
SRW	Soldier Radio Waveform
SUGV	Small Unmanned Ground Vehicle
SUTES	Small Unit Team Exploratory Simulation
TRAC	Training and Doctrine Command Analysis Center
TRADOC	Training and Doctrine Command
UAV	Unmanned Air Vehicle
UGV	Unmanned Ground Vehicle
UO	Urban Operations
UO FACT	Urban Operations Focus Area Collaborative Team
VIC	Vector-in-Commander
WPSM	Warfighter Physiological Status Monitor

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EXECUTIVE SUMMARY

With the collapse of the Soviet Union at the end of the Cold War, the U.S. military has had an increasing requirement to prepare for and conduct urban operations (UO). This UO requirement spreads across the spectrum of conflict, from high intensity combat to peacekeeping and humanitarian missions, often simultaneously. The contemporary operating environment facing the U.S. military is characterized by militias, armed gangs, and terrorist cells.[2] Recognizing that the superior weapons and combined arms tactics of U.S. forces are virtually negated in an urban environment, cities will likely become the battleground of conflicts. Perhaps the most challenging aspect of UO is the difficulty in differentiating combatants from noncombatants.

The mingling of civilians and combatants forces the military to adopt more restrictive rules of engagement (ROEs) to reduce the risk of civilian casualties.[3] Problems and incidents arise when Soldiers are unable to positively identify a potential enemy or hostile intent. Conventional forces armed only with traditional weapons normally have two options: (1) the threat of a violent response (passive) or (2) the use of deadly force (active). These two extremes have virtually no middle ground. The reluctance of military and/or peacekeeping forces to employ deadly force on unconfirmed enemy targets creates a vulnerability. This vulnerability may only be rectified by giving Soldiers an alternative to deadly force that is more effective than merely the threat of a violent response. Equipping a small combat unit (SCU) with non-lethal weapons (NLWs) may be that alternative.

The U.S. Department of Defense (DoD) defines NLWs as "weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel,

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[2] Douglas C. Lovelace, Jr. and Steven Metz, "Nonlethality and American Land Power: Strategic Context and Operational Concepts," Army War College, Strategic Studies Institute, Carlisle Barracks, PA, 1998, p. 7. Retrieved 10 May 2006 from the World Wide Web at http://handle.dtic/mil/100.2/ADA299046.

[3] Joseph Siniscalachi, "Non-Lethal Technologies: Implications for Military Strategy," Air War College, Maxwell Air Force Base, Montgomery, AL, 1998, p. 25. Retrieved 10 May 2006 from the World Wide Web at http://handle.dtic.mil/100.2/ADA399046.

while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment."[4] Although the U.S. military employs a wide variety of NLWs in humanitarian and peacekeeping operations, very little research has been done to determine the most appropriate NLW to use across the spectrum of operations, especially combat. Many may argue that NLWs have no place in combat—unfortunately, this ignores the reality that noncombatants have become more prevalent on the modern battlefield. In the 1950s, noncombatants accounted for about one-half of all casualties; in the 1980s, the rate rose to about 80%.[5]

As indicated by a capability requirement, the U.S. Army's Future Force Warrior (FFW) program (aimed at providing unsurpassed individual and squad lethality, survivability, communications, and responsiveness) is seeking a non-lethal solution.[6] NLWs may add flexibility to combat operations and enhance force protection by providing a tool that friendly troops can use to engage threatening targets with reduced risk of noncombatant casualties and collateral damage. This capability requirement is further elaborated in the Ground Soldier System (GSS, the successor to the FFW program) Capability Development Document:

> The Soldier and small unit will need to employ non-lethal effects in urban and complex terrain where the enemy may intermingle with noncombatants. Small units may have missions to control an area where strict rules of engagement may preclude injury to noncombatants. Non-lethal effects will aid the ground Soldier to see, understand and act first by providing the capability to dislocate enemy forces hiding in restricted and urban terrains or among the general population.[7]

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[4] United States Army, Marine Corps, Navy, Air Force, and Coast Guard, *NLW-Tactical Employment of Non-Lethal Weapons*, FM 3-22.40, MCWP 3-15.8, NTTP 3-07.3.2, AFTTP (l) 3-2.45, and USCG Pub 3-07.31, Multiservice publication, January 2003, p. I-1.

[5] Siniscalachi, p. 45.

[6] The Wexford Group International, Inc., *The United States Army Future Force Warrior Concept Capability Plan for the Small Combat Unit*, (Columbus, GA: September 2005), p. 22.

[7] "Future Force Warrior (FFW)," U.S. Army Natick Soldier Center (NSC). Retrieved May 2006 from the World Wide Web at http://ffw.natick.army.mil/content.htm.

Unfortunately, the lack of a solution is best summed up by U.S. Air Force Colonel Joseph Siniscalachi:

> While employment of non-lethal technologies is maturing for tactical applications, the evolution of non-lethal technologies for the more general warfighting applications is still being conceptualized. It is here where advocates claim that non-lethal technologies may make the greatest contribution to future warfighting.[8]

The first objective of this research was to select an appropriate NLW and employment tactic to be used for operations that span the spectrum of operations—from combat operations to humanitarian missions. The NLW selected for combat (and other) operations for this research was the XM303 (Figure 1).

Figure 1. XM303

The XM303 is similar in appearance to the M203 grenade launcher. In place of a grenade launcher, it uses compressed air to propel a paintball-like projectile at point targets at a range of up to 50 meters. Soldiers may use the NLW as an interrogation asset to determine intent. This principle is similar to the way police typically yell "halt or I will shoot." In which case, the alleged criminal (or suspect) is to remain in place with the threat of being shot if the individual does not comply. An NLW may be used to convey the same message. The reaction to the "message" (being hit with a paintball) will be used to determine the intent of the targeted individual. Compliance consists of the targeted individual immediately assuming the prone position (surrendering). Failure to comply will immediately subject the individual to lethal fire. This concept must be clearly communicated to the local populace through an extensive Psychological Operations (Psy-Ops) campaign before hostilities commence, in order to facilitate this understanding.

A scenario consisting of a night UO in the Caspian Sea area of operations, specifically Azerbaijan, was created within the agent-based simulation (ABS)

[8] Siniscalachi, p. 4.

Pythagoras. The intent was to determine the impact of employing NLWs in an urban combat environment (with civilians on the battlefield). Insight was determined by using an imperfect friend or foe identification modeling framework and varying three factors: the ability of U.S military forces to positively identify a target, the range of the selected NLW, and the distribution/number of NLWs in an SCU. After running the model 150 times, the output data were analyzed and resulted in the following insights:

- Blue survivability does not suffer from using NLWs. Quick, lethal response (if noncompliant), superior optics/engagement ability, and FFW body armor offset the risk of lethal fire returned by the (once unconfirmed) target.
- It is better to engage with NLWs at 25 meters versus 50 meters. Getting closer allows for better identification (before engaging and allowing subsequent return fire if engaged with NLWs).
- When it is extremely difficult to differentiate combatants from noncombatants, it is better to have more NLWs (increased distribution) available to the SCU than to engage at an extended range.
- In conditions where it is very easy to discriminate friend from foe, the use of NLWs may cause slightly more civilian casualties than not using an NLW. This is associated with a higher probability of noncompliance than the probability of misidentifying. If you shoot enough civilians with NLWs, a few are (unfortunately) bound to be noncompliant. In such environments, Soldiers should consider this characteristic before employing lethal means.
- Stopping a Suicide Bomber is crucial to operational success, especially when it is difficult to identify combatants from noncombatants. It is not difficult to understand why. Any NLW capability dramatically reduces the chance of a successful suicide attack, regardless of identification ability.

- Each increase in NLW capability (e.g., distribution and range) results in additional Hostile Civilian surrenders.
- NLWs can be used to interrogate rather than incapacitate. When employment focuses on determining intent rather than delivering sufficient force/pain to incapacitate, accidental deaths and animosity are greatly diminished.

Civilians, and adversaries who are virtually indistinguishable from civilians, will likely remain a fixture on the battlefield for quite some time. Military operations must consider both the enemy and the often unwilling participants. Under the provisions of the Law of Armed Conflict, we have an obligation to safeguard noncombatants from unnecessary suffering. While lethal means must always be the default method of force, NLWs may significantly reduce civilian casualties without reducing our combat effectiveness (CE).

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I. INTRODUCTION

According to UN estimates, the urban population of developing countries increases by about 150,000 per day; projections indicate . . . three-fifths of the world's population . . .will live in urban areas by 2015.

Handbook for Joint Urban Operations,
Joint Staff, J-8, Land and Littoral Warfare Assessment Division
17 May 2000

It's the only place they—our future adversaries—can take our technology and mute it. . . . We avoid the cities, but that is where we will be taken—so we had better learn to fight and win in the city.

General Charles C. Krulak, USMC
At 12th BRIMS Conference
12-15 May 2003

A. THE CONTEMPORARY OPERATING ENVIRONMENT

The conclusion of the Cold War sparked a revolution in U.S. military operations and strategy. Many thought that the conclusion of the Cold War would initiate a dramatic drawdown of U.S. military forces and a period of military inactivity. With the collapse of the Soviet Union, conventional warfare would no longer be characterized by large-scale, force-on-force armored divisions battling in relatively open terrain. Unfortunately, the end of this rivalry did not signal a decrease in U.S. military operations; only a decrease in the importance attached to some of the traditional principles of warfare, especially mass (concentrate combat power at the decisive place and time).[9] The bipolar characteristic of the Cold War actually imposed structure on the world by buffering tensions and conflict between nonstate actors.[10] Some political scientists believe that the rise of nonstate actors will dominate the future global scene, with its many religious factions and cultural rivalries. Militias, armed gangs, and terrorist cells may dominate contemporary

[9] United States Army, *Operations*, Field Manual 3. Washington, D.C.: U.S. Government Printing Office, 2001, p. 4-13.

[10] Joseph Siniscalachi, "Non-Lethal Technologies: Implications for Military Strategy," Air War College, Maxwell Air Force Base, Montgomery, AL, 1998, p. 24. Retrieved 10 May 2006 from the World Wide Web at http://handle.dtic.mil/100.2/ADA399046

asymmetric conflict.[11] This has, and will probably continue to translate to increased U.S. military operations.

Cities will likely become the strategic centers of these conflicts. Combat will occur in urban areas because of the concentration of national power there and because our enemies, recognizing the complexity of urban warfare, will choose to fight there rather than face American military superiority on open terrain. Our superior standoff engagements may not be appropriate in urban engagements, even if they are substantially more precise than those currently available today. Urban Operations (UO) will involve "face-to-face confrontations and close-in solutions."[12] Under some circumstances, the identities of our adversaries may be somewhat uncertain, causing the use of deadly force for purposes other than self-defense to be further constrained by the rules of engagement (ROEs).[13]

B. TRANSFORMATION AND NON-LETHAL WEAPONS (NLWs) REQUIREMENT

The Army's Future Force Capstone Concept describes how the U.S. Army proposes to meet the future combat needs of the Contemporary Operating Environment (COE). This document outlines an aggressive transformation program to leverage current and emerging technology to develop what is being termed the Future Force.[14] This Future Force is envisioned to be a "more strategically responsive, deployable, agile, versatile, lethal, survivable, and sustainable force; effective in all situations from major combat operations (MCO) to homeland security."[15] A key component of this Capstone Operational Concept is the precondition that this force must be prepared to

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[11] Douglas C. Lovelace, Jr. and Steven Metz, "Nonlethality and American Land Power: Strategic Context and Operational Concepts," Strategic Studies Institute, Army War College, Carlisle Barracks, PA, 15 June 1998, p. 7. Retrieved 10 May 2006 from the World Wide Web at http://handle.dtic/mil/100.2/ADA299046.

[12] Ibid., p. 25.

[13] United States Army, Marine Corps, and Navy, *Non-Lethal Weapons: Tactical Employment of Non-Lethal Weapons*, FM 3-22.40 (FM 90-40), MCWP 3-15.8, NTTP 3-07.3.2, AFTTP (1) 3-2.45, USCG PUB 3-07.31, 2003, p. III-1.

[14] United States Army, "The Army in Joint Operations: The Army's Future Force Capstone Concepts 2015-2024," TRADOC Pamphlet 525-3-0.

[15] The Wexford Group International, Inc., p. 7.

simultaneously and subsequently conduct stability operations.[16] To achieve Future Force objectives, the Army seeks to synergize combat platforms, weapons, robotics, and support equipment with the most important component of the transformation—the Soldier.

At the 2003 Infantry Conference at Fort Benning, Georgia, General Kevin Byrnes, the Training and Doctrine Command (TRADOC) Commander, noted that recent operations in Iraq and Afghanistan reinforced the notion that the caliber of the Soldiers, not the caliber of the weapons, makes the biggest difference in battle. Additionally, as the likelihood of the U.S. military being involved in large force-on-force engagements decreases, more emphasis must be placed on the contributions of the individual Soldier. This realization is characterized in the Soldier as a System (SaaS) initiative. According to Byrnes, this is the most important program in the Army.[17]

In order to achieve the Army Transformation goals described in the Army Capstone Concept, a Future Force Warrior (FFW) Small Combat Unit (SCU, roughly equivalent to a platoon) must possess enhanced lethality, mobility, survivability, interoperability, and adaptability to operate across the entire spectrum of operations, from humanitarian and peacekeeping operations to full-scale combat. <u>One of the most challenging capability requirements for the FFW is the ability to achieve desired non-lethal effects at ranges of up to 25 meters</u> (see Figure 2 for this and other requirements).[18]

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[16] "The Army in Joint Operations (The Army's Future Force Capstone Concept 2015-2024)," presentation by BG(P) David Fastabend. Retrieved 10 May 2006 from the World Wide Web at http://www.blueskybroadcast.com/Client/Army_Stratcom_7.05/docs/fcs.chalk.talk23AUG05.pdf.

[17] COL Charles Durr and David J. Libersat, "Soldier as a System (SaaS)," *Infantry Bugler*, Winter 2004. Retrieved 11 May 2006 from the World Wide Web at http://www.infantryassn.com/Bugler%20issues/Inf_2004_4.pdf.

[18] The Wexford Group International, Inc., p. 22.

Core (All Soldiers)

Capability	Parameters and Values
Lethality	• Engage Enemy Combatants to 300 Meters • Achieve Desired effects on defilade targets up to 35 meters • Achieve Desired non-lethal effects up to 25 meters
Force Protection	• Integrated Tailorable Protection from Battlefield Threats up to 7.62mm to include protection of extremities, improved eye, hearing and head protection, blast debris protection, IED detection, avoidance, neutralization, and protection, enhanced Individual Soldier active and passive protection.
Mobility	• Enhance Full Range of Motion to perform all core critical Soldier tasks & drills. • Reduce weight of Soldiers Load to 60 lbs
Sustainability	• Contain/Capable of carrying Ammunition & Physiological Necessities – 8 Hr Mission • Provide a hands-free, on-the-move hydration
Reliability	• Provide abrasion resistance, strength, and durability to achieve a 120 day service life in the field environment
Training	• Must provide each Soldier the capability to receive training/re-training and/or tutoring on any necessary skill required upon demand, perform mission rehearsal, and support mission completion, regardless of location

Figure 2. FFW Capability Requirements for All Soldiers

C. PROBLEM STATEMENT

As previously stated, the U.S. military has an increasing requirement to prepare for and conduct UO. This UO requirement spreads across the spectrum of conflict, from high intensity combat to peacekeeping and humanitarian missions (Stability and Support Operations—SASO), perhaps simultaneously. Regardless of which portion(s) of the spectrum of warfare U.S. forces are involved, urban engagements are inevitable and present major challenges. Superior standoff weapons ranges and combined arms tactics are quickly negated in the confined terrain of a complex and usually unfamiliar urban environment. Differentiating between the enemy and civilians in this environment will endanger our forces and their mission. Conventional forces, armed only with traditional weapons, normally have two options: (1) the threat of a violent response (passive) or (2) the use of deadly force (active). These two extremes have virtually no middle ground.

The reluctance of military and/or peacekeeping forces to employ deadly force on unconfirmed enemy targets creates a vulnerability. This vulnerability may be mitigated by equipping an SCU with a viable alternative to deadly force—NLWs.

As indicated by a capability requirement to have non-lethal effects, the FFW program is still seeking a non-lethal solution. This lack of a solution is best summed up by U.S. Air Force Colonel Joseph Siniscalachi:

> While employment of non-lethal technologies is maturing for tactical applications, the evolution of non-lethal technologies for the more general warfighting applications is still being conceptualized. It is here where advocates claim that non-lethal technologies may make the greatest contribution to future warfighting.[19]

D. SCOPE

Although the U.S. military employs a wide variety of NLWs in humanitarian and peacekeeping operations, very little research has been done to determine the most appropriate NLW for use across the spectrum of operations, especially combat. Many may argue that NLWs have no place in combat—unfortunately, this ignores the reality that noncombatants have become more prevalent on the modern battlefield. In the 1950s, noncombatants accounted for about one-half of all casualties; in the 1980s, the rate rose to about 80%.[20]

Peacekeeping operations in Bosnia, Somalia, Rwanda, and Haiti highlight the difficulties of adopting our existing military tools to new strategic settings.[21] Under the provisions of the Law of Armed Conflict, we have an obligation to safeguard noncombatants from unnecessary suffering.[22] While lethal means must always be the default method of force, NLWs may significantly reduce civilian casualties without reducing our combat effectiveness (CE). The objectives of this research are: select and equip the Soldier with the most appropriate NLW for the FFW SCU; develop an imperfect identification framework; explore the tactics and distribution of NLWs in an

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[19] Siniscalachi, p. 4.

[20] Ibid., p. 45.

[21] Ibid., p. 80.

[22] United States Army, *The Law of Land Warfare*, Field Manual 27-10, (Washington, D.C.: U.S. Government Printing Office, 2001), p. 4-13.

SCU; explore the advantages of using NLWs in combat operations; and examine the consequences of not using NLWs.

E. THESIS ORGANIZATION

To determine the impact of equipping the FFW SCU with NLWs, this research will first explore the background and potential future of NLWs. The NLW deemed most suitable for combat operations will be modeled within a simulation. This simulation will attempt to capture an imperfect identification framework and the functionality of employing an NLW in an urban scenario to explore the effects of NLWs. Analysis will follow by varying a multitude of inputs within the simulation to gain insight on the potential impact of equipping the FFW SCU with NLWs.

II. NON-LETHAL WEAPONS (NLWs)

The principle that civilians must be protected lies at the heart of International Law of Armed Conflict.

Donald Rumsfeld
U.S. Secretary of Defense
19 February 2003

The development and acquisition of non-lethal weapons systems will expand the number of options to commanders confronted with situations in which the use of deadly force is inappropriate.

General Michael Hagee
Commandant, USMC
2 April 2003

A. NLWs DEFINITION AND BACKGROUND

Typically, when one thinks of NLWs, riot gas, pepper-spray, tasers, and stun guns come to mind. Some of these weapons (especially tasers) have frequently been in the media and have come under scrutiny since their inception—usually because the "non-lethal" weapon had lethal consequences. There is generally an abundance of confusion surrounding the terminology used to describe weapons designed without the purpose of killing. In fact, numerous terms (less-than-lethal, prelethal, disabling, soft kill, etc.) are used by different agencies to describe desired/intended effects of these weapons. Although the term NLW does imply the incapacity of lethal effects, the U.S. Department of Defense (DoD) has adopted the term "non-lethal" as the approved name for these weapon systems and defines it as:

> . . .weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment. . . . Non-lethal weapons are intended to have relatively reversible effects on personnel and materiel. The term 'non-lethal' does not mean zero mortality or nonpermanent damage; these are goals and not guarantees of these weapons.[23]

[23] United States Army, Marine Corps, Navy, Air Force, and Coast Guard, *NLW-Tactical Employment of Non-Lethal Weapons*, (FM 3-22.40, MCWP 3-15.8, NTTP 3-07.3.2, AFTTP (l) 3-2.45, USCG Pub 3-07.31), Multiservice publication, January 2003, p. I-1.

NLWs are employed for a wide variety of objectives: discouraging aggression, limiting escalation of hostile actions, taking military action when lethal means are not authorized, protection, and incapacitating/disabling personnel and equipment (refer to Appendix A, DoD Policy for NLWs).[24] NLWs are generally categorized by three core capabilities: counter-personnel, counter-materiel, and counter-capability. This research focuses on the use of counter-personnel NLWs for small unit urban combat operations. These types of weapons may use kinetic rounds (soft ammunition, like sponge rounds or rubber bullets), chemicals (such as oleoresin capsicum (OC), commonly called pepper-spray), directed energy (lasers, acoustic, electromagnetic, and microwaves), or electrical charges (tasers, stun gun). Effects range from passive (a warning from a loud speaker or laser dot), to sensory discomfort (eyes stinging from pepper-spray), to physical pain (hit with batons or shot with soft bullets), and unfortunately, sometimes to injury or death. The most notorious and arguably disastrous example of military use of an NLW occurred in October 2002, when Russian forces used the chemical fentanyl against Chechen hostage-takers in a Moscow theater. Unfortunately, nearly 130 of the 800-900 hostages died of overdoses and an undisclosed number were left with permanent disabilities.[25] Obviously, extreme care must be exercised in the employment of NLWs.

The U.S. military has successfully employed NLWs in numerous past operations and continues to use them in support of current operations in Iraq. In 1995, Marines in Somalia successfully used NLWs in support of humanitarian missions (Operation United Shield).[26] In 1999, during international peacekeeping operations in Kosovo, U.S. forces used NLWs to disperse crowds and protect themselves without killing those they were

[24] Department of Defense Directive #3000.3, "Policy for Non-Lethal Weapons," (Washington, D.C.: Department of Defense Printing Office), Sections 4.4 and 4.5.

[25] Retrieved 10 May 2006 from the World Wide Web at http://en.wikipedia.org/wiki/Moscow_Theatre_Siege.

[26] Personal notes taken from Penn State University's online Non-Lethal Weapons Certificate Program, Module 1, January-February 2006.

sent to protect.[27] NLWs have also been successfully employed in military prison compounds, such as Abu Ghraib in Iraq.[28]

B. WHY DO U.S. FORCES NEED NLWs?

> *Just as policemen carry firearms, so must our military use weapons of great power. The need for that will not soon vanish, but as society evolves, there will frequently be a need for some middle ground, when we wish to stop people from doing things we find wrong, but to do so without creating widows and orphans in the process.*[29]
>
> Tom Clancy
> Author, 1999

As previously mentioned, there was a 30% increase in noncombatant casualties between the 1950s and the 1980s. This alarming trend continues to rise as increasing numbers of refugees, immigrants, and noncombatants are caught in the crossfire of civil and ethnic strife and battles involving states, rogue states, failed nation-states, and terrorists.[30] Regardless of which portion of the spectrum of warfare U.S. forces may be involved in, urban engagements are inevitable and present major challenges. Unable to use superior standoff and combined arms tactics, SCUs are forced to adapt to the confined terrain of a complex, urban environment. Urban operations are further complicated by the difficulty associated with separating the opposing leadership and armed forces from the noncombatants,[31] as adversaries often blend in with the local populace of innocent civilians. Some sectors of the population may even rise against U.S. forces and become active participants in acts of violence, as seen in Somalia in October 1993.[32]

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[27] Personal notes taken from Penn State University's online Non-Lethal Weapons Certificate Program, Module 1, January-February 2006.

[28] Interview between LTC Ray Smith, Requirements Officer, Capabilities and Requirements Division at the Joint Non-Lethal Weapons Directorate and the author, September 2005.

[29] Quote taken from the Forward of John B. Alexander, *Future War: Non-Lethal Weapons in Twenty-First Century Warfare*, (New York: St. Martin's Press, 1999), p. xi.

[30] Margaret-Anne Coppernoll, "The Non-Lethal Weapons Debate," 1999. Retrieved 10 May 2006 from the World Wide Web at http://www.nwc.navy.mil/press/Review/1999/spring/art5-SP9.htm.

[31] Ibid., p. 7.

[32] Mark Bowden, *Black Hawk Down: A Story of Modern War*, Penguin Books, 1997.

The mingling of civilians and combatants will force the military to adopt more restrictive ROEs or new strategies to reduce the risk of civilian casualties while at the same time maintain effectiveness against the threat. The U.S. military is currently restricted in the tools it can employ, which means that intervention is constrained.[33]

U.S. forces are very reluctant to engage unconfirmed enemy targets and civilians for good reasons. One source of this reluctance stems from the set of guidelines that all U.S. Soldiers are bound to follow—ROEs. ROEs form the guideline for the employment of lethal force, but, more importantly, are designed to prevent unintended casualties (especially civilian) and collateral damage.[34] Problems and incidents arise when the situation is unclear, such as when a Soldier is unable to positively identify a potential enemy or the hostile's intent. Stress, duress, and uncertain conditions can lead the most experienced and disciplined Soldiers to make mistakes, which can jeopardize goodwill efforts and degrade our international image. Not only can mistakes cause obvious damage to the target, the psychological and judicial consequences could be career- and life-altering to the trigger-puller. This fear often makes Soldiers reluctant to use lethal means, which clearly limits Soldiers' capabilities and effectiveness, as well as potentially increasing their vulnerability. This vulnerability may only be rectified by giving Soldiers an effective alternative to deadly force that is more effective than merely the threat of a violent response. The effective use of NLWs may overcome these deficiencies and perhaps even provide a greater tactical and strategic edge.[35]

Achieving military objectives without the use of lethal force is not a new concept, especially in peacekeeping operations. During Operation United Shield, Marines in Somalia claimed that NLWs were a valuable asset for humanitarian operations and, if required, could be successfully applied to other missions throughout the spectrum of conflict.[36] NLWs may add flexibility to combat operations and enhance force protection

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[33] Siniscalachi, p. 25.

[34] United States Marine Corps, *Inter-Service Non-Lethal Individual Weapons Instructor Course (INIWIC)*, Fort Leonard Wood, MO, Chapter 8, p. 4.

[35] Douglas C. Lovelace, Jr. and Steven Metz, pp. 14-15.

[36] Personal notes taken from Penn State Univeristy's online Non-Lethal Weapons Certificate Program, Module 1, January-February 2006.

by providing a tool that friendly troops can use to engage threatening targets with reduced risk of noncombatant casualties and collateral damage.[37] This capability requirement is further elaborated on in the Ground Soldier System (GSS, the successor to the FFW program) Capability Development Document:

> The Soldier and small unit will need to employ non-lethal effects in urban and complex terrain where the enemy may intermingle with noncombatants. Small units may have missions to control an area where strict rules of engagement may preclude injury to noncombatants. Non-lethal effects will aid the ground Soldier to see, understand and act first by providing the capability to dislocate enemy forces hiding in restricted and urban terrains or among the general population.[38]

While lethal means must always be the default method of force, NLWs may potentially reduce civilian casualties without risk of friendly casualties (associated with misclassifying a hostile as a neutral, allowing the enemy to engage). They may also provide a more effective means to capture targets alive (if required). Employing these means may demonstrate a high moral position and a commitment to contain the violence, which could possibly lead to increased public support, both domestically and abroad, while avoiding the unrest associated with unintended civilian casualties (such as depicted in the book and subsequent movie, *Black Hawk Down*).[39] Unfortunately, clear guidelines for the effective employment of non-lethal force throughout the spectrum of operations have not been established.

While police actions and peacekeeping missions have clear applications for the use of NLWs, this research explores the role of NLWs in actual urban combat operations at the small unit level. More specifically, does equipping a FFW SCU with NLWs increase CE by reducing civilian casualties without increasing (and possibly even decreasing) friendly casualties? In order to begin addressing the shortcomings surrounding our understanding of the use of NLWs, models and simulations should be leveraged to gain insight and aid in the decision-making for the selection and

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[37] United States Army, Marine Corps, Navy, Air Force, and Coast Guard, *NLW-Tactical Employment of Non-Lethal Weapons*, (FM 3-22.40, MCWP 3-15.8, NTTP 3-07.3.2, AFTTP (l) 3-2.45, USCG Pub 3-07.31), Multiservice publication, January 2003, p. I-1.

[38] TRADOC System Manager-Soldier (TSM-S), Capabilities Development Document for Ground Soldier System (Draft), 13 June 2005, p. 55.

[39] Bowden, 1997.

employment of NLWs. Of course, before this concept can be modeled and analyzed, a candidate weapon system and munition must be selected.

C. NLW SELECTION

Five factors were considered when selecting a NLW to for combat operations:

1. **Versatility** – The NLW must be suitable across the entire spectrum of operations, from combat to humanitarian missions. This factor also considers combat load and logistics support.

2. **Ease of Employment** – Transitioning from lethal fire to non-lethal must not detract from the combat mission.

3. **Performance** – This rather broad category covers things such as effective range, accuracy, rate of fire, reload time, weight, etc.

4. **Safety/Public Acceptability** – Using an NLW that maims is perceived to potentially permanently injure, or deemed cruel. Considerations include probability of accidental death from the munition, as well as the possibility of confusing non-lethal with lethal means.

5. **Other** – Includes advantages/disadvantages not covered in the previous categories, such as multifunctionality, tailorable effects, training requirements, etc.

When all of these factors were considered (see Appendix B, NLW Selection Criteria, for details), the NLW selected for combat (and other) operations for this research was the XM303 (Figure 3).

Figure 3. XM303

The XM303 is similar in appearance to the M203 grenade launcher. In place of a grenade launcher, it uses compressed air to propel a paintball-like projectile at point targets at a range of up to 50 meters. The primary intended effect is blunt,

trauma-induced pain. Secondary effects are achieved through the projectile payload, which, upon impact, dispenses washable paint, permanent paint, or OC.

D. NLW EMPLOYMENT/TACTICS

The XM303 system was selected for this research effort with a recommended modification and accompanying employment tactic. Instead of trying to induce incapacitation through pain, it is proposed that Soldiers may use the NLW as an interrogation asset to determine intent. This principle is similar to the way police typically yell "halt (or get down on the ground) or I will shoot." The alleged criminal (or suspect) is to halt or remain in place with the threat of being shot if the individual does not comply. An NLW may be used to convey the same message. The reaction to the "message" (being hit with the XM303 non-lethal round) will be used to determine the intent of the targeted individual. During a phone interview in November 2005, Sid Heal, who was involved with Operation United Shield in Somalia, discussed how the use of NLWs can determine a suspect's intent:

> A shot of OC into the face of a civilian who crosses a posted 'no entry' line can give you the ability to read his intention. If he clears his eyes and keeps charging into the no-man's zone, then you know he didn't just overlook or misunderstand the sign, for you have put the message in universally understood terms. If he runs away, you know that you have saved him from a worse outcome. If he gets up and runs at you, that is his informed choice.[40]

When a target is engaged with the XM303, the target will act either in compliance or not in compliance. The compliance action must be known for this tactic to be effective. Compliance consists of the targeted individual immediately assuming the prone position. Conceptually, a two-man team could then approach and make an assessment to either release or secure and evacuate the individual to the rear. Failure to comply will immediately subject the individual to lethal fire. This concept must be clearly communicated to the local populace wherever NLWs are employed. An extensive Psychological Operations (Psy-Ops) campaign must be launched before hostilities in order to facilitate this understanding. The longer U.S. military forces use this tactic, the

[40] Phone interview between Charles "Sid" Heal, Commander, Los Angeles Sheriff's Department and the author, November 2005.

more compliant noncombatants (and even combatants) will be. Once this practice is established, future operations will require less extensive Psy-Ops efforts.

Once a Soldier determines hostile intent, lethal means should and will be employed during combat operations. The challenge is to determine hostile intent quickly and at a safe distance. If a Soldier only has lethal means, when a possible threat is detected, ambiguous intent may allow the "threat" to delay engagement and get quite close to a Soldier (think of a suicide bomber). If a Soldier fires early (before hostile intent is clearly established), it could potentially cause an unintended consequence (e.g., a civilian gets shot for not understanding the situation). Many times warning shots are not authorized (some consider it the first shot of a firefight), further jeopardizing the safety of the Soldier. In that case, a Soldier has very little time and standoff distance to deal with the target once intent is unambiguously determined.

A NLW essentially enables a Soldier to interrogate a possible threat through engagement. Compared with the typical time needed to determine hostile intent (if it can be) with only lethal means, a Soldier employing an NLW could determine hostile intent several times over. This may increase the standoff distance and engagement time in which the Soldier can engage the target.

To further improve the effectiveness of this tactic, the air pressure (currently 300 psi) of the XM303should be reduced to minimize the possibility of injury. By reducing the potential for causing civilian casualties, a small unit can continue on its mission rather than be delayed by caring for and evacuating casualties. This casualty-reducing tactic may also demonstrate good will to the host nation and to the world. Rather than trying to incapacitate (via pain), the NLW is used primarily as an interrogation tool, and therefore causing significant pain (associated with the conventional goal of NLWs—to incapacitate) is unnecessary and should not degrade the weapon's performance at less than 50 meters.

Another tactical employment concept for this NLW is to fill the munition with a permanent infrared (IR) dye, thereby marking the individual (unbeknownst to them). The rationale for this is that with conventional dye, the target could simply duck out of sight and change clothes. With the IR dye, the marked individuals do not realize the necessity

of changing—Soldiers will be able to identify them with IR devices. When previously engaged personnel return to the area of operation, a very clear intent of hostile actions is implied—and potentially justifies lethal engagement means.

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III. MODELING NLWs IN COMBAT OPERATIONS

All models are wrong. Some are useful.

George Box
Professor of Statistics, University of Wisconsin, 1979

Reality is complex, but models don't have to be.

Craig Reynolds
Computer Scientist and a Pioneer of Agent Modeling, 1987

A. MODELING "COMBAT"

Some may claim that modeling combat is easy—F.W. Lanchester developed differential equations in 1916 to mathematically compare losses of opposing forces on the battlefield (with simplistic underlying assumptions).[41] Although simple Lanchester Equations are useful for demonstrating some features of combat (e.g., the value of concentrating forces), they furnish a limited basis for describing most combat situations. A considerable weakness is that Lanchester Equations assume that the sides' strengths can be characterized by scalar quantities. A considerable challenge awaits the analyst trying to assign values to sides with a different organization, mix of equipment, and doctrine. More difficult still is the treatment of qualitative factors, such as the effects of terrain or the differences in competence between equally sized and equipped forces of different nations.[42]

DoD uses models and simulations (M&S) to enhance/supplement training for Soldiers, units, and staff; explore future capabilities, tactics, and force structure; and as an aid to the acquisition process. All three types of simulation models employ some level of abstraction—because, as retired Army General Paul Gorman once said, "Anything but war is simulation." By generalizing some facets of a combat engagement (similar to

[41] Jerome Braken, Moshe Kress, and Richard Rosenthal, Introduction to "Warfare Modeling," Danvers, MA, 1995, p. 1.

[42] Paul Davis, "Aggregation, Disaggregation, and the 3:1 Rules in Ground Combat." Retrieved 11 May 2006 from the World Wide Web at http://www.rand.org/pubs/monograph_reports/MR638/Chap3.html.

Lanchester Equation applications), analysts concentrate on representing specific actions or characteristics in other areas in order to gain insights to assist decision makers.

Some aspects of combat are easier to quantify and represent, such as the range of a weapon, the speed of a vehicle, the logistical demands of a unit, the protection afforded by terrain, equipment failure rates, etc. Other aspects are intangible and much more difficult to quantify (and therefore represent). Modeling individual characteristics and behaviors, such as leadership, experience, fatigue, fear, loyalty, aggression, and the complex, human decision-making process, is a challenge. Obviously, these and countless other factors influence military conflicts. One of many ways to describe the combat environment is asserted in Figure 4. An even greater challenge is encountered in modeling the synergy joining the overlapping regions. An example of such a synergy is the increased effectiveness of weapons fired by experienced and well-trained Soldiers, led by competent leaders.[43]

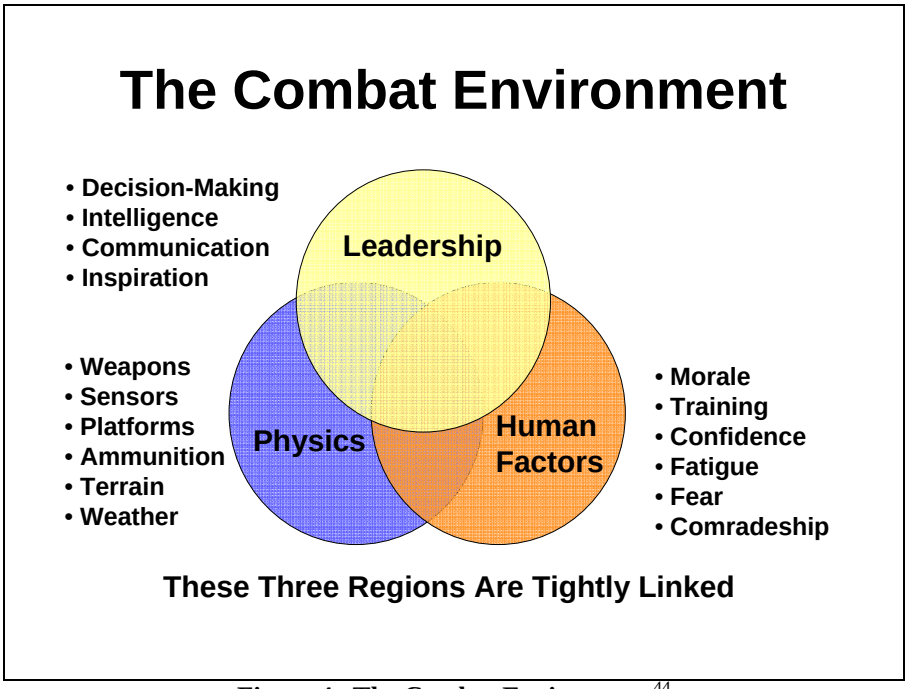

Figure 4. The Combat Environment[44]

[43] *Pythagoras Manual*, Version 1.9, p. 17. Retrieved 12 May 2006 from the World Wide Web at http://sky.mhpcc.hawaii.edu:8080/r/Software/pythagoras/pyth19/pyth_19_manual.pdf.

[44] Ibid., p. 19.

Simulations typically leverage immense volumes of data to represent the attributes of the terrain military forces may fight on, the weather and light conditions that forces are subject to, the countless number of possible weapon-target pairings, and the attributes of weapon systems (including munitions and shooter characteristics), just to name a few. Admittedly, no model can capture all the necessary data to represent all aspects of a military battle. Yet, there is undeniable value in the potential insights the models can provide. Even though accurately modeling combat may be an insurmountable task, mathematically representing certain aspects of combat is arguably achievable. At a very basic level, it is as simple as agents (be they tanks, battalions, or Soldiers) maneuvering and firing on one another. Data can be dynamically referenced to calculate a number of things—from movement rates and probabilities of detection to tracking logistics, to name just a few. Although computational advancements have significantly increased the fidelity, resolution, and speed in DoD M&S, we must recognize serious shortcomings to modeling actual combat. The skill of the analyst using the model is what produces useful insights. This research attempts to capture assumptions and behaviors related to NLWs to gain insight on combat implications.

B. MILITARY M&S NEEDS

With the Soldier and small unit level of warfare being the centerpiece of Army Transformation goals and objectives,[45] an Army-wide panel, the Soldier Modeling and Analysis Working Group (S-MAWG), was formed in 2003 and tasked to gain "full visibility of existing and planned model representations of battlefield phenomenon important to the conduct of analysis focused at the individual Soldier and small unit level."[46] The models evaluated by the S-MAWG were: CASTFOREM, COMBAT XXI, JANUS, OneSAF, SSE, VIC, AWARS, CAEN, IUSS, AIMS, and JCATS (see List of Abbreviations, Acronyms and Symbols). Through a series of evaluations, the S-MAWG identified deficiencies in current modeling capabilities that "must be addressed within models and simulations to enable credible analysis of the decision issues that are

[45] United States Army, *The Army*, Field Manual 1, (Washington, D.C.: U.S. Government Printing Office, 14 June 2005), p. 4-3. Retrieved 12 May 2006 from the World Wide Web at http://www.army.mil/fm1/chapter2.html#section5.

[46] Larry Larimer and Pedro Habic, "Soldier Modeling and Analysis Working Group (MAWG) Evaluation Report," TRADOC Analysis Center-White Sands Missile Range, NM, March 2004, Abstract.

especially pertinent to the individual Soldier and small unit."[47] One of the identified deficiencies was NLWs. In fact, no model surveyed by the group explicitly portrayed the use and effects of NLWs.

Other prominent organizations involved in modeling and supporting combat operations (down to the unit and Soldier level) have also recognized this deficiency. The U.S. Army's Urban Operations Focus Area Collaborative Team (UO FACT), whose purpose is to direct the Army's modeling research pertaining to UO, identified modeling NLWs as an Army M&S priority and has recommended funding for research efforts in this area.[48] The Army Materiel Analysis Activity (AMSAA) identified "non-lethal weapon performance as a significant analysis void for army acquisition and warfighting analysis."[49] The tri-service Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) also identified the need for NLW performance estimates based on priority requests from Combatant Commands. As such, the two organizations are working together on this high priority support to commanders in the field.[50]

C. MODELING NLWs: EMPLOYMENT CHALLENGES

The first and perhaps the biggest challenge involved in modeling NLWs is to simply identify the appropriate targets for these types of weapons. While it is asserted that non-lethal means are only reserved for noncombatants and lethal means for enemy combatants, modeling imperfect identification is a considerable challenge. Traditional military M&S does not address this problem, typically only representing "red" and "blue" forces. Although some early Army models do represent noncombatants (like JANUS), their role is notional at best. One of the most impressive achievements of late is the ability of a combat model to represent multiple sides—i.e., beyond just red and blue forces (currently in COMBAT XXI and in the developing OneSAF Objective System).

[47] Larry Larimer and Pedro Habic, "Soldier Modeling and Analysis Working Group (MAWG) Evaluation Report," TRADOC Analysis Center-White Sands Missile Range, NM, March 2004, Abstract.

[48] Interview between LTC John Willis, Program Officer, Urban Operations Focused Area Collaborative Team and the author, 12 May 2006.

[49] Email correspondence with Mr. Brad Bradley, former Head of the Infantry Team, Armor/Infantry Branch and Non-lethal Lead, U.S. Army Materiel and Analysis Activity, "Non-lethals," 12 May 2006, office communication.

[50] Ibid.

Representing more than two sides may require a very dynamic set of rules and behaviors for interaction (see Table 1). Although Side 2 may view Side 3 as neutral, the feelings are not reciprocal (Side 3 views Side 2 as hostile). This common phenomenon occurs when multiple factions or ethic groups are in close (or even distant) proximity.

	Side 1	**Side 2**	**Side 3**	**Side 4**
Side 1	Friendly	Friendly	Hostile	Friendly
Side 2	Friendly	Friendly	**Neutral**	Friendly
Side 3	Hostile	**Hostile**	Friendly	**Neutral**
Side 4	Friendly	Hostile	**Hostile**	Friendly

Table 1. Sides Relationship Example[51]

Establishing relationships still does not solve the identification challenge. Consider a situation where a team assigned to Side 3 is moving through an unfamiliar urban environment at night and spots an individual approximately 50 meters ahead. This individual could represent any one of the four possible sides. What is the probability of successfully differentiating neutral from enemy (even friendly), especially if they are dressed (and sometimes even equipped/armed) the same way? Depending on Side 3's actions, outcomes range from no engagement (neutral) to incorrect engagement (incorrectly identified neutral as hostile), to being engaged (misidentified a hostile as a neutral and fired upon). Mission success, a potential international incident, or mission failure could all be attributed to encounters such as these. This very real problem is not well represented in current DoD M&S.

Lastly, even if a simulation model does consider the identification challenge, current military models do not incorporate NLWs. This is largely due to the nature of NLWs—they are still an immature technology and tactic for warfare.[52] Current models do well at representing conventional weapons. Conventional research and development of NLWs seeks to determine the probability of incapacitation. This is fraught with a myriad of mitigating circumstances, from distance, to motivation, to size and musculature of the intended target. Establishing probabilities of hit, accidental death, and even injury

[51] John R. Surdu, Doug Parsons, and Oanh Tran, "OneSAF Objective System: Modeling the Three Block War," p. 3. Retrieved 12 May 2006 from the World Wide Web at http://www.bucksurdu.com/Professional/Documents/SMTW67_OOS_Three_Block_War_final_draft.pdf.

[52] Siniscalachi, p. 24.

are straightforward compared to modeling the reaction/behavior of an individual hit by an NLW. An individual may wish to surrender, but may not know how. The act of running or seeking cover may be construed as posturing for attack. The challenge of proper interpretation or reading of the target's reaction must be taken into account when attempting to model NLWs in combat operations.

D. AGENT-BASED MODELING AND DATA FARMING

As mentioned previously, the strengths of traditional military M&S lie in its ability to leverage tangible and quantifiable aspects of the environment (weather, terrain composition, elevation, etc.) and the agents (Soldiers, tanks, units, noncombatants) that interact within a specified scenario. In order to address the challenges described above, it is necessary to enumerate human factors (individual characteristics and behaviors). Unfortunately, quantifying a Soldier's motivation and level of caution is not something that can be easily measured. Faced with these challenges, a nontraditional (nonmilitary specific) approach was used to explore the impact of NLWs in combat operations—Agent-Based Simulations (ABS), also known as Multi-Agent Simulations (MAS). ABS are not new to DoD analysts; these types of models have been used for years, only the terminology and a few aspects (such as representing knowledge and behavior) of ABS are new.[53]

ABS are based on the idea of representing the behaviors of entities/agents and the possibility to "represent an emergent collective behavior that results from the interactions of an assembly of autonomous agents."[54] At a simplistic level, ABS are low-resolution models comprised of individual agents that interact according to states and rules of behavior.[55] These agents may: communicate with other agents; are driven by a set of tendencies or motivations; possess resources; are capable of perceiving their environment (sensors); possess skills; and behave with the intent of satisfying their

[53] Thomas M. Cioppa and Thomas W. Lucas, "Military Applications of Agent-Based Simulations," 2004 Winter Simulation Conference, p. 2.

[54] Jacques Ferber, *Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence*, (Boston, MA: Addison-Wesley, 1999), p. 35.

[55] Robert Axtell, "Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences," Center on Social and Economic Dynamics, The Brookings Institute, 2000.

user-defined objectives.[56] Within this construct, the very factors not considered in traditional DoD M&S will be quantified and serve as input to ABS.

Unfortunately, the same difficulties of quantifying these human factor variables are still not solved (see Figure 3). As mentioned previously, even if we could accurately approximate attribute values of our own forces, characterizing opposing, neutral, and cooperative forces is an even bigger challenge, with no guarantee of ever establishing the "correct" attribute value. Therefore, it makes sense to incorporate a broad range of input variable levels to explore the corresponding consequences for better understanding. However, varying a multitude of input factors soon results in exponential growth of possible combinations. This approach is impractical when applied to traditional DoD simulations characterized by time-intensive set-up and run-times.

> The scenario generation process for our high-resolution simulations is man-hour intensive and requires detailed knowledge of the simulation's underlying data and operating assumptions. Often times, the analyst is limited to a small set of simulation runs due to the simulation's complexity, scenario development constraints, and the decision maker's timeline. Consequently, they may only obtain a limited view of possible outcomes.[57]

In order to examine a greater range of possible inputs and circumstances, an exploratory analysis approach is needed. Design-of-experiments (DOE) is an approach to handle the exponential growth of combinatorial factors. Instead of using every possible combination of input variable levels, the DOE methodology used in this exploration is the Nearly-Orthogonal Latin-Hypercube (NOLH). This approach efficiently explores the vast space of possible outcomes—commonly called the study space. Using this efficient approach, it is not uncommon for these low resolution models to reduce the required time to complete all of the model runs (each run being a specific set or combination of factor levels) from billions of computing years to days of computing on a personal computer.[58] This computational time can then be significantly reduced by submitting the DOE (with

[56] Ferber, p. 62.

[57] Lloyd Brown, Thomas Cioppa, and Thomas Lucas, "Agent-Based Simulations Supporting Military Analysis," *Phalanx*, April 2004.

[58] Charles A. Sulewski, "An Exploration of Unmanned Aerial Vehicles in the Army's Future Combat Systems Family of Systems," Final Thesis and Conclusion Outbrief given to TRAC leaders and staff, 5 December 2005.

accompanying scenario) to a bank of super-computers, such as those at the Maui High Performance Computing Center (MHPCC).

ABS are uniquely qualified to tackle this formidable exploratory approach (otherwise known as data-farming) used to obtain insight on the study space. ABS offer relatively quick scenario generation and incredibly fast run times. By leveraging high-performance computing centers, analysts can consider many alternatives in a short amount of time.[59] The insight gained from this exploratory approach can then be used as input for higher resolution military models, vastly saving time.

E. PYTHAGORAS BACKGROUND AND OVERVIEW

Pythagoras, developed by Northrop Grumman in conjunction with Project Albert and the United States Marine Corps, was chosen as the ABS to support this research. As with most ABS, Pythagoras is a low resolution model/simulation that is easy to learn, platform independent, and compatible for data farming. Pythagoras's color value methodology and "soft-decision" rules make it well suited to represent the attributes necessary to model NLWs. Capabilities taken directly from the Pythagoras Manual[60] are listed below (underlined text used to accentuate applicability to modeling NLWs):

- Incorporates soft rules to distinguish unique agents
- Uses <u>desires</u> to motivate agents into moving and shooting
- Includes the concept of <u>affiliation</u> (<u>established by sidedness</u>**,** <u>or color value</u>) to differentiate agents into members of a unit, friendly agents, neutrals, or enemies
- Allows for <u>behavior-changing events</u> and actions (called triggers) that may be invoked in response to simulation activities
- Retains traditional weapons, sensors, and terrain

[59] Charles A. Sulewski, "An Exploration of Unmanned Aerial Vehicles in the Army's Future Combat Systems Family of Systems," Masters Thesis, Naval Postgraduate School, Monterey, CA, December 2005, p. 29.

[60] *Pythagoras Manual*, p. 18.

An overview of Pythagoras (to include behavior rules) is summarized below and taken either directly or indirectly from the *Pythagoras Manual* or from the simulation creators.[61]

1. Pythagoras History and Overview

In 1997, the U.S. Congress authorized a research project to evaluate nontraditional combat simulation modeling techniques that could potentially model three areas largely omitted from existing combat models:

- **Nonlinearity** – Disproportionate effects of small input changes
- **Intangibles** – Human factors such as leadership and others impact outcome
- **Coevolving Landscape** – Adversaries anticipate actions and base decisions on their anticipation

Project Albert, initially led by the Marine Corps, was conceived with these three objectives in mind. Tasked with developing ABS to model human behavior and its effect on combat, Pythagoras enables users to create intelligent agents and assign behaviors based on motivators and detractors. These agents use fuzzy-logic (soft rules) to capture the complex and dynamic nature of interacting with the environment and other agents (see Figure 3).

2. Pythagoras Soft Rules

Military orders are often ambiguous and mean different things to different people. An order to "hold fire until the enemy gets close" may mean six miles to a fighter pilot, but may mean six feet to embassy security. Even if several people agree on a distance—say, 400 feet—some will evaluate that distance a little long and be seen as trigger-happy, whereas others will evaluate it a little short and be seen as overcautious. Fuzzy logic attempts to capture this complex, dynamic nature of interpretation, while creating a mathematical underpinning. Soft decision rules assign each agent its own threshold to

[61] Edmund J. Bitinas, Zoe A. Henschied, and Lap V. Troung, *Pythagoras: A New Agent-Based Simulation System*. Retrieved 12 May 2006 from the World Wide Web at http://www.ms.northropgrumman.com/PDFs/TRJ2003/03ssBitinas.pdf.

reflect a variation of human factors between individual agents. These rules also ensure traceability.

This approach allows these agents desires and thresholds to be varied from replication (simulation run) to replication, and to be varied from agent to agent within a replicate. Agents can adhere to their base values strictly or loosely (a mean value with an allowable range) within a replicate or use some combination of loose and strict adherence. Depending on the level of adherence, either common behavior or highly individualistic behavior could emerge, from cohesive units with high training and discipline to single entities acting on their own.

IV. SOUTHWEST ASIA SCENARIO OVERVIEW

A. VIGNETTE BACKGROUND

In an attempt to share commonality with previously conducted FFW research (formerly Objective Force Warrior—OFW), the selected vignette was taken from the "Study Plan Supporting Analysis of the Objective Force Warrior – Night Attack in a Major Urban Area". This analysis, conducted from October 2004 through May 2005, used an internally developed simulation called Small Unit Team Exploratory Simulation (SUTES—see Appendix C for details).

The vignette consists of a night urban operation in the Caspian Sea AO, specifically Azerbaijan (see Figure 5). The SCU-sized mission is within the context of a larger mission to seize key sections of the capital city (Baku) held by Insurgents in order to assist the exiled and legitimate (host) government (see Appendix D: Road to War and Appendix E: Base Scenario Order).[62]

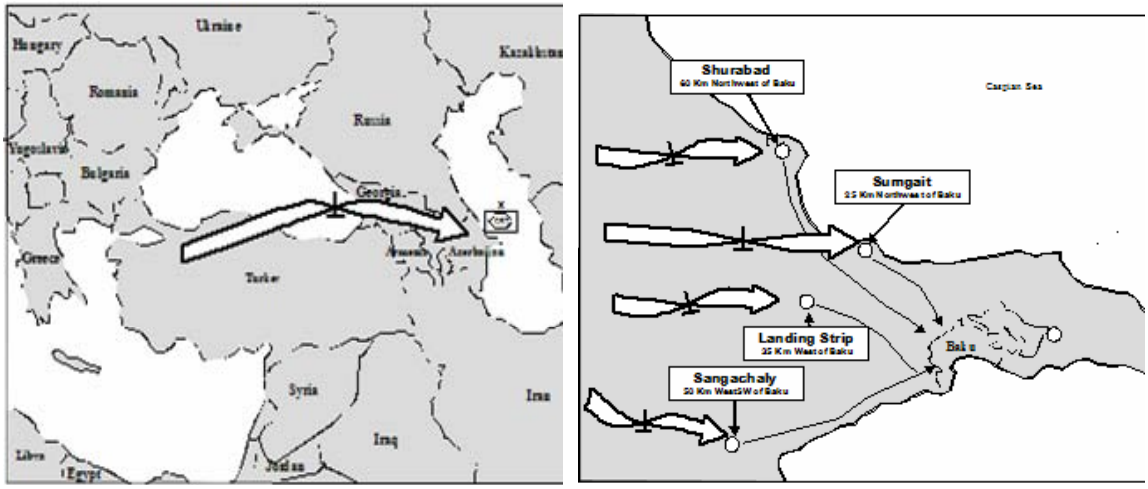

Figure 5. Overview of Vignette Location

The SCU is tasked with moving through an urban area (Movement to Contact—MTC) to seize and secure a building currently controlled by Insurgents. An MTC is common to most military operations and is the focus of this research.

[62] Annex C and Annex A of "The Study Plan Supporting Analysis of the Objective Force Warrior – Night attack in a Major Urban Area," prepared by the Dismounted Battlespace Battle Lab, Fort Benning, GA, 23 June 2003.

B. FRIENDLY FORCES: THE FFW

1. Background

The Army's FFW Program is designed to make the Soldier and small unit more lethal and survivable on both the current and envisioned battlefield.[63] FFW uses a system of systems approach to meet all projected Soldier needs through technology developments. FFW is an Advanced Technology Demonstration (ATD) program and is

> . . . the Army's flagship Science and Technology initiative to develop and demonstrate revolutionary capabilities for Future Force Soldier systems. . . FFW notional concepts seek to create a lightweight, overwhelmingly lethal, fully integrated individual combat system, including weapon, head-to-toe individual protection, netted communications, Soldier-worn power sources, and enhanced human performance. The program is aimed at providing unsurpassed individual and squad lethality, survivability, communications, and responsiveness . . .[64]

While FFW is a stand-alone program, it is designed to be integrated with the current force (Stryker) and the developing Future Combat Systems (FCS) combat and support platform.[65]

2. Composition and Capabilities

FFW is designed to be integrated into the existing structure of the infantry platoon. The base organization for the FFW SCU consists of three rifle squads (each squad contains 2 teams of 4 men and a Squad Leader); a weapons squad (2 machine gun teams of 3, an antiarmor team of 2, and a Squad Leader); and a platoon headquarters (see Figure 6).

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[63] Booze Allen Hamilton, "Future Force Warrior CONOPS," Version 1.0, 22 August 2005, p. 3.

[64] "Future Force Warrior (FFW)," U.S. Army Natick Soldier Center (NSC). Retrieved May 2006 from the World Wide Web at http://ffw.natick.army.mil/content.htm.

[65] Booze Allen Hamilton, p. 5.

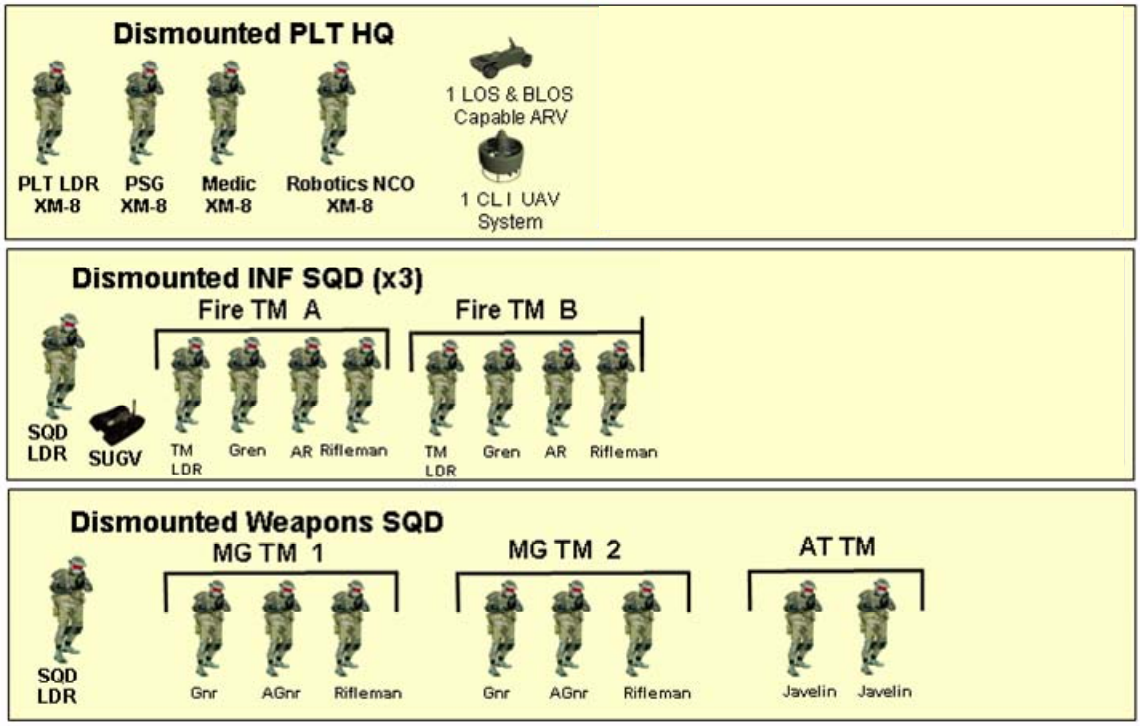

Figure 6. FFW Platoon Organization with Potential Augmentations[66]

Some of the FFW capability increases are highlighted below and further details of the program and equipment are shown in Appendix F.

- **Command and Control** – Leaders have enhanced situational awareness (SA) of their Soldiers' locations and health status of the platoon. Near instantaneous transmission of information (voice/data/video) down to the individual Soldier level.
- **Survivability** – The integrated battle ensemble provides improved ballistic and fragmentary protection. The ensemble incorporates the load bearing ability into the ensemble, eliminating the need for separate load bearing equipment.
- **Lethality** – Soldiers have access to NETFIRES (Netted Effects) with precision munitions (laser-guided or global positioning system (GPS)).

[66] OFW MAPEX MOUT Vignette Description, Annex A (DRAFT), OFW ATD Integration Analysis and Simulation Team, p. 37.

Increased precision and lethality of the organic weapons. Cooperative engagements maximize long-range lethality.

- **Mobility** – Lighter weight equipment.
- **Survivability** – Integrated battle ensemble with body armor and improved ballistic protection. Integrated sensors and optics in helmet provide better SA.

C. THREAT AND NONCOMBATANT DESCRIPTION

Paralleling previous research, this vignette uses a dismounted group of enemy personnel characterized as Insurgents armed with Soviet-style weapons. The legitimate government of Azerbaijan has been overthrown by the Azari Islamic Brotherhood (AIB—a coalition of antigovernment factions) and forced into exile. The AIB has garrisoned small units (platoon and squad size) throughout the capital city (Baku) to secure key elements of power and control the populace. The AIB are well trained, capably led, and are able to conduct operations day or night (limited night vision).[67]

Perhaps the most difficult and realistic facet of this scenario is the difficulty U.S. forces will have discerning friend from foe. Complicating the already challenging urban environment, enemy forces (Insurgents) do not wear a uniform and actively blend in with the local populace. Unfortunately (and more challenging still), half of the locals are sympathetic to the Insurgents and may actually engage U.S. forces.

D. CONCEPT OF THE OPERATION

The FFW SCU will advance on two avenues of approach (two squads on one route, one squad on a parallel route) to the objective (OBJ BLUE), a media building currently controlled and used by the Insurgents (see Figure 7). As the SCU travels under the cover of night toward the objective, it will encounter three types of individuals/groups: Enemy Insurgents, Hostile Civilians, and Neutral Civilians. Unfortunately (and realistically), U.S. forces do not have perfect identification capability

[67] Annex A of "The Study Plan Supporting Analysis of the Objective Force Warrior—Night Attack in a Major Urban Area," prepared by the Dismounted Battlespace Battle Lab, Fort Benning, GA, 23 June 2003.

and therefore can only characterize encounters in two ways: (1) with identified Insurgents (either by hostile actions or armed/equipped); and (2) with individuals or groups not identified as Insurgents.

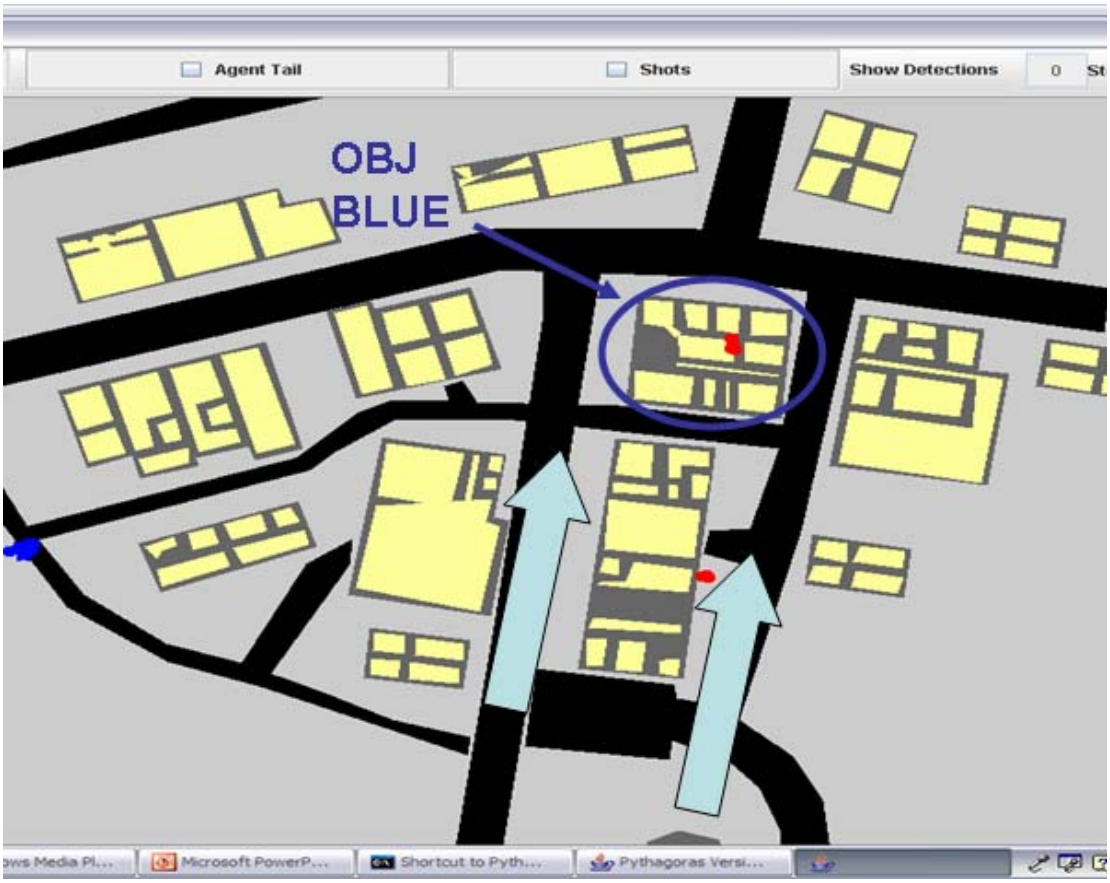

Figure 7. Pythagoras Scenario Representation

The action taken in the first encounter is obvious for this vignette—open or return fire. The action for the second encounter is more challenging and will depend on the distance to the individual(s). Assuming that a sufficient Psy-Ops campaign predated this mission, the local populace should leave the AO when they identify U.S. forces conducting operations. As such, when they are within the SCU's "area of concern," the SCU will employ NLWs to essentially "interrogate" the target. This area of concern is part of the unit's ROE and will be varied in this research from 25 to 50 meters. The reactions of targeted individuals will determine the response—compliant/surrendered personnel will be sent to the rear; noncompliant personnel will be engaged with lethal means.

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V. MODELING METHODOLOGY

A. BUILDING THE SCENARIO: GETTING STARTED

1. Collaboration and Disclaimer

This research was a coordinated effort with U.S. Army graduate student Major Jon Alt's thesis research titled "Exploring a Future Force Warrior Small Combat Unit Operating in an Urban Environment." A base case scenario was jointly developed in order to compare and synergize FFW research efforts. This chapter is intended to introduce the reader to the Pythagoras modeling process and aspects specific to the scenario. Further details are provided by the *Pythagoras Manual* (available upon request at http://www.projectalbert.org/downloads.html and in Appendix G.

2. The Playbox

According to the *Pythagoras Manual*, the first step to modeling a scenario is to define the pixel distance and time step. The "playbox," or area of interest, is represented in Pythagoras by a maximum of 1,000 by 1,000 pixels. Scaling the terrain features of the vignette to the "playbox" with the accompanying time step is essential to bound and realistically represent interactions of agents with other agents, sensors, communication devices, and the terrain. Once established, performance data such as movement rates, weapon ranges, and effective ranges of communications and sensor devices are scaled and represented in the model. For this research, the area of interest has been modified at the request of the TRADOC Analysis Center in Monterey, California (TRAC-Monterey) to substitute the Baku, Azerbaijan AO (see Figure 5) used in the vignette with the McKenna MOUT (Military Operations on Urbanized Terrain) site at Ft. Benning, Georgia (see Figure 8).

Figure 8. Aerial Photo of McKenna MOUT Site, Ft. Benning, GA

Tailoring the scenario to a known complex often used for training may provide benefits and lessons learned that may be incorporated into training for military units stationed stateside. More importantly, it aids in comparative analysis. MAJ Alt used commercial software (Microsoft Paint) to map the training area into Pythagoras from an aerial photo of the training area (see Figure 9) with accompanying urban sprawl.

Figure 9. Overhead Photograph of McKenna MOUT Site

Using known distances/spacing of the McKenna MOUT site, a 3-to-1 ratio of pixels to meters was established. The time step for the simulation was set to equal two seconds in order to trace specific combat actions in Pythagoras and approximate the time required to complete the mission in the vignette. Attributes to characterize the cover and concealment as well as movement rates were then assigned to the features to approximate the affect of the terrain on the agents moving about in the urban environment.

B. THE EQUIPMENT AND PLAYERS

With the terrain, scale, and time step established, the analyst then must represent the opposing (and neutral) sides. In order to interact within the simulation, all agents in Pythagoras must be assigned at least one weapon, one communication device, and one sensor.

1. Equipping the Forces

The weapons and equipment for the FFW SCU and enemy forces are listed in Tables 2 and 3). See Appendix H for equipment description and capabilities.

Agent	Weapon #1	Weapon #2	Comm #1	Comm #2	Sensor
Platoon Leader	M4	grenade	Soldier Radio Waveform	Joint Tactical Radio System	Fused Thermal and IR
Platoon Sergeant	M4	grenade	Soldier Radio Waveform	Joint Tactical Radio System	Fused Thermal and IR
Squad Leader	M4	grenade	Soldier Radio Waveform	Joint Tactical Radio System	Fused Thermal and IR
Team Leader	XM303	grenade	Soldier Radio Waveform	Joint Tactical Radio System	Fused Thermal and IR
Grenadier	XM104	None	Soldier Radio Waveform	Warfighter Physiological Status Monitor	Fused Thermal and IR
Automatic Rifleman	M249	grenade	Soldier Radio Waveform	Warfighter Physiological Status Monitor	PVS-14
Rifleman	M4	grenade	Soldier Radio Waveform	Warfighter Physiological Status Monitor	PVS-14
Machine Gunner	M240	None	Soldier Radio Waveform	Warfighter Physiological Status Monitor	PVS-14
Asst Machine Gunner	M4	grenade	Soldier Radio Waveform	Warfighter Physiological Status Monitor	PVS-14
Anti-Tank Soldier	M4	Javelin	Soldier Radio Waveform	Warfighter Physiological Status Monitor	PVS-14

Table 2. Blue Forces Equipment List

Agent	Weapon #1	Weapon #2	Comms	Sensor
Insurgent Leader	RPK-74	RPG	Insurgent Radio	Night Vision Device
Insurgent Soldier	AK-47	grenade	None	None

Table 3. Insurgent Equipment List

The performance of the weapons and equipment used by the agents must be scaled to the playbox for a realistic representation. See Appendix I for further details and performance scaling in Pythagoras.

2. Assigning "Sidedness"

In order to distinguish forces in Pythagoras, "sidedness" is assigned through the use of three colors: red, green, and blue. The sidedness, or color values (0-255) of the three colors, allows agents to perceive/identify other agents as members of their own unit, friendly to the agent, neutral to the agent, or hostile to the agent. The process of assigning color values can be a very complicated one, especially when there are more than two sides and the relationships between sides differ from each side's perspective (see Table 1 – Sides Relationship Example).

For illustrative purposes, the "blueness" of an agent can be selected to represent the allegiance of an agent. If an agent has a blueness (blue value) equal or very close to another agent's blueness, it can represent being in the same unit (in our case, a team). A slightly larger difference in values can represent a friendly relationship (such as within a platoon or company). Larger differences in blue values can represent enemy relationships. Neutral relationships exist between the predetermined friendly and enemy distance limitations (or "Color Radius"). Other agents do not necessarily have to use the same rule set or colors to determine relationships. In this way, multiple sides may be represented in the model. Figure 10 illustrates the assignment of color values to each agent and the Color Radius sets the tolerance (differences in color values) associated with different relationships (Unit, Friendly, or Enemy). The resulting relationships are seen in Figure 11.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1					Unit				Friendly				Enemy			
2	Agent Name	Red	Green	Blue	Color Radius	Use Red	Use Green	Use Blue	Color Radius	Use Red	Use Green	Use Blue	Color Radius	Use Red	Use Green	Use Blue
3	US-1stSqd-Tm Ldr	0	0	230	1	0	0	1	11	0	0	1	131	0	0	1
4	US-1stSqd - Riflemen	0	0	230	1	0	0	1	11	0	0	1	131	0	0	1
5	US-2ndSqd - Riflemen	0	0	220	1	0	0	1	11	0	0	1	131	0	0	1
6	Insurgent	255	0	50	0	0	0	0	60	0	0	1	106	0	0	1
7	Civilian	0	0	155	0	0	0	0	0	0	0	0	255	0	0	1
8	Hostile Civilian	0	0	100	0	0	0	1	51	0	0	1	100	0	0	1
9																

Figure 10. Pythagoras Sidedness Worksheet – Value Assignment

	A	B	C	D	E	F	G
1		US-1stSqd-Tm Ldr	US-1stSqd - Riflemen	US-2ndSqd - Riflemen	Insurgent	Civilian	Hostile Civilian
2	US-1stSqd-Tm Ldr	--	UNIT FRIEND	FRIEND	ENEMY		ENEMY
3	US-1stSqd - Riflemen	UNIT FRIEND	--	FRIEND	ENEMY		ENEMY
4	US-2ndSqd - Riflemen	FRIEND	FRIEND	--	ENEMY		ENEMY
5	Insurgent	ENEMY	ENEMY	ENEMY	--		FRIEND
6	Civilian					--	

Figure 11. Pythagoras Sidedness Worksheet – Resulting Relationships

In this example, U.S. forces define unit relationships using blue (represented as a "1" in the binary "Use Blue" column). Because the 1st Squad Riflemen have the same

blue value as the 1st Squad Team Leader (230, as shown in Figure 10), the blueness difference is less than radius (of 1) and therefore falls under the Unit category. This relationship is confirmed in the Resulting Relationships Worksheet (Figure 11). Because the difference is also less than the Friend radius of 11, it is also identified as Friend. The difference for the Riflemen from the 2nd Squad is 10 and therefore falls under the Friend category, but not the Unit category. For an enemy relationship, the difference between values has to be greater that the unit radius value. Because the Enemy Color Radius (131) is less than the difference between each of the blue agents' colors, and the Insurgent's blue value is 50 (a difference of 180), the resulting relationship is Enemy. Neutral relationships are indicated by an absence of a relationship. This dynamic functionality also allows the analyst to account for imperfect identification.

C. BEHAVIORS

1. Movement Desires and Terrain Preferences

With the terrain and agents now represented in Pythagoras, the actions comprising the vignette are tailored into Pythagoras in a number of ways. Generally, agents travel by assigned waypoints. Rules and tendencies affect how agents travel to the next waypoint. Two factors that affect the path are the agent's movement desires and its terrain preferences. Movement desires allow the user to simulate unit cohesion and tactics by manipulating the agents' desire to move toward or away from other agents (unit, friendly, and enemy). Terrain preferences likewise guide an agent in route selection by avoiding "bad" terrain and preferring "good" terrain (user defined).

2. Generalized Agent Behaviors

The following descriptions apply to the behaviors of the agents within the vignette/simulation:

- **U.S. Forces:** Move along two avenues of approach (streets) directly to the objective, OBJ BLUE. The SCU will move as fire teams (using tactical spacing) along the building to avoid being engaged in the middle of the streets. The SCU will not pursue targets, but will purposely continue to the objective to support future integrated tactics. The SCU engage with

lethal means only those perceived to be enemy; personnel perceived as neutral will be engaged with an NLW if they are inside the weapon range.

- **Insurgents:** Four teams of Insurgents patrol the area and will aggressively pursue and attack U.S. forces when detected. Insurgents will fight to the death.
- **Hostile Civilians:** Randomly move about the scenario (but favor the streets). They will not always be perceived as hostile. When they detect U.S. forces, they will wait a random amount of time before engaging. Once they engage U.S. forces, they will be clearly identified as enemy.
- **Civilians:** Randomly move about the scenario, but will avoid groups of U.S. forces. If engaged with lethal means, surrounding Civilians (including Hostile) will attack.
- **Suicide Bomber:** Once he detects a group of U.S. Soldiers, he will try to get within 10 feet of them before detonating his bomb.

3. Behavior Triggers

Triggers are events in the simulation that cause an agent to change its behavior. Examples of triggers include being shot at, detecting an enemy or friend, the passing of an amount of time, reaching an objective, or even a change in color(s). This dynamic functionality allows the user to program chained triggers to represent complex interactions and reactions (like tactics and decision-making).

D. REPRESENTING NLWs IN PYTHAGORAS

Pythagoras uses the term “weapon” to describe an influence tool. As such, it can represent the damaging effects of conventional weapons or even the healing or restorative powers of medicine and food. Alternatively, it can also represent intangible effects such as fear, hunger, pain, or encouragement. Instead of bullets or bombs, the “intangible effects” weapons essentially shoot color at the targets. When an agent is hit by this “painting” weapon, it may change its color values. When triggers are programmed to corresponding changes in color values, behaviors can be modeled. In this way, agents

involved in a humanitarian relief effort can “feed” starving people; a loudspeaker weapon can spur aggression; or an NLW can influence a target to surrender.

In this scenario, if an NLW hits a target, it “paints” (adding or subtracting color) a designated amount of color(s) to the agent. When a threshold value is reached, a programmed trigger changes the agent’s behavior, perhaps causing actions characterized as surrendering. The probability of an agent surrendering depends on its assigned vulnerability to color changes. By tailoring these vulnerabilities and the amount of color painted to an agent, different probabilities of surrender can be assigned to different agents (Neutral Civilians, Hostile Civilian, and Insurgents).

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VI. THE EXPERIMENT

A. MEASURES OF EFFECTIVENESS (MOEs)

In order to determine the impact of equipping the FFW SCU with NLWs, some MOEs must be selected to describe and compare the output results of the experiment. Just as the score of a sporting event describes the outcome of a game (or match, event, etc.), combat operations typically use kills or attrition to gauge success and failure. The MOEs for this research address the very basic measures of warfare: lethality and survivability. These two MOEs were also the most important MOEs of previous FFW research. Preliminary analysis of hundreds of tailored scenario runs consistently yielded no Insurgent survivors and therefore resulted in eliminating lethality from MOE consideration. Since survivability also (although not traditionally) applies to noncombatants, unintended casualties (either from lethal or non-lethal munitions) and surrendered personnel will also be accounted for with MOEs. A third MOE was used to capture the very real risk of a Suicide Bomber attacking the unit. This attack is modeled to be without an explosive payload in order to simplify analysis (i.e., it does not degrade U.S. force's survivability statistics).

MOE 1: Survivability – Percentage of Friendly (Blue) Noncasualties

MOE 2: Collateral Damage – Percentage of Civilian Casualties

MOE 3: Suicide Bomber's Success – Percentage of Successful Suicide Attacks

B. PRIMARY DESIGN FACTORS

The primary objective of this research effort is to determine the combat implications of employing an NLW. This is essentially a binary variable—collecting model MOEs with and without NLWs. In this experiment, an NLW range of 0 meters represents the base case—a Soldier does not possess an NLW (only lethal) and must rely on physically restraining an individual. The range will then be changed to 25 meters (the FFW capability requirement) and subjected to the same conditions. The collected MOEs will be the basis of comparison. Exploration also includes the effects of increasing the number of NLWs available to the unit as well as an extended range capability to determine if more of either (or both) is better and, if so, how much better.

- **NLW Range:** 0 meters, 25 meters, 50 meters
- **NLW Distribution:** 6 per SCU, 12 per SCU

Because the employment of NLWs in combat operations is intimately linked to imperfect identification, three levels of identification will be explored for both cases (with and without NLWs). This is used to approximate the difficulty of discerning friend from foe in combat. It can represent the skill of the Insurgents to blend into the local population or the targeting ability of experienced Soldiers familiar with the opposing forces. A practical example of this phenomenon is recognizing the footwear of Insurgents in a crowd—running shoes rather than typical/regional sandals to expedite departure upon discovery.[68] These levels attempt to capture the probability of shooting the opposing forces versus a noncombatant in the wrong place at the wrong time (see Appendix G for implementation details):

- **Most Dangerous/Risky** – Characterized by more restrictive engagement criteria due to difficulty associated with identifying Insurgents. U.S. forces will be able to positively identify Insurgents only 20% of the time; 15% for Hostile Civilians. This means the Insurgents (and Hostile Civilians) typically get to shoot first. Civilians will be mistaken as the enemy 10% of the time.
- **Least Dangerous/Risky (Best Case)** – Characterized by an easier ability to separate the Insurgents from the Civilians. U.S. forces will be able to positively identify an Insurgent 80% of the time and 70% for Hostile Civilians; Civilians will be mistaken as the enemy only 5% of the time.
- **Most Likely Case** – A 50% chance of identifying an Insurgent correctly; 57% chance of identifying Hostile Civilian correctly; Civilians will be mistaken as the enemy 8% of the time.

[68] Phone interview between U.S. Air Force Major William Pramenko, Chief of Health Effects Branch, Joint Non-Lethal Weapons Directorate and the author, May 2006.

C. SECONDARY DESIGN FACTORS

As previously mentioned, accurately characterizing behaviors, performance, and tactics is a considerable challenge with no guarantee of accuracy. Therefore, it makes sense to incorporate a broad range of input variable levels to explore the corresponding consequences to the MOEs. These input variables are often not controllable by decision makers and are often referred to in the military community as "the enemy has a vote." This means that the location, composition, tactics, or capabilities may be different than expected and undoubtedly requires further experimentation to explore "what-if" scenarios (often referred to as branches and sequels). A thorough (or robust) DOE accounts for these controllable and uncontrollable factors (synonymous to noise factors) and arguably reflects real (or potentially real) circumstances. The NOLH DOE allows the analyst to analyze and estimate multiple effects, interactions, and thresholds by efficiently varying a multitude of variables.[69]

Secondary factors with accompanying levels are listed in Table 4. Qualitative descriptions of levels are used to describe behavioral responses (a scaled score) or distance to initial location (within a prescribed perimeter) for the agents. Any number of levels may be explored between the low and high values.

Factor	Variable Range	Explanation
Number of Insurgents	8 – 40	The number of Insurgents in the scenario
Number of Civilians	3 – 30	The number of Civilians in the scenario
Number of Hostile Civilians	3 – 30	The number of Hostile Civilians in the scenario
Civilian Surrender Resistance	Low – High	Effectiveness of NLWs on Civilians
Hostile Surrender Resistance	Low – High	Effectiveness of NLWs on Hostile Civilians
Insurgent Surrender Resistance	Low – High	Effectiveness of NLWs on Civilians
Civilian Proximity	Low – High	How close Civilians will approach U.S. Forces
Animosity of Hostile Civilians	Low – High	Probability of attacking U.S. forces
Location of Insurgents	Random Distribution	Initial start point of Insurgent Patrols
Location of Civilians	Random Distribution	Initial start point of Civilians
Location of Hostile Civilians	Random Distribution	Initial start point of Hostile Civilians

Table 4. Uncontrollable Factors and Levels

[69] Thomas M. Cioppa, "Efficient Nearly Orthogonal and Space-Filling Experimental Designs for High-Dimensional Complex Models," Ph.D. Dissertation, Operations Research Department, Naval Postgraduate School, Monterey, CA, 2002.

D. SCOPING CONSIDERATIONS

As mentioned previously, this research effort was closely coordinated with MAJ Jon Alt to explore FFW SCU operations in an urban environment. Extensive efforts were spent attempting to accurately represent current and future technologies and external enabler capabilities to establish a base case for both research efforts. With the base case established, different methodologies and directions were pursued to investigate our respective research questions. In order to isolate the (potential) effect of NLWs, many aspects of the scenario were intentionally simplified and/or not modeled for several reasons.

1. "Walk, Crawl, Run"

This represents a philosophy used by the Army for training and implies the obvious—build up fundamental (and usually easier) skills before attempting more difficult tasks. Beginner-, intermediate-, and advanced-level progression applies to real life and to M&S—especially when addressing uncharted/novel solutions. A proposed solution must first pass simplistic and conceptual tests before subjecting it to more complicated conditions and situations. This research reflects a novel application of NLWs in combat and therefore exploration must start with (overly) simplified conditions.

One of the biggest challenges in this research and on the battlefield is target discrimination. Proposing a framework to handle varying levels of identification ("Sidedness" in Pythagoras) is tested in conjunction with the employment of a new type of combat weapon (NLW with accompanied tactic proposed in Chapter II). This initiative alone quickly exceeds a beginner's level and therefore necessitates testing in very simplistic combat conditions before asymmetric and synergistic military tactics and capabilities are addressed.

2. Simplifying Combat

There is inherent danger associated with attempting to model too much: the more one tries to imitate reality, the more uncertainty is introduced into the model. For illustrative purposes, if it is desired to determine if it is advantageous to substitute a more

accurate, but slower (rate of fire) direct fire weapon for small unit operations, it does not make sense to vary (or perhaps even represent) the effects of indirect fires. While it may be useful in a general sense, it is more difficult to attribute the changes in MOE levels to the weapon in question. Attempting to represent these types of aspects subjects the model to more scrutiny (variance). As such, indirect fires are not represented in the simulation. This decision is supported by the assertion that the use of indirect assets in a populated urban environment is not desirable. Also, if opposing sides have similar or offsetting capabilities, there is no utility in explicitly modeling if proportional MOEs are used.

Another reason to simplify combat is to address more general or more difficult conditions. Assets or support may not be available for a particular small unit tasked to move through an urban environment (occupied with enemy and noncombatants). Lastly, the contributions of current and anticipated improvements (equipment, robotics, sensors, etc.) for the FFW SCU (to include external enablers) are unproven in the laboratory **or** on the battlefield. As such, the following assumptions and scoping considerations were made for this research:

1. Ground Robotics – Small Unmanned Ground Vehicles (SUGVs) and Armed Robotic Vehicles (ARVs) are anticipated to be an integral part of the FFW SCU. These assets are unproven and may not be available/operational to all SCUs.

2. Unmanned Aerial Vehicles (UAVs) – The exact variant, number, and performance of the UAV to be used for the FFW SCU is still being investigated/researched. This technology/capability is a tremendous asset, but suspect at differentiating the enemy from noncombatants. The SA gained by these assets more than likely level the playing field against forces operating on their own familiar terrain. As such, one may argue that situational awareness is roughly equal for the forces and therefore need not be modeled.

3. XM104 Cooperative Engagement – A fire control device mounted on the future grenadier's weapon.[70] The fire control device receives the coordinates and target

[70] TRADOC System Manager-Soldier (TSM-S), "Capability Development Document for Ground Soldier System: ACAT I," 13 June 2005, pp. 57-58.

description over the SCU network. This unproven capability is potentially risky to employ while moving through an urban environment occupied with noncombatants.

4. Reduced Exposure Fire – The Soldier's sight picture is transmitted to a remote display, thereby reducing head and shoulder exposure during engagements. Its capability is unproven.[71]

5. Mortars/Artillery – Not modeled for reasons given above.

E. DATA SOURCES AND MODEL ASSUMPTIONS

1. Perfect Friendly Identification – Through the use of the FFW communication network, communication and Blue Force Tracking (BFT) is assumed to yield perfect friendly location/identification. Although ambitious and optimistic, friendly fires are not considered in this research, but potentially strengthen the need for NLWs.

2. Perfect Communication – Through the use of the FFW, communication and coordination for tactics and movements are assumed to be perfect.

3. Movement Rates and Techniques – Assumed to be representative of an SCU's movement through an urban area. Increased sensors, communication, and armor do not inhibit movement rates.

4. Simplified Engagements – Weapon ranges are limited to 200 meters for practicality (urban environment at night); multiple targets are randomly prioritized; coordinated fire involves no more than a squad (9 personnel).

5. Performance Data Accuracy – Performance data for weapons, sensors, and equipment were collected from AMSAA and are assumed to be accurate.

6. Civilian and Hostile Civilian Modeling – No effort was made to represent all possible civilians in the vignette; only a designated number for exploratory purposes.

F. PYTHAGORAS LIMITATIONS AND SHORTCOMINGS

Throughout the conduct of this research, several students using the Pythagoras model discovered bugs and shortcomings in version 1.8. As such, Northrop Grumman

[71] TRADOC System Manager-Soldier (TSM-S), "Capability Development Document for Ground Soldier System: ACAT I," 13 June 2005, p. 4.

provided fixes and new version releases: 1.9, 1.9.1, and 1.9.2, and 1.10 (Beta). While each new version fixed known problems/shortcomings and provided more capabilities, additional bugs and shortcomings were subsequently discovered. Unfortunately, support and data farming were no longer available for previous versions after version 1.10 (Beta) was released.

Deficiencies in behavior triggers, knowledge retention, and data collection methods led Northrop Grumman to tailor a fix specific to this research effort. Unfortunately, this custom version is not able to leverage the data farming tools of Project Albert. This deficiency is expected to be resolved with the anticipated June 2006 1.10 final version release. Consequently, only the primary design factors could be explicitly modeled for this research.

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VII. DATA ANALYSIS

A. DATA COLLECTION AND POST PROCESSING

Without the ability to leverage data farming techniques (using a NOLH design), the primary design factors were manually varied and run in the batch mode of Pythagoras. This corresponds to traditional M&S analysis methods. Some of the secondary design factors are accounted for by leveraging the tolerance functionality in Pythagoras. Variations in starting locations, movement desires, hostility appearance (for identification purposes), and resistance (to surrender) allow for a more robust design and broader analysis (rather than indicating that all analysis is only warranted for very exact conditions).

Each of the 15 design points (different scenario conditions, see Table 5) were replicated 10 times (with the same starting and subsequent random seeds for each design point), yielding a total of 150 output files. Each of these output files were converted (renamed) to comma separated value (.csv) files, consolidated by design point, and summarized to confirm data (anomaly checking).

Design Point	NLW Carried By	Misidentification Level	NLW Range
1	Team Leaders (6)	High	No NLW
2	Team Leaders (6)	High	25 Meters
3	Team Leaders (6)	High	50 Meters
4	Team Leaders (6)	Mid	No NLW
5	Team Leaders (6)	Mid	25 Meters
6	Team Leaders (6)	Mid	50 Meters
7	Team Leaders (6)	Low	No NLW
8	Team Leaders (6)	Low	25 Meters
9	Team Leaders (6)	Low	50 Meters
10	All Leaders (12)	High	25 Meters
11	All Leaders (12)	High	50 Meters
12	All Leaders (12)	Mid	25 Meters
13	All Leaders (12)	Mid	50 Meters
14	All Leaders (12)	Low	25 Meters
15	All Leaders (12)	Low	50 Meters

Table 5. Design Points

B. INITIAL INSIGHTS

When comparing the Blue (U.S.) Survivability scores in Table 6, increasing either the range or distribution (number) of NLWs results in slightly higher Blue Survivability

scores. It seems that being able to interrogate a potential enemy with NLWs offsets the risk of allowing an unconfirmed enemy to engage first. Although the enemy may then return with lethal fire, there may be several reasons why Blue Survivability generally does not suffer: the speed at which Blue forces immediately engage with lethal means; superior protection offered by FFW body armor; and/or because typical Insurgent forces are at a disadvantage engaging U.S. forces at nighttime, as the U.S. military "owns" the night (with its superior sensors and targeting devices).

NLW Range	Blue Survivability
No Range	0.63
25 Meters	0.66
50 Meters	0.66

NLW Distribution	Blue Survivability
Team Leaders	0.65
All Leaders	0.67

Table 6. Blue Survivability Based on Range and Distribution

Not only does this logic apply to the enemy, it also applies (even more so) to Hostile Civilians. The ability to interrogate Hostile Civilians (forcing surrender or subsequent lethal engagement) generally offsets the increased risk of them engaging at a later time (modeled to attack at a random time). A Hostile Civilian who complies/surrenders may recognize that their life has been spared (because we used an alternative to deadly force). Moreover, their friends and family may also recognize this. Thus, employing NLWs has the potential to diffuse/lessen hostility toward U.S. forces rather than fueling the anger of the local populace had the targeted individual been engaged with lethal means.

An analysis of Civilian Survivability in Table 7 yields similar results. Increased NLW capabilities lead to marginally better Civilian Survivability scores. This may be attributed to the ability to identify a threat from a nonthreat—more precisely, the consequences of mistakes. Civilians may be (unfortunately) mistaken as an enemy, depending on their movement and possessions. Soldiers have different probabilities of correctly identifying them as neutral rather than enemy. When a Blue Force Soldier engages someone with an NLW, it potentially "saves" that individual from being mistaken as an enemy by another Soldier (and subsequently engaged with lethal means). While that may not always be the case, an NLW offsets this risk.

NLW Range	Civilian Survivability
No Range	0.86
25 Meters	0.88
50 Meters	0.88

NLW Distribution	Civilian Survivability
Team Leaders	0.86
All Leaders	0.89

Table 7. Civilian Survivability Based on Range and Distribution

A similar analysis of Suicide Bomber Success Rate yields predictable results (see Table 8). Increased NLW capabilities lead to greatly reduced Suicide Bomber Success Rates. Averaged throughout the entire experiment, one Suicide Bomber has a 50% chance of being perceived as a threat (as reflected in the no NLW statistic). Just having the ability to interrogate such an individual dramatically reduces their chance of success. It is interesting to note that doubling the number of NLWs distributed to the SCU cuts the Suicide Bomber Success Rate in half.

NLW Range	Suicide Bomber Success Rate
No NLW	0.50
25 Meters	0.05
50 Meters	0.00

NLW Distribution	Suicide Bomber Success Rate
Team Leaders	0.033
All Leaders	0.017

Table 8. Suicide Bomber Success Based on NLW Range and Distribution

Before determining the significance of these statistics, it is worth mentioning that these results are important in verifying the framework of the model—consistent and arguably intuitive. This in itself is a significant accomplishment. While this research is exploratory, this identification framework can be applied to existing or future scenarios to better approximate UO, with or without NLWs. This framework can also be used to compare alternative NLWs, especially if input data (surrender probabilities, misidentification rates, hostility) are more precisely approximated.

C. A CLOSER LOOK

In order to obtain more insight on the combinatorial effects of NLW range and distribution on all three MOEs, the ten replications at each design points were consolidated and examined within each Misidentification Level (see Table 9). Because Blue Survivability is historically the most important combat MOE, the design points are ranked within each Misidentification Level in descending Blue Survivability order (top is best). Bold numbers represent the highest scores within each Misidentification Level.

Misidentification Level	NLW Distribution	NLW Range	Suicide Success Rate	Civilian Survivability	Blue Survivability
Low	All Leaders	50 Meters	**0.0**	0.913	**0.790**
Low	All Leaders	25 Meters	**0.0**	0.963	0.777
Low	Team Leaders	50 Meters	**0.0**	0.963	0.749
Low	Team Leaders	25 Meters	**0.0**	0.925	0.733
Low	Team Leaders	No NLW	0.1	**0.988**	0.731
Mid	All Leaders	25 Meters	**0.0**	**0.838**	**0.690**
Mid	Team Leaders	50 Meters	**0.0**	0.813	**0.690**
Mid	All Leaders	50 Meters	**0.0**	**0.838**	0.659
Mid	Team Leaders	25 Meters	**0.0**	0.800	0.659
Mid	Team Leaders	No NLW	0.6	0.725	0.641
High	All Leaders	50 Meters	**0.0**	**0.890**	**0.569**
High	Team Leaders	25 Meters	0.2	0.850	0.567
High	All Leaders	25 Meters	0.1	0.888	0.564
High	Team Leaders	No NLW	0.8	0.863	0.531
High	Team Leaders	50 Meters	**0.0**	0.838	0.518

Table 9. Effect of NLW Capabilities at Each Misidentification Level

Intuitively, one would think the increased NLW range and distribution (All Leaders and 50 Meters—these rows are shaded above) would consistently yield the most favorable results for all three MOEs. This only occurs within the High Misidentification Level. Of course, this is the most demanding and dangerous level. That same combination actually yields the worst Civilian Survivability score within the Low Misidentification Level. Strangely, at the low level, the base case (Team Leaders and No NLW) actually has the highest Civilian Survivability score.

Other anomalies occur within the High Misidentification Level—the base case (Team Leaders with No NLW) has better Blue and Civilian Survivability scores than Team Leaders with the extended NLW range (50 meters) and a better Civilian Survivability score than Team Leaders with the 25-meter NLW range. Since there is no clear combination of NLW capabilities that yield the best results across all MOEs regardless of Misidentification Level, an aggregated score is used. An overall CE score is calculated using weighted MOEs.

D. SCORING THE EXPERIMENTS: RESPONSE FUNCTION CALCULATIONS

In order to evaluate and compare the contribution of NLWs at each design point, a CE score is calculated using weighted MOEs (see Table 10) in the following subjective manner:

	U.S./Blue Force Survivability	Civilian Survivability	Suicide Bomber Success Rate
Weight	**0.5**	**0.3**	**0.2**

Table 10. MOE Weightings for CE Score

This weighting reflects a professional judgment and is not approved by the FFW program. Although the success of a Suicide Bomber can considerably affect the survivability of the U.S. forces, this research does not address explosive payload or the consequences of such a potential threat in an attempt to isolate NLW effects. The following equation is therefore used to calculate CE:

CE = (U.S. Surv)*(0.5) + (Civilian Surv)*(0.3) – (Suicide Success Rate)*(0.2)

This equation also does not account for Hostile Civilians (lethality, survivability, or surrendered). Addressing the contributions and effects of these players may be a significant factor to be explored with future research.

E. DO NLWs CONTRIBUTE TO HIGHER CE SCORES?

In order to determine the most dominant factor for determining CE (from the three primary factors: NLW Range, NLW Distribution, or Misidentification Rate), batch runs at each design point were aggregated and investigated. A tree diagram (see Figure 12) and box plots (see Figure 13) confirm that Misidentification Level is the biggest and clearest factor driving CE scores. This means that the success of U.S. military forces (in this scenario and simulation) largely depend on how well we can differentiate friend from foe. This logic supports heavily leveraging technology to maintain and push our advantage in the realm of sensors/vision devices (e.g., thermal, IR, etc.), especially in conditions of limited visibility. It also confirms the importance of actually addressing this issue in combat (and combat analysis). This is especially pertinent with Civilians (both neutral and hostile) on the battlefield, an anticipated condition.

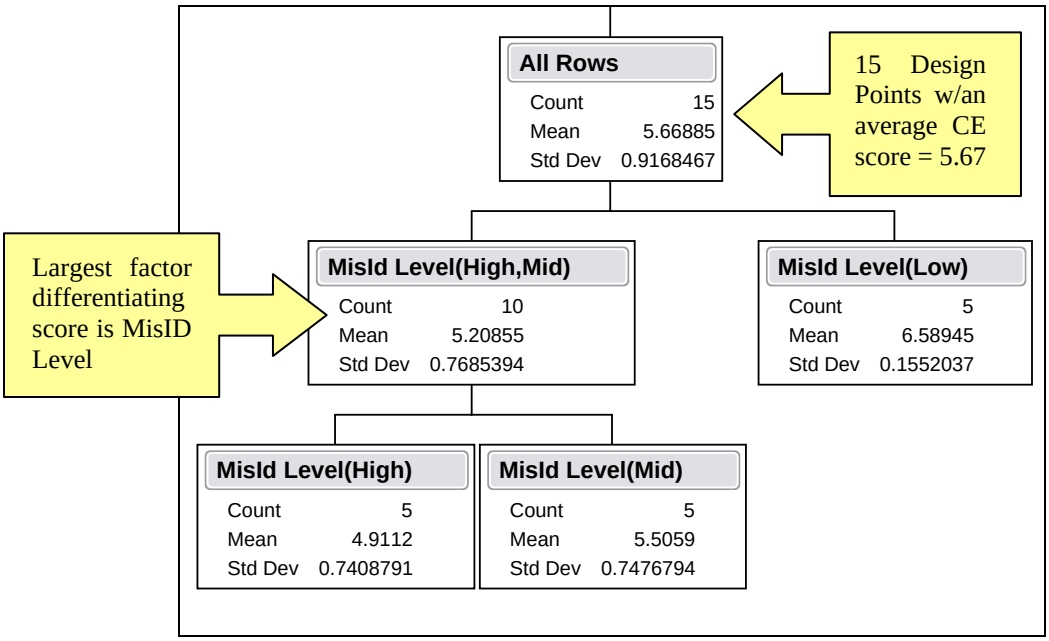
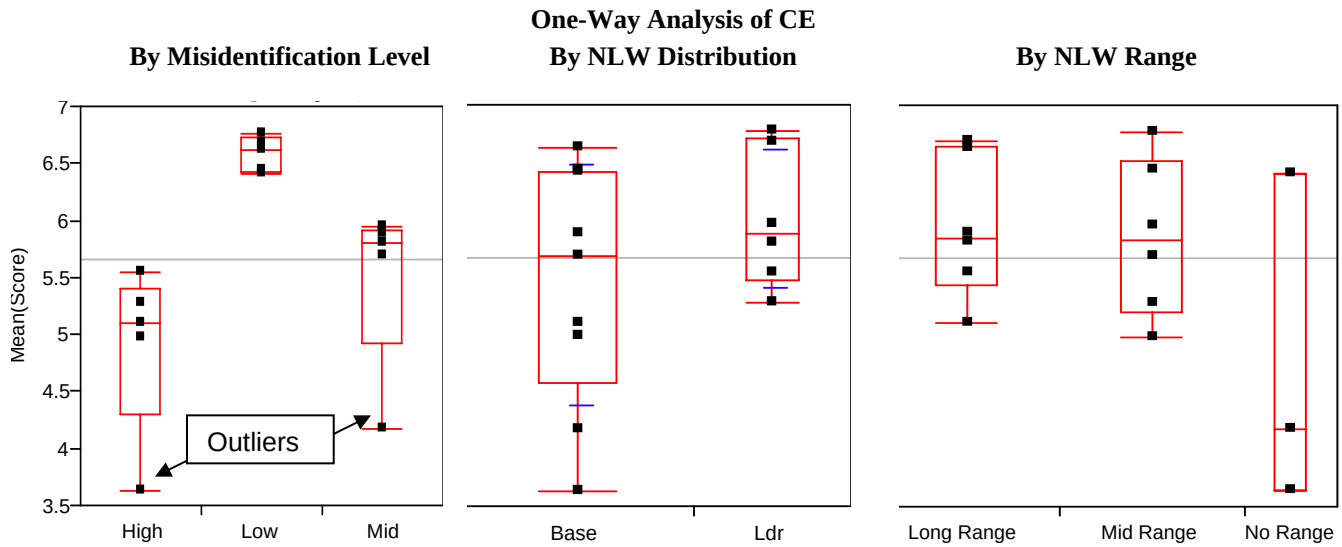


Figure 12. Tree Diagram of Most Relevant Factor for CE

The tree diagram above depicts the significance of the Misidentification Level in determining the CE score. Not only does it represent the greatest difference between the highest CE scores and the rest of the design points, it also is the second biggest factor in differentiating CE scores (the lowest scores from the rest, or middle). The contributions of NLW distribution and range to CE score clearly play a less important role compared to the Misidentification Level. This conclusion comes as no surprise, as our success depends on how well we can target differentiate the enemy, especially when the enemy has no problem identifying U.S. forces (we are in uniform).

The boxplots (which depict the means and quartiles of scores and the means) in Figure 13 support this assertion. The boxplot of the CE score by Misidentification Level clearly separate CE scores. If a few extreme outliers were not included in our consideration there would be very little overlap. The other boxplots (by primary factor) have significant overlap. While it would be fairly simple to categorize the Misidentification Level by a CE score or even predict the CE score at a given Misidentification Level, it would not be so easy with the NLW distribution or range boxplots. The means of the NLW distribution are very close to the same score, as are the means of the long- and mid-range NLW boxplots.



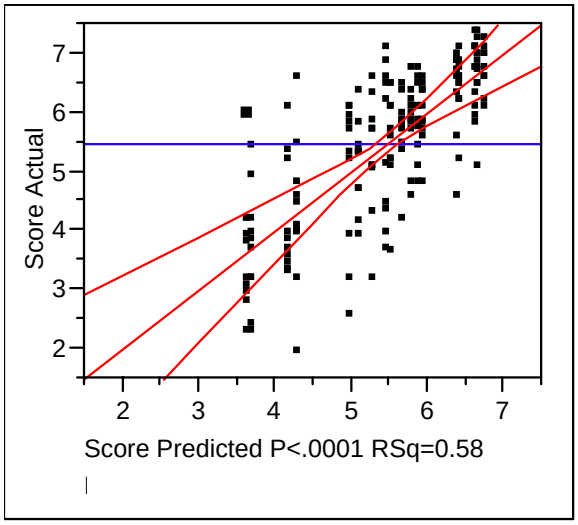
conditions, and ability to differentiate targets). When these levels/scenarios were isolated, the following CE scores are observed in Table 11:

NLW Distribution	Misidentification Level	NLW Range	CE Mean Score
All Leaders (12)	High	50 Meters	5.55
All Leaders (12)	High	25 Meters	5.28
Team Leaders (6)	High	50 Meters	5.10
Team Leaders (6)	High	25 Meters	4.98
Team Leaders (6)	High	No NLW	3.64
All Leaders (12)	Low	25 Meters	6.77
All Leaders (12)	Low	50 Meters	6.69
Team Leaders (6)	Low	50 Meters	6.63
Team Leaders (6)	Low	25 Meters	6.44
Team Leaders (6)	Low	No NLW	6.42
All Leaders (12)	Mid	25 Meters	5.96
Team Leaders (6)	Mid	50 Meters	5.89
All Leaders (12)	Mid	50 Meters	5.81
Team Leaders (6)	Mid	25 Meters	5.69
Team Leaders (6)	Mid	No NLW	4.18

Table 11. Ranked CE Scores by Misidentification Rate

While the exact combination of NLW distribution and range may still be debatable, there is no question that any NLW capability is better than none—the lowest CE score at each level comes from an SCU without an NLW. It is interesting to note that a larger distribution of NLWs appears to be more important than an extended range capability (All Leaders equipped with NLWs yielded the highest CE scores in all three categories). The extended range does not seem to always improve CE scores.

By fitting a regression model to the data, the amount of the contribution of each factor to the CE score can be quantified. In order to do a full factorial regression, three additional design points were created and replicated (All Leader, No NLW, and High/Mid/Low Misidentification Levels, 10 times each). Although these design points are actually the same as the base (Team Leader) cases, it allows the regression model to maintain degrees of freedom when calculating interactions. While the overall regression model only accounts for 0.581 of the variance of the model (as seen by $R^2 = 0.581$; the closer this value is to 1.0, the better the model), the Whole Model Actual versus Predicted Plot certainly captures a trend (see Figure 14). It is important to note that this regression model is unable to account for the secondary factors that were varied with the tolerance capabilities of the simulation.



Summary of Fit	
RSquare	0.581
RSquare Adj	0.537
Root Mean Square Error	0.865
Mean of Response	5.474
Observations (or Sum Wgts)	180

Figure 14. Regression Analysis: Whole Model Plot and Summary of Fit

When the final version of Pythagoras 1.10 is released, the ability to data farm and therefore capture unaccounted (and uncollected/recorded) model variations (such as vulnerability, hostility, and movement desires) will most certainly yield a better predictive model. Additionally, the ability to use the MHPCC will yield several thousand replications (rather than just 10) to better shield the model from extreme outliers.

By looking at the Parameter Estimates of the regression model in Table 12, significant factors become readily apparent by examining the far right column (Prob>|t|). Any value less than 0.05 indicates that the factor has a statistically significant

contribution, either positively or negatively, to the CE score. The amount of the contribution is found within the Estimate column.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.4740773	0.064456	84.93	<.0001
NLW Possession[Base]	–0.032216	0.064456	–0.50	0.6179
MisId Level[High]	**–0.761859**	**0.091154**	**–8.36**	**<.0001**
MisId Level[Low]	**0.930005**	**0.091154**	**10.20**	**<.0001**
NLW Possession[Base]*MisId Level[High]	–0.104385	0.091154	–1.15	0.2538
NLW Possession[Base]*MisId Level[Low]	0.1244172	0.091154	1.36	0.1742
NLW Range[Long Range]	**0.4691227**	**0.091154**	**5.15**	**<.0001**
NLW Range[Mid Range]	**0.3818977**	**0.091154**	**4.19**	**<.0001**
NLW Possession[Base]*NLW Range[Long Range]	–0.037834	0.091154	–0.42	0.6787
NLW Possession[Base]*NLW Range[Mid Range]	–0.117225	0.091154	–1.29	0.2003
MisId Level[High]*NLW Range[Long Range]	0.1428593	0.128911	1.11	0.2694
MisId Level[High]*NLW Range[Mid Range]	0.0390093	0.128911	0.30	0.7626
MisId Level[Low]*NLW Range[Long Range]	–0.214555	0.128911	–1.66	0.0980
MisId Level[Low]*NLW Range[Mid Range]	–0.17913	0.128911	–1.39	0.1666
NLW Possession[Base]*MisId Level[High]*NLW Range[Long Range]	–0.047515	0.128911	–0.37	0.7129
NLW Possession[Base]*MisId Level[High]*NLW Range[Mid Range]	0.1039518	0.128911	0.81	0.4212
NLW Possession[Base]*MisId Level[Low]*NLW Range[Long Range]	–0.081967	0.128911	–0.64	0.5258
NLW Possession[Base]*MisId Level[Low]*NLW Range[Mid Range]	–0.140276	0.128911	–1.09	0.2781

Table 12. Fitted Regression Model Parameter Estimates (with Significant Factors bolded)

These model parameters indicate that the Misidentification Levels and NLW Range are the only factors that can be confidently attributed to the CE score <u>across all design points</u>, as evident by the Prob>|t| values of "<.0001." A high Misidentification Level will decrease the CE score (as indicated by a negative estimate value of –0.76). Surprisingly, increasing NLW distribution fails to have a significant effect on increasing CE, almost contrary to observations. A low Misidentification Level or possessing an NLW (either the mid range of 25 meters or the long range of 50 meters) will increase the score (as seen by the positive estimate values of 0.93, 0.38, and 0.47, respectively). Logically supporting the obvious—U.S. forces will do better the more they can differentiate friend from foe.

Examining the residuals in the model (the errors or difference in value associated with each data point to the predicted value/regression line) can reveal inconsistencies, especially when there is some heteroscedasticity, which this plot displays in Figure 15. Investigation reveals that the majority of these outliers are associated with the unusual (but not unlikely) result of a failed Suicide Bomber attempt when the FFW SCU does not have an NLW (and therefore scores highly). The remaining outliers are attributed to instances when Insurgents go inside buildings and fire on the SCU (sniper-like). This emergent behavior is seen very rarely, but brings this very real danger to light.

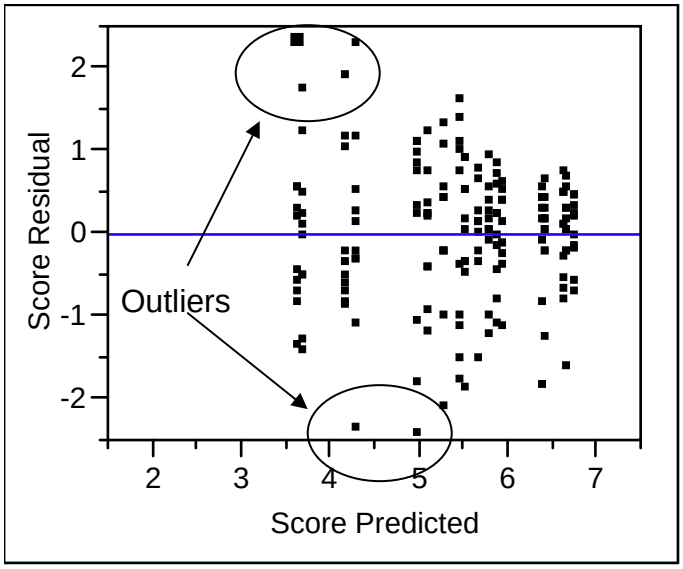


Figure 15. Residual by Predicted Plot

Lastly, the most significant factors within each Misidentification Level are investigated—see Figures 16 through 18. Within the High and Low Misidentification Levels, the most significant factor contributing to the CE score was the success of the Suicide Bomber, followed by the NLW Distribution. Within the Mid-Level Misidentification Level, the most important factor is NLW procession (distribution), followed by range. The importance of this revelation is that identifying and neutralizing a Suicide Bomber is instrumental to successful SCU UO. Having the NLWs distributed to a greater number of personnel is more favorable.

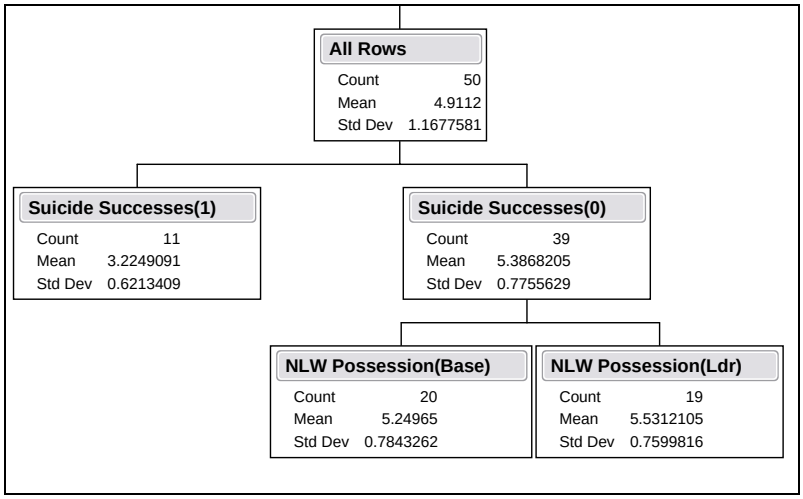


Figure 16. High Misidentification Level's Most Significant Factors

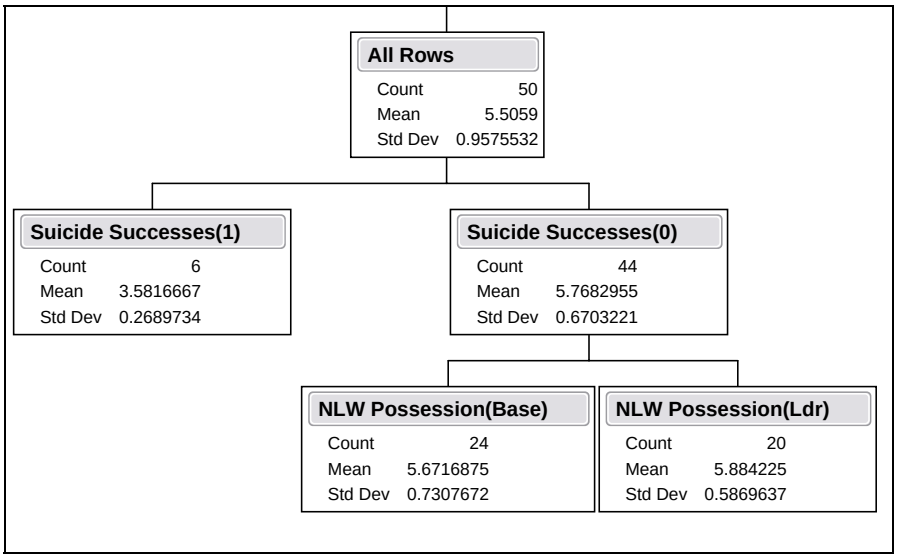


Figure 17. Mid Misidentification Level's Most Significant Factors

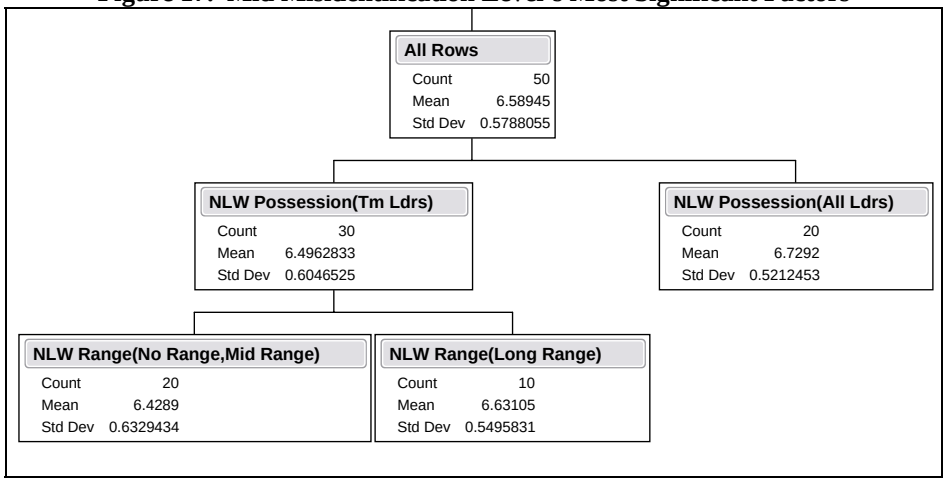


Figure 18. Low Misidentification Level's Most Significant Factors

F. ADDITIONAL CONSIDERATIONS

While this analysis has focused on the primary combat implications of NLWs (lethality and survivability), it has not considered the value of surrendered personnel, especially Hostile Civilians. The FFW scenario used by this research only vaguely refers to Civilians (in the coordinating instructions of the operations order (OPORD):[72] "Some Civilians in AO are considered neutral. Some are considered hostile." Surprisingly, this reference to Civilians is more in-depth than is typical. How one interprets and models hostility can vastly affect the outcome. This research chose to represent a notional number of Hostile Civilians that will attack at a random time. While this obviously

[72] Annex A – A Company/1st CAB OPORD, OFW MAPEX MOUT Vignette Description by the OFW ATD Integration and Analysis Team, October 2003.

affects U.S. forces' survivability, what is not captured in the data analysis is the survivability of the Hostile Civilians. One reason for this is because they are virtually indistinguishable from the enemy/Insurgents on the battlefield—they are both shooting at U.S. forces. When U.S. forces encounter an unconfirmed/potential target and engage with NLWs, all targeted individuals make the decision to be treated as an enemy or as a surrendered person (based on compliant or noncompliant actions). The true identity/allegiance may not be known for some time. Hence the hesitancy of this research effort to weigh this aspect.

To shed some light on the data collected by the design points, surrendered Hostile Civilians has been added to Table 13. There is no question that NLWs lead to the surrender of Hostile Civilians (in this simulation). When addressing only Hostile Civilian surrenders, increasing the engagement range of NLWs leads to an increase in the number of Hostile Civilian surrenders. Additional distribution of NLWs does not appear to impact the number of surrenders.

MisID Level	NLW Distribution	NLW Range	Suicide Success Rate	Civilian Survivability	Hostile Civilian Surrender	Blue Survivability
Low	All Leaders	50 Meters	**0.0**	0.913	0.125	**0.790**
Low	All Leaders	25 Meters	**0.0**	0.963	0.100	0.777
Low	Team Leaders	50 Meters	**0.0**	0.963	0.150	0.749
Low	Team Leaders	25 Meters	**0.0**	0.925	0.063	0.733
Low	Team Leaders	No NLW	0.1	**0.988**	0.000	0.731
Mid	All Leaders	25 Meters	**0.0**	**0.838**	0.138	**0.690**
Mid	Team Leaders	50 Meters	**0.0**	0.813	0.238	**0.690**
Mid	All Leaders	50 Meters	**0.0**	**0.838**	0.288	0.659
Mid	Team Leaders	25 Meters	**0.0**	0.800	0.163	0.659
Mid	Team Leaders	No NLW	0.6	0.725	0.000	0.641
High	All Leaders	50 Meters	**0.0**	**0.890**	0.425	**0.569**
High	Team Leaders	25 Meters	0.2	0.850	0.338	0.567
High	All Leaders	25 Meters	0.1	0.888	0.338	0.564
High	Team Leaders	No NLW	0.8	0.863	0.000	0.531
High	Team Leaders	50 Meters	**0.0**	0.838	0.438	0.518

Table 13. Effect of NLW Capabilities at Each Misidentification Level (Hostile Surrenders included)

VIII. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDY

If the only tool you have is a hammer, you tend to think of every problem as a nail.

Attributed to Abraham Maslow
1908-1970

A. DISCLAIMER

While this research has attempted to model a capability to be used in combat, it is important to note that the data analyzed is from a low resolution and unverified model. While every effort has been made to debug the model, improvements in the now available Pythagoras version 1.10 will undoubtedly yield better insight when coupled with data farming techniques. While the conclusions of this analysis are made from very specific parameters, they must not be overstated. The author believes this research to be a stepping stone to what some may call more responsible warfare.

B. BOTTOM LINE

This research finds that U.S military operations, especially the FFW SCU, can benefit from the employment of NLWs. Given supporting Psy-Ops in the area to explain/broadcast employment tactics, the use of the proposed NLW (XM303) with accompanying tactic (interrogation) will not degrade U.S. survivability. Contrary to what opponents of the use of NLWs in combat believe, NLWs may, in fact, improve survivability, especially in the presence of potential suicidal attacks. Employing NLWs can also potentially spare the lives of civilians, neutral and hostile, thereby helping U.S. military forces win the hearts and minds of the local populace.

C. RESEARCH RELEVANCY, INSIGHTS, AND CONCLUSIONS

The initial motive of this study was to explore whether NLWs could be used across the spectrum of military operations. This is especially relevant in light of current operations in Iraq. A significant challenge is presented to these Soldiers who are tasked to conduct combat, peacekeeping, and humanitarian operations, often concurrently. Without the means to deal with questionable and very stressful situations, one cannot

help but wonder (assuming effective use of NLWs) whether there would be fewer "incidents" and investigations of the U.S. military for civilian casualties during operations in Iraq.

> Ominously, there are also reports of atrocities in other places, committed by young soldiers who cracked under the pressure of a war fought on a battlefield with no front lines, no easy way to tell civilians from insurgents, and no end in sight.[73]

In exploring this serious concern, it became quite clear that not only is it a challenge to employ NLWs in uncertain conditions, it is also difficult to create realistic models. In light of these multifaceted challenges, some relevant issues, insights, and conclusions are categorized and provided below.

1. Combat Identification

- Before NLWs can be considered for combat M&S, a framework for identification needs be established. This research has established such a methodology and asserts that non-lethal means should only be reserved for potential threats to safety and mission accomplishment.
- The level at which U.S. military forces can confidently differentiate combatants from noncombatants (and friendlies) is a critical measure that should be factored into planning and operations. CE scores in this research are significantly affected by this ability.
- Identifying the allegiance of personnel engaged (regardless of means) may not be possible. The local media may, of course, reach their own conclusions. There is an undesirable, but nonetheless real tradeoff between inadvertently releasing an enemy or hostile civilian from custody

[73] Evan Thomas and Scott Johnson, "Probing a Bloodbath: The Marines were well prepared for war, but not for insurgency. Did some of them snap—and slaughter innocent civilians in cold blood?" *Newsweek*, 12 June 2006. Retrieved 4 June 2006 from the World Wide Web at http://www.msnbc.msn.com/id/13124487/site/newsweek/site/newsweek/.

(after surrender) and inadvertently engaging a civilian in the wrong place at the wrong time.

- Allegiance of personnel on the urban battlefield can be dynamic. This modeling methodology allows for changing alliances based on events (such as a civilian being fired on with lethal means and communicating to others—potentially causing a riot).

2. Hostile Civilians

- A civilian becomes a combatant the moment hostility is shown, regardless of intent. For the safety of the Soldiers and the unit, these actions should (and have, in this study) receive lethal engagement.
- Hostile civilians are unpredictable and may pose a threat when least expected. One or several Soldiers may safely pass such an individual before hostility is displayed. These individuals are potentially more dangerous than a recognized adversary.
- Suicide bombers are a viable and very dangerous threat. Having some means to interrogate these individuals is essential to safety and mission accomplishment. Misunderstandings (such as misidentifying an enemy attack) can jeopardize the mission and the image of the U.S. military. We cannot win the hearts and minds of the locals by improperly engaging them with lethal means.

3. Non-Lethal Weapons (NLWs)

- This research recommends an NLW that can be employed and supported across the spectrum of military operations: the XM303.
- NLWs can be used to interrogate/determine intent rather than incapacitate. When employment focuses on determining intent rather than delivering sufficient force/pain to incapacitate, accidental deaths and animosity are greatly diminished.

- The success of NLWs may be directly related to the extensiveness of an accompanied Psy-Ops campaign explaining said tactics. Perceived intentions of the target are directly tied to compliance or noncompliance in accordance with the Psy-Ops guidance.

4. Simulation Results

- Blue survivability does not suffer from using NLWs. Quick, lethal response (if noncompliant), superior optics/engagement ability, and FFW body armor offset the risk of lethal fire returned by the (once unconfirmed) target.
- An extended range NLW (50 meters) generally yields higher CE scores than a 25-meter range or even a greater number of NLWs distributed to the SCU.
- Under conditions when it is difficult to differentiate targets (High Misidentification Level), it is advantageous to have more NLWs (increased distribution) than extended range.
- In conditions where it is relatively easy to discriminate friend from foe, (Low Misidentification Level), the use of NLWs may cause slightly more casualties than not using an NLW. This is associated with a higher probability of noncompliance than the probability of misidentifying. If you shoot enough civilians with NLWs, a few are (unfortunately) bound to be noncompliant. In cases of low misidentification, Soldiers should consider this characteristic before employing lethal means.
- Stopping the Suicide Bomber is crucial to success, especially during High Misidentification. It is not difficult to understand why. Any NLW capability dramatically reduces the chance of a successful suicide attack, regardless of identification/misidentification ability.
- Each increase in NLW capability (distribution and range) results in additional Hostile Civilian surrenders.

D. RECOMMENDATIONS FOR FUTURE RESEARCH

Throughout the tenure of this research, I have generally seen the reactions of surrounding military personnel toward the use of NLWs in combat operations change. Initial reactions were perceived as a futile (academic) effort whose employment would jeopardize the users in combat. As these personnel became more familiar with the proposed employment and tactic, opinions generally changed to increasing confidence and support of such a tactic as if it were inevitable and obvious. This is reminiscent of the visit I paid to the JNLWD staff, who informed me that the biggest obstacle to the employment of NLWs is lack of education about their use. Once NLWs and their applications are properly understood, they tend to become much better supported and, in this researcher's opinion, doctrinally inevitable.

Educating individuals on the use of NLWs is a demanding task. Applications of employing NLWs can be difficult—especially in uncertain situations. Modeling the real world circumstances that support the use of NLWs has been a challenge to the military M&S community. While this research effort cannot confidently define the precise consequences of NLWs in combat operations, the insights provided hope to spur additional work. This area is relatively uncharted territory and could certainly benefit from additional research. Some suggestions are listed below.

- Use the increased functionality of Pythagoras version 1.10 to gain additional insights through data farming.
- Investigate how to determine the tactical identification level of regional areas and specific operations. This could assist in tailoring NLW employment tactics.
- Define metrics for cost and benefit of surrendered personnel (neutral, hostile, and enemy) to be used for evaluating a more comprehensive CE score and for future analytical comparisons.
- Determine the regional Psy-Ops efforts required to initiate proposed NLW tactics.

- Increase the range of behaviors in modeling NLWs to better characterize hostility and reactions. Improvements should include reactions to getting hit with lethal weapons (since civilians could potentially initiate mob behavior) and non-lethal weapons (e.g., if an enemy flees to engage at a later time) weapons.
- Adapt a similar identification framework to existing and future M&S.
- Customize the payload of NLWs to include a dye or irritant to dissuade noncompliance.

E. CONCLUDING REMARKS

Adversaries that are virtually indistinguishable from civilians will likely remain a typical phenomenon on the battlefield for quite some time. As a result, military operations must consider both the enemy and the often unwilling participants. Under the provisions of the Law of Armed Conflict, we have an obligation to safeguard noncombatants from unnecessary suffering.[74] While lethal means must always be the default method of force, non-lethal weapons may significantly reduce civilian casualties without reducing our combat effectiveness.

[74] United States Army, *The Law of Land Warfare*, Field Manual 27-10, (Washington, D.C.: U.S. Government Printing Office, 2001), p. 4-13.

APPENDIX A – DoD POLICY FOR NLWs

Department of Defense

DIRECTIVE

NUMBER 3000.3
July 9, 1996
Certified Current as of November 21, 2003

ASD(SO/LIC)

SUBJECT: Policy for Non-Lethal Weapons

References: (a) Title 10, United States Code
(b) DoD Directive TS-3600.1, "Information Warfare (U)," December 21, 1992

1. PURPOSE

This Directive under reference (a):

1.1. Establishes DoD policies and assigns responsibilities for the development and employment of non-lethal weapons.

1.2. Designates the Commandant of the Marine Corps as Executive Agent (EA) for the DoD Non-Lethal Weapons Program.

2. APPLICABILITY AND SCOPE

This Directive:

2.1. Applies to the Office of the Secretary of Defense, the Military Departments (including the Coast Guard, when it is operating as a Military Service in the Navy), the Chairman of the Joint Chiefs of Staff, the Unified Combatant Commands, the Defense Agencies, and DoD Field Activities.

2.2. Applies to all non-lethal weapon development and acquisition programs and the employment of fielded non-lethal weapons.

2.3. In general, does not apply to command and control warfare or any other military capability not designed specifically for the purpose of minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment,

even though they may have these effects to some extent. However, for those matters involving information warfare, refer to reference (b).

3. DEFINITION

3.1. Non-Lethal Weapons. Weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment.

3.1.1. Unlike conventional lethal weapons that destroy their targets principally through blast, penetration and fragmentation, non-lethal weapons employ means other than gross physical destruction to prevent the target from functioning.

3.1.2. Non-lethal weapons are intended to have one, or both, of the following characteristics:

3.1.2.1. They have relatively reversible effects on personnel or materiel.

3.1.2.2. They affect objects differently within their area of influence.

4. POLICY

It is DoD policy that:

4.1. Non-lethal weapons, doctrine, and concepts of operation shall be designed to reinforce deterrence and expand the range of options available to commanders.

4.2. Non-lethal weapons should enhance the capability of U.S. Forces to accomplish the following objectives:

4.2.1. Discourage, delay, or prevent hostile actions.

4.2.2. Limit escalation.

4.2.3. Take military action in situations where use of lethal force is not the preferred option.

4.2.4. Better protect our forces.

4.2.5. Temporarily disable equipment facilities, and personnel.

4.3. Non-lethal weapons should also be designed to help decrease the post-conflict costs of reconstruction.

4.4. The availability of non-lethal weapons shall not limit a commander's inherent authority and obligation to use all necessary means available and to take all appropriate action in self-defense.

4.5. Neither the presence nor the potential effect of non-lethal weapons shall constitute an obligation for their employment or a higher standard for employment of force than provided for by applicable law. In all cases, the United States retains the option for immediate use of lethal weapons, when appropriate, consistent with international law.

4.6. Non-lethal weapons shall not be required to have a zero probability of producing fatalities or permanent injuries. However, while complete avoidance of these effects is not guaranteed or expected, when properly employed, non-lethal weapons should significantly reduce them as compared with physically destroying the same target.

4.7. Non-lethal weapons may be used in conjunction with lethal weapon systems to enhance the latter's effectiveness and efficiency in military operations. This shall apply across the range of military operations to include those situations where overwhelming force is employed.

5. RESPONSIBILITIES

5.1. The Assistant Secretary of Defense for Special Operations and Low-Intensity Conflict under the Under Secretary of Defense for Policy, shall have policy oversight for the development and employment of non-lethal weapons.

5.2. The Assistant Secretary of Defense for Strategy and Requirements, under the Under Secretary of Defense for Policy, shall have policy oversight for the review of crisis action and deliberate plans, and shall ensure that the availability of non-lethal weapons is considered in their development.

5.3. The Under Secretary of Defense for Acquisition and Technology shall have principal oversight responsibility for the DoD Non-Lethal Weapons Program, including joint Service program coordination to help highlight and prevent duplication of development in both classified and unclassified programs.

5.4. The Chairman of the Joint Chiefs of Staff shall:

5.4.1. Advise the Secretary of Defense on development and employment of non-lethal weapons.

5.4.2. Assess military requirements for non-lethal weapons acquisition programs.

5.4.3. Monitor the development of Service non-lethal weapon programs.

5.4.4. Develop and promulgate joint doctrine, as appropriate, to incorporate emerging capabilities of non-lethal weapons.

5.5. The Commanders of the Unified Combatant Commands shall:

5.5.1. Ensure that procedures exist for the integration of non-lethal weapons into operational mission planning.

5.5.2. Identify the warfighting requirements of the Unified Combatant Commands.

5.6. The Secretaries of the Military Departments and the Commander in Chief of the United States Special Operations Command shall:

5.6.1. Ensure the development and implementation of employment concepts, doctrine, tactics, training, security procedures, and logistics support for fielded non-lethal weapons systems in accordance with policies defined in this Directive.

5.6.2. Ensure that a legal review of the acquisition of all non-lethal weapons is conducted. The review should ensure consistency with the obligations assumed by the U.S. Government under all applicable treaties, with customary international law, and, in particular, the laws of war.

5.6.3. Ensure that only those non-lethal weapon development programs that satisfy the general requirements of technical feasibility, operational utility, and policy acceptability are considered for support.

5.6.4. Consistent with existing guidelines on management of acquisition programs, establish guidelines to emphasize that non-lethal weapons must:

5.6.4.1. Achieve an appropriate balance between the competing goals of having a low probability of causing death, permanent injury, and collateral material damage, and a high probability of having the desired anti-personnel or anti-materiel effects.

5.6.4.2. Not be easily defeated by enemy countermeasures once known; or if they could, the benefits of a single opportunity to use the weapon in a given context would be so great as to outweigh that disadvantage.

5.6.4.3. Achieve an effect that is worth the difficulty of providing the intelligence support required for mission planning and damage assessment.

5.6.5. Consistent with applicable security guidelines, provide program visibility to the Chairman of the Joint Chiefs of Staff and the Unified Combatant Commanders.

5.7. The Secretary of the Navy shall ensure that the Commandant of the Marine Corps serves as the EA for the DoD Non-Lethal Weapons Program. The EA shall be responsible for program recommendations and for stimulating and coordinating non-lethal weapons requirements.

5.8. The Assistant Secretary of Defense for Command, Control, Communications, and Intelligence shall:

5.8.1. Establish policy and provide direction for development of the necessary DoD informational and intelligence capabilities to enable effective use of non-lethal weapons.

5.8.2. Provide policy and guidance when non-lethal weapons matters involve DoD information warfare under DoD Directive TS-3600.1 (reference (b)).

5.9. The Assistant Secretary of Defense for Public Affairs shall coordinate and approve guidance on public affairs matters concerning non-lethal weapons and their use.

6. EFFECTIVE DATE

This Directive is effective immediately.

John P. White
Deputy Secretary of Defense

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APPENDIX B – NLW SELECTION CRITERIA

The first thing we do, let's kill all the lawyers.

William Shakespeare, *Henry VI*

A. GETTING STARTED

The primary source (directly referenced or abbreviated throughout this appendix unless otherwise noted) used in this selection process is FM 3-22.40 *Non-Lethal Weapons: Tactical Employment of Non-Lethal Weapons*. Before diving into selecting the most appropriate NLW, it is worth examining the core capabilities and limitations of NLWs.

1. Core Capabilities

Core capabilities are those fundamental competencies that enable U.S. forces to achieve desired operational objectives. The core capabilities fall into three major categories: counterpersonnel, countermateriel, and countercapability.

a. Counterpersonnel Capabilities:

(1) To incapacitate personnel. Incapacitation is achieved when the weapon's effects render personnel unable to physically or mentally act in a hostile or threatening manner and should be reversible through the passage of time.

(2) To deny personnel access to an area through physical or mental discomfort.

(3) To clear facilities and structures of personnel. Reduces the risks of noncombatant casualties and collateral damage while simultaneously minimizing the advantages accruing to an enemy defending a built up area.

(4) To seize personnel. Intended to augment lethal means used to capture specified individuals.

b. Countermateriel Capabilities:

(1) Rendering equipment and facilities unusable without complete destruction by attacking only weapons of war and supporting infrastructure.

(2) Disabling or denying the use of vehicles, vessels, and aircraft entry into targeted areas or access within an AO.

c. Counter Capability Capabilities:

(1) Disable or neutralize facilities and systems. This includes disabling/neutralizing electrical generating facilities, command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems, Integrated Air Defense Systems (IADS), weapons systems, optical sensors, electrical sensors, and

navigation capabilities with such controlled effects as to allow for selective, precise engagement.

(2) Deny the use of weapons of mass destruction (WMD). Mission needs include rendering a WMD inoperative; containing the potential release of deadly agents/contaminants; and preventing or neutralizing the production, storage, deployment (transport), employment, and delivery of WMD.

2. Limitations: Effectiveness, Perception, and Legality

a. The effectiveness of NLW is dependent on factors such as motivation, age, environmental and human factors, range of engagement, and numerous others. NLW can be lethal if improperly applied. Furthermore, countermeasures for thwarting virtually all nonlethal options are usually apparent, quickly learned, and readily available. Because they are not intended to kill, nonlethal options teach adversaries what to avoid in the future. Small unit commanders must prepare to keep one step ahead of belligerents.

b. The perceptual limitation is that personnel may misunderstand the appropriate applications of NLW across the range of military operations. The incorrect perception that NLW will allow wars and MOOTW to be prosecuted without casualties may lead to conflicting expectations between political and military leaders. All leaders, political and military, involved in planning and executing military missions must understand there are no "nonlethal operations."

c. Some proposed NLW might be forbidden by law or policy. Accordingly, it is essential that all NLW developments be evaluated by appropriate authorities to ensure they comply with the law of war, U.S. law, and U.S. treaty obligations. Use of NLW containing chemical agents, for instance, must be evaluated in the context of the Chemical Weapons Convention. Also, using RCA in an armed conflict requires Presidential approval.

B. NLW SELECTION FACTORS

In light of the capabilities and limitations of NLWs, five factors were considered when selecting an NLW for combat operations: versatility, ease of employment, performance, safety, and others.

1. Versatility: The NLW must be suitable across the entire spectrum of operations, from combat operations and the Global War on Terrorism, to humanitarian and peacekeeping operations, to homeland defense. The typical U.S. Soldier is already encumbered with an incredible amount of gear and increasing his/her load must be carefully balanced against the benefits provided by additional equipment. One NLW should be capable of handling multiple/different situations. Logistics support for the system and munitions must also be considered.

2. Employment Ease: Transitioning from lethal fire to non-lethal must not detract

from the combat mission. Soldiers cannot afford to sling their primary weapon in order to employ an NLW and thereby create a potential vulnerability.

3. Performance Parameters: This rather broad category covers things such as effective range, accuracy, rate of fire, reload time, weight, etc.

4. Safety and Public Acceptability: Using an NLW that maims or is perceived to have the potential to permanently injure or is deemed cruel will not help us win the hearts and minds of the populous. Included in this factor are the probability of accidental death from the munition itself (usually due to range of engagement) and the possibility of the Soldier confusing non-lethal means with lethal means during engagement.

5. Other: Includes system advantages and disadvantages not covered in the previous four categories, such as multi-functionality, tailorable effects, training requirements, and unambiguous messages sent to targeted personnel.

C. NLW INITIAL SCREENING

Since this research seeks to model urban combat operations, the most appropriate NLW should have a counterpersonnel capability at a range of 25 meters (FFW capability requirement) with potential range improvements to 50 meters. Upon examining the vast array of NLWs with a counterpersonnel capability (according to FM 3.22-40, the online NLWs Certification course documents, personal interviews with JNLWD and Las Angeles Sherriff department personnel, and online), initial screening was done with the two most restrictive factors/criteria—Employment Ease and Safety. The NLW must be able to be employed rapidly and safely. These two criteria essentially demand:

- lethal and non-lethal means must be available on the same platform (M16/M4/M203)
- transition between lethal and non-lethal cannot involve changing munitions
- no confusion between lethal and non-lethal munitions

This restriction eliminated the vast majority of the possible options. Soldiers cannot afford to eject rounds in a weapon and reload with the alternate munition. Not only does this require quite possibly crucial time, it also allows for inadvertently confusing the type of munition being loaded, especially during limited visibility. The remaining NLWs for consideration are listed and described below.

Lightweight Shotgun System (LSS) – The LSS is magazine fed and fires all 12 gauge munitions (up to 3” shells) to include non-lethal.

FN303/XM303 – The FN303 is a semi-automatic, compressed air launcher, shoulder-fired weapon designed exclusively for the employment of non-lethal munitions (blunt impact, marking, and OC).

M203 – conventional M203 that fires 40 mm NL munitions, to include: Crowd Dispersal Cartridge (CDC), Sponge Grenade, and Foam/Rubber Baton Round.

Laser Illuminator[75] – temporarily impairs and adversary's ability to fire a weapon. Loads into a modified M-203 40mm grenade launcher which can be ejected and replaced with a grenade in an emergency. It briefly illuminates an opponent with harmless, low power laser light. Realizing he has been targeted, the aggressor hides or flees rather than risk death by fire. On night operations it can degrade human night vision capability and electronic night vision devices.

Laser Dazzler[76] – a high resolution green laser used to flash-blind and disorient an aggressor at long range. Available in various sizes, from pen-sized devices to rifle size units.

D. NLW SELECTION: FN303

These five systems were then scrutinized against all five factors and the FN303 was deemed the most appropriate for combat operations as well as operations across the spectrum of conflict. A few of the key features of the system are listed:

- very low risk of injury
- easily supportable
- fires very rapidly, accurately, and quietly
- *can be used to interrogate a targets intent*
- can use a payload containing dyes (to mark even vehicles) or OC

A very brief explanation below outlines the deficiencies of the other 4 systems (in the opinion of the author):

LSS – the kinetic 12 gauge rounds have the potential to cause serious injury or death from blunt trauma, especially at ranges less than 10 meters (at night in an urban environment, this range is not uncommon). Several are not effective past 20 meters. While the LSS is versatile by itself to fire non-lethal and lethal means, the possibility arises of confusing the two. The target and surrounding personnel may be confused of

[75] "No Longer Science Fiction: Less Than Lethal and Directed Energy Weapons," Defense, Issue 1, 2005, http://www.defense-update.com/products/s/saber-203.htm.

[76] http://www.defense-update.com/products/s/sabershot.htm.

non-lethal intent because it will be indistinguishable (sound) from a lethal application (an observer will hear the discharge and then may see the target drop—unclear which munition was used).

M203 – similar to the LSS in that serious trauma or death can occur, especially at a range less than 10 meters. Also can fire both types of munitions (lethal and non-lethal), which means they can be confused. Rate of fire for this system is very slow. Logistically, the rounds are cumbersome.

Laser Illuminator/dazzler – are logistically very supportable and conducive to interrogation, but are limited during daylight hours. Not tailorable. Target must be looking at the firer. Employment intent may not be a clear.

E. FN303/XM303 SYSTEM DESCRIPTION[77]

The FN303 Less Lethal Launcher is completely dedicated to reduced lethality and liability, the basis of the FN303 concept lies in its ammunition. The projectiles used are a fin-stabilized polystyrene body and nontoxic bismuth forward payload to provide both a more accurate and greater effective range than other less than lethal weapons. Secondary effects from projectiles can be delivered via a chemical payload depending on mission requirements. Magazines have a 15-round capacity with a clear rear cover to allow for rapid ammunition payload verification. The 3000-psi compressed air reservoir powers the FN303 launcher for an effective range of 50 meters at a point specific target with a maximum range of 100 meters. In addition to the flip-up iron sights, the integrated Picatinny 1913 rail can be used to mount red dot sights or other accessories.

Figure 1. XM303 Less Lethal Launcher

The projectiles have been specially designed to break up on impact, thereby eliminating any risk of penetration injury. The four types of projectiles available are: training/impact - 100-percent nontoxic glycol base; washable paint - fluorescent pink pigment in a nontoxic glycol base; permanent paint - latex-based polymeric paint; and Oleoresin Capsicum (OC) - orange-dyed nontoxic glycol base plus 10-percent OC (pepper) concentrate at 2 million Scoville Heat Units.

Additional details and performance measures can be obtained through the Human Effects Center of Excellence at the Joint Non-Lethal Weapons Directorate (see slides below regarding this weapon system).

[77] FN303 Less Lethal Launcher Urgent Fielding Requirement Safety Assessment, U.S. Army Aberdeen Test Center, Aberdeen Proving Ground, MD, 18-26 November 2003.

FN303 Projectiles

Washable

Fluorescent pink pigment in a glycol base

Training/Blunt Impact
100% non-toxic glycol base

Indelible marking
Yellow permanent latex based polymeric paint

OC Liquid
Orange dyed non-toxic glycol base with 5% OC (pepper) concentrate

- Projectiles utilize a fin stabilized polystyrene body and non-toxic bismuth forward payload
- Primary effect is trauma from the 15J/cm3 impact
- Magazine holds 15 projectiles

FN-303 Less-Lethal Launcher Description (FCT + JNLWP)

Under-Barrel Config.

TECHNOLOGY

- ✓ **Compressed air powered launcher designed to fire 0.68 caliber 8.5 g less-than-lethal projectiles**
- ✓ **Made of Durable, Light-weight Polymer**
- ✓ **Allows for greater engagement range (100m), higher accuracy, and higher rates of fire than any currently fielded non-lethal capability**
- ✓ **In excess of 100 semi-auto shots per air bottle**
- ✓ **Both stand-alone and under-barrel (for the M16/M4) versions are available**
- ✓ **Integrated Picatinny rail for mounting red dot sights or other accessories.**

CAPABILITIES OF ITEM

- **Point Targets out to 50m**
- **Area Target out to 100m**
- **Deny an area to personnel**
- **Stand alone or under-barrel version**
- **Use of Iron Sights Effective out to 50m**
- **Use of Optical Sighting (Red Dot) recommended over 50m**
- **Muzzle velocity of 85-90 m/s, chamber pressure of 40 Bar**

STATUS

- **Rapid Equipment Fielding of 30 systems to CTF-180 (Bagram AB, Afghanistan), February 2004**
- **UMR completed for 80 systems to MNC-I**
- **Limited Safety Confirmation testing has been completed**

APPENDIX C – SMALL UNIT TEAM EXPLORATORY SIMULATION (SUTES)

Disclaimer: The information provided in this appendix was extracted directly from the FFW Exploratory Analysis Phase II Report prepared by Robert S. Alexander 31 July 2005. It is intended to provide background on the simulation used for previous experimentation and analysis as well as for comparisons to the simulation used for this thesis research using Pythagoras.

The Small Unit Team Exploratory Simulation (SUTES) was custom-built by the analysis team to model FFW Small-Combat Unit operations. It was intended as an interim tool while simulations such as OneSAF and IWARS were built and validated. SUTES was built to be a screening tool used to explore a wide range of factors, each modeled at a basic level of fidelity. As such, SUTES is not an engineering model. In general it represents physics implicitly, not explicitly. For example, it models weapon accuracy with tables of inherent error over range, not with a flyout model.

Basic combat models in SUTES are derived from OneSAF Testbed (OTB). Sensor acquisition of targets is modeled by the ACQUIRE target acquisition algorithm. The ACQUIRE model considers the thermal or optical contrast of the target with its background and compares it with the resolution of the sensor to determine the resolution achieved at the measured range. The sensor resolution achieved is then compared with the Johnson Criterion to determine what level of target acquisition (no detect, detect, classify, recognize, identify) is achieved.

Munition accuracy is modeled by inherent error in degrees for each type of munition. This measure serves as the standard deviation σ of a Normal(0, σ) distribution from which the actual error is drawn. Using this error in degrees to compute the error in meters at the appropriate range, the damage achieved is determined by referencing a Uniform(0,1) random number to a damage probability table which lists probabilities of mobility kill, firepower kill, mobility and firepower kill, and catastrophic kill.

Each entity moves over a path defined by waypoints and legs between waypoints. Intended speed is specified for each leg along with other parameters. The mobility

algorithm considers the intended speed of each entity and constrains it by the maximum speed allowed by the soil type at the location of the entity.

Behaviors are scripted, not automated. Many combat simulations represent complex behaviors of entities and units. Since these behaviors attempt to model human decision-making, they are often complex and difficult to encode. Often these behaviors are disappointing in their fidelity. Rather than embark on a long process of building behaviors into SUTES, in keeping with the intent that SUTES be an interim screening tool, the deliberate design decision was made to require the user to script most behaviors. Therefore, for example, a user will plot waypoints for a squad and cause one fire team to wait in an overwatch position until the other fire team completes its bound, instead of expecting the simulation to represent a "bounding overwatch" behavior. One implication for analysis using SUTES is that the actions of the users in scripting a scenario are very much a part of the analysis itself. Several reactive behaviors are modeled in SUTES. An entity, upon detecting an enemy, will normally engage the enemy unless his "rules of engagement" attribute prevents it. He will report the entity to others on his radio network. Upon being engaged, an entity will normally go prone and return fire. When nearby friends are engaged, he will react in the same manner. There is one basic decision criteria which an entity can use to choose between one of two branches in his route, which is to branch if he is aware of enemy within a specified range. A supporting decision criterion allows entities to branch depending on the branch chosen by another entity. Using this construct, for example, a leader can choose between two branches, and his subordinate Soldiers will follow his lead without the need for them to make an independent decision.

An important input to the attrition, target acquisition, and mobility algorithms is performance data for the various systems in use. The performance data used in Exploratory Analysis was derived from three sources. For FFW-specific systems, the FFW IPTs provided input. The most important of these systems was the fused thermal/infrared sensor, for which data was provided by DRSOptronics via the Headgear IPT. For systems related to Future Combat Systems, unclassified data from the FCS program was used where available. For other systems, data from the OneSAF TestBed (OTB) simulation was used, for example, for PVS-14 Night Vision Goggles.

APPENDIX D – ROAD TO WAR

Disclaimer: The information provided in this appendix was extracted from the "Study Plan Supporting Analysis of the Objective Force Warrior – Night Attack in a Major Urban Area" prepared by the Dismounted Battlespace Battle Lab, Ft Benning, GA, 23 June 2003. It is an abbreviated summary of "Vignette B: Night Attack into an Urban Environment" and is intended to provide background to the scenario used for analysis.

Background: In 2014, twenty years of independence for the Trans-Caucasus States found serious socio-political, ethno-religious, and economic conflict spreading through the region. Azerbaijan emerged as the leading economic power through the exploitation of Caspian and Central Asian oil reserves. Azerbaijan's politics were deeply divided; its citizens and Karabakh refugees demanded the government take military action against the Armenian Karabakh. The Azerbaijani government refused to act, and refugees from the Nagorno-Karabakh Internal Liberation Organization [NKILO], using terror and armed force to achieve their goals, began a cross-border campaign designed to force a confrontation between the two countries. Observing these developments, Armenia and Iran viewed the Azerbaijani government's instability as an opportunity for exploitation. Armenia began massing maneuver forces along the Azerbaijani border and repositioned mobile Theater Ballistic Missile launchers. Both countries perceived a low risk of failure and were willing to impose a military solution upon "the Azerbaijani problem."

In late November, the Azeri Islamic Brotherhood (AIB), a coalition of anti-government factions supported by NKILO and ANFAR military forces, subverted the bulk of an Azeri Motorized Rifle Brigade, which mutinied to join them. The brigade seized control of most of the historically significant Icheri Sheher (Inner Town) district but a desperate defense by loyal government forces managed to secure the centers of government within the city. Meanwhile, two armed clan-based factions of the Azeri Islamic Brotherhood, the Aziz and Daha, extended their control of the eastern and western outskirts of Baku and intensified their efforts to overthrow the legitimate government.

As a last resort, the Azerbaijani government requested assistance from the Russian Federation to defeat the insurgents and preclude an anticipated invasion by Armenian forces. On 15 December, Russia proposed a coalition of US and Russian forces to restore order within Azerbaijan and stabilize the government. Two days later, the US agreed to the proposal and the two nations created a coalition force.

In January 2015, after consultations by the three governments, the President of the United States authorized the deployment of Air Force assets into Turkey to establish staging bases for the deployment of US forces. The Army's expeditionary distribution battalion of the expeditionary support force accompanied the Air Expeditionary Force (AEF) into theater to establish visibility and throughput capability as far forward as possible.

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APPENDIX E – BASE SCENARIO ORDER

Disclaimer: The information provided in this appendix is intended to describe the vignette and operations order (OPORD) used by the OFW ATD Integrated Analysis and Simulation Team during a October 2003 MAPEX.

A Company/1st CAB (ICV) OPORD

Copy 1 of 1 Copy
A Company / 1st CAB (ICV)
Baku, Azerbaijan (UK813076)
____1700L____NOV 03

OPERATION ORDER
Reference: Map, Special series, Baku Azerbaijani 1:250,000
Time Zone Used Throughout the Order: LOCAL
TASK ORGANIZATION:
A Company/1st CAB (ICV)
1st Platoon
2nd Platoon
3rd Platoon

1. SITUATION:

A. Enemy Forces.

(1) Enemy Activities. The legitimate government of Azerbaijan has been overthrown by the Azari Islamic Brotherhood (AIB) and forced into exile. The AIB has garrisoned small units (Platoon and Squad size) throughout the capital city of Baku to secure key elements of power and control the populace. They have taken control of the Government Television and Radio Studio situated on the third floor of the Government House (OBJ BLUE), situated 2 miles inland from the bay of Baku, and are broadcasting propaganda in their effort to influence the local populace.

(2) Composition, Disposition, Strength/Capabilities

(a) Composition. Each motorized infantry company has 3 platoons with 3 squads each. Each platoon has three BMP-2 armored fighting vehicles. Each squad has 8-10 soldiers. The AIB also fields guerilla companies of 2 or 3 platoons with 3 squads each. Each company is equipped with a mix of communist block weapons (AK47s, RPKs, RPG 7/22s, etc). Limited night vision equipment exists, often distributed to squad leaders mission by mission. The enemy operates with separate heavy weapons platoons equipped with 4 x 82mm mortars and 16 surface to air missile launchers (SA-18 type).

(b) Disposition. The AIB has positioned a motorized infantry platoon near the Government House (OBJ BLUE) with the mission of securing it. The platoon hides the armored fighting vehicles in various garages in the vicinity, moving them daily. Security of the Government House rotates among the squads of the platoon.

(c) Capabilities/Strength. The AIB (Azari Islamic Brotherhood) are

well trained and capably led. They are able to conduct operations under all weather conditions, day or night. They are familiar with the terrain and can live off the land with the help of the local populace. The AIB is very adept at conducting centralized operations within a large area. Squad sized elements are expected to influence populations in an area in excess of 8 square Km. They use platoon and company-sized caches to re-supply ammunition and medical supplies. They are capable of surviving off of stolen US rations. Their primary means of re-supply is through the local populace, which moves supplies by trucks (civilian and military), or Technical All-Terrain Vehicle (ATVs). The C2 for the AIB is decentralized. Each squad will have some type of radio equipment, but messengers are often used to relay orders. In addition to captured ordinance, the insurgents have homemade mines, booby traps, and hand grenades. Expect the AIB to use captured munitions to fabricate all types of booby traps and anti-handling devices. The AIB has very skilled 82mm mortar and SA-18 AD teams. Each team is highly drilled at employment and evasion. The AIB squads are particularly well trained in several battle drills, to include the baited ambush, and break contact. All members can be considered expert marksman.

(3) Most Probable Course of Action. The AIB will continue to patrol in zone and attempt to disrupt the movement of US forces through the area. Upon our entry into the AO we can expect the AIB to remain at Level I operations, meaning they will not show themselves until the last possible opportunity. AIB recon teams will seek to determine our patterns and attempt to identify weaknesses in the force protection of our C2 and logistical infrastructure. They will also conduct terrorist attacks against population centers and civilian leaders, primarily in the Government House area. They will operate in teams and squads, only massing into platoons and companies when they need additional combat power. The mortars and air defense weapons will be used to harass and interdict US forces in an attempt to disrupt normal operations and create casualties. They will avoid decisive engagement. They will fight to retain supply caches, C2 sites, and heavy weapons. Surveillance suggests that the squad securing OBJ BLUE is attempting to protect the Government Building from reoccupation by legitimate government officials, rather than to defend against a deliberate attack, since the occupying squad does not emplace exterior barriers, conduct exterior patrols or man observation posts, but patrols the interior halls of the building. Upon contact, the squad conducting building security will most probably defend the TV/Radio studio on the third floor, and the platoon defending OBJ BLUE will most probably attempt to reinforce the dismounted squad with the platoon's three armored fighting vehicles and other two infantry squads.

B. Friendly Forces.

(1) Higher Headquarters: 1st CAB (IAV) has advanced through BAKU along axis of advance Raiders with Recon Company leading. Upon initial detection of the enemy by Recon Company, A Company and B Company passed through Recon Company with B Company on the left and A Company on the right. C Company has been given a follow-and-support mission behind A Company. Recon Company is conducting a hasty reorganization eight blocks South of OBJ BLUE. On order, A Company will attack OBJ BLUE, Azerbaijani Government House (HU 123456), to

secure the radio and television studio and B Company will attack OBJ GREEN (HU 113456) to seize key road intersections in order to limit enemy freedom of movement in the west-central portion of the city.

INTENT:

- Prevent the AIB from controlling the key central section of the capital city of Baku.
- Restore the legitimate Government's use of its Government Building and TV/Radio Studio.

CONCEPT:

The A Company will conduct a penetration of OBJ BLUE. The decisive point is the capture of the radio/television station. This is decisive because it will break the OPFOR's ability to reach the public, and return that ability to the legitimate government. Desired end state is the radio/television station secured and operational, and the Government House secured.

2. MISSION: O/O A Company attacks OBJ BLUE vic (HU 123456), in order to secure the radio/television station.

3. EXECUTION:

A. Concept of the Operation. O/O 1st Platoon seizes OBJ BLUE in order to secure the TV/Radio studio, while 2nd and 3rd Platoons occupy positions east, north-east, and north-west of OBJ BLUE to block enemy from reinforcing OBJ BLUE. Decisive to this operation is the rapid seizure of the central stairwells and center of the third floor of OBJ BLUE 1 (Government House). This is decisive because it will prevent AIB from destroying the radio/television station and allow its control. 3rd Platoon weapons squads will provide supporting fires from the roof of Building 6 onto the East Wing of OBJ BLUE. Platoon ARV-Ls will be positioned to control the streets and open area north of OBJ BLUE. 1st Platoon ARV-L will be used initially to attack by fire into the first floor north entrance of Bldg 1 (OBJ BLUE), and then be controlled by A Company Robotics NCO. Desired end state is the radio/television station in the Government House secured and unit postured to defend it from counterattack.

(1) Maneuver. (See Operations Overlays, Figures 1-5). A Company will dismount and move covertly to assault positions south of Buildings 5, 6, and 17, then move covertly to initial breach positions. When platoons report "Ready", Company Commander will initiate a coordinated attack on initial breach targets with the command "Execute". Following a ten-second delay, synchronized attack of breach targets will begin.

(2) Effects.

(a) Preplanned Target Reference Points identified along likely avenues of approach.

(b) Initial attack of breach targets and supporting fires will be synchronized ten seconds following commander's command "Execute". 1st Platoon ARV-L will attack by fire on the first floor north entrance of Bldg 1, 1st Platoon squads will breach their initial entry points, and 2nd and 3rd Platoons will breach their initial

entry points.

(c) 18 LAMs and 12 PAMs are available for Company use. 2 LAMs will be launched when Commander issues the "Execute" command, and will loiter for 25 minutes. An additional two LAMs will then be launched and the loitering LAMs will be directed to fire at any target of opportunity. PAMs will be launched at targets of opportunity vicinity TRP A100, A101, A102, and A103.

(3) ADA Operations. N/A

(4) Intelligence. UGS Field will be emplaced by Class II UAV north of Bldgs 16, 18, and 19, to detect tracked or wheeled vehicles or dismounted personnel moving from the north toward OBJ BLUE.

(5) Electronic Warfare. N/A

(6) Engineering. 2nd and 3rd Platoon ARVs will attack by fire to destroy manhole covers into under-street tunnels upon the Commander's "Execute" command. 1st Platoon ARV under company control will be responsible for manholes on the street directly north of OBJ BLUE, but will not attack them until 1st Platoon's northern squad has entered Entry Point BRAVO. Each shot by 1st Platoon ARV in front of OBJ BLUE will be preceded by a check of friendly positions and a notification to 1st Platoon personnel to prevent fratricide through north-facing windows.

(7) Deception. N/A

B. Tasks to Maneuver Units.

(1) 1st Platoon seizes OBJ BLUE in order to secure the TV/Radio studio

(a) Position Class I UAV on the roof of building 1 and orient to the north.

(b) Deploy ARV-A(L) to north side of bldg 1 to attack Bldg 1 first floor main entrance by fire. ARV-L will then be detached to Company control for use in blocking enemy reinforcements to OBJ BLUE.

(c) Enter OBJ BLUE by three simultaneous breaches into first floor north and south, and second floor south via Entry Points ALPHA, BRAVO, and CHARLIE. Clear Stairwells NORTH and SOUTH, clearing rooms as needed to control line of communication out of Bldg 1, and seize TV/Radio Studio on the third floor of Bldg 1.

(d) When TV/Radio Studio is controlled, clear the rest of Bldg 1 and be prepared to defend Bldg 1 from armored or dismounted counterattack.

(2) 2nd Plt occupies Buildings 2, 14, and 15 and defends in order to block enemy forces from reinforcing OBJ BLUE

(a) Position Class I UAV on top of Objective Blue (Bldg 1) and orients to the North.

(b) Deploy ARV-A(L) on the north side of building 14, oriented north and east to block reinforcements.

(c) Detach 2 SUGVs to Company Robotics NCO.

(3) 3rd Plt occupies Buildings 4 and 3 in order to block enemy forces from reinforcing OBJ BLUE, and supports by fire from the roof of Bldg 6 with one weapons squad.

(a) Position class I UAV on roof of building 3, and orients its sensor to the north along building 1.

(b) Deploy ARV-A(L) to the north-east side of building 10, to block reinforcements from the north and west.

(c) O/O attack and clear and seize the first three floors on the west end of building 1.

(d) Occupy support-by-fire position on the roof of Bldg 6 with one weapons squad and attack by fire the first floor west-facing windows of the East Wing of Bldg 1 during entry of 1st Platoon into Bldg 1. O/O lift fires from the first floor windows and shift to second floor windows. O/O lift and shift fires to third floor windows. O/O lift fires from Bldg 1 and move to 3rd Platoon positions.

(e) Detach 2 SUGVs to Company Robotics NCO.

C. Tasks to Combat Support Units.

(1) A Company 1SGT

(a) Establish CCP and Log Point at Bldg 22.

(2) ROBOTICS NCO

(a) Maintain OAV fly over route through out the fight.

(b) Maintain control of 4 SUGVs from 2nd and 3rd Plt at Log Point as replacements.

(c) Locate with Company TAC CP.

D. Coordinating Instructions.

(1) Company SOP for marking a cleared room.

(2) Some civilians in AO are considered neutral. Some considered hostile.

(3) MOPP 0 in effect.

(4) All leaders down to squad level will carry Tactical Rules of Engagement. Leaders will brief all soldiers on TACROE NLT 0900L.

4. SERVICE SUPPORT.

A. Concept of Logistical Support.

(1) MULEs will carry all supplies. They will be located vic Bldg 3.

B. Material and Services.

(1) Supply.

(a) Class I. Ration cycle is MMM. A Company has its own water. All water in AO is non-potable. Water from approved sources only is authorized for consumption. Water re-supply through PSG.

(b) Class II. CPOGs unavailable.

(c) Class IV. N/A

(d) Class V. TBD

(e) Class VII. None available.

(2) Transportation. N/A

(3) Services. N/A

(4) Labor.

(a) EPWs not authorized to do labor.

(5) Maintenance. N/A

C. Medical Evacuation and Hospitalization.

(1) Aerial evacuation authorized for Urgent casualties only.

(2) BAS is in BSA.

(3) One MULE per platoon will be unloaded of supplies and used for CASEVAC as required.

5. COMMAND AND SIGNAL.

A. Command.

(1) Succession.

(a) CO CDR

(b) CO XO

(c) 1st PLT LDR

(d) 2nd PLT LDR

(e) 3rd PLT LDR

(2) Commander with TAC CP (dismounted) south of Bldg 10 till H Hour, moves to roof of Bldg 10 at H Hour.

(3) Main CP (mounted) with vehicles at HU 123436 under control of XO.

B. Signal.

(1) COI index 1-9 in effect.

(2) Minimum radio transmissions throughout operations.

(3) Wire communications not authorized.

(4) Recognition signals IA

APPENDIX F – FUTURE FORCE WARRIOR OVERVIEW

Disclaimer: Information provided in this appendix is intended to provide a brief background on the FFW program and highlight some current and anticipated technology developments used in this research. It was extracted directly from or based on the below listed sources. Major Jon Alt's thesis research titled "Exploring Tactics, Techniques, and Procedures for a Future Force Warrior Small Combat Unit" provides additional details.

1) Booz Allen Hamilton, *Future Force Warrior CONOPS*, Version 1.0, (22 Aug 2005).
2) Wexford Group International, Inc., *The United States Army Future Force Warrior Concept Capability Plan for the Small Combat Unit*, (Columbus, GA, September 2005).
3) Capabilities Development Document for Ground Soldier Systems: ACAT I.
4) Future Force Warrior Engineering Design Evaluation (EDE) #4 Report.
5) Alexander, Robert S. Future Force Warrior; Exploratory Analysis Phase II Report, Future Force Warrior ATD, Fort Benning GA, 2005.

A. FUTURE FORCE WARRIOR PROGRAM (FFW) OVERVIEW

As the likelihood of US military involvement in large force-on-force engagements becomes less and as the Army transforms into the Future Force, more emphasis must be placed on the contributions of the individual Soldier. The Army's Future Force Warrior Program is designed to develop and demonstrate enhanced capabilities for Future Force Soldier systems with a goals of a 10x increase in capabilities at the small unit (platoon size and below) level.[78] FFW is designed to make the Soldier and small unit more lethal and survivable on both the current and envisioned future battlefield.[79] According to the Booz Allen Hamilton, the FFW program is:

> *"…the Army's flagship Science and Technology initiative to develop and demonstrate revolutionary capabilities for Future Force Soldier systems...FFW notional concepts seek to create a lightweight, overwhelmingly lethal, fully integrated individual combat system, including weapon, head-to-toe individual protection, netted communications, Soldier-worn power sources, and enhanced human performance. The program is aimed at providing unsurpassed individual and squad lethality, survivability, communications, and responsiveness—a formidable warrior in an invincible team."*[80]

[78] Booz Allen Hamilton, p. 3.

[79] Ibid, p. 2.

[80] Booz Allen Hamilton FFW Small Unit CONOPS Overview presentation, slide 3.

The FFW program is an Advanced Technology Demonstration (ATD) initiative intended to improve upon the Land Warrior program and to ultimately become the baseline to the Ground Soldier System (GSS).[81] The FFW uses an integrated system of systems to meet all projected Solider needs thru technology developments. This type of approach is also being used for the transformation initiative for combat/combat support platform developments known as the Future Combat System (FCS). While the FFW is a stand alone program, it is designed to be integrated with the current force (Stryker) as well as the future forces (FCS).[82]

B. FFW COMPOSITION

The FFW program is designed to be integrated into the existing structure of the typical Infantry platoon. The SCU will cooperatively employ enabling technologies to obtain increased lethality and survivability. The base organization for the FFW SCU is three rifle squads and one weapons squad (each squad remains 9-men, see Figure 19) with enabling technologies distributed throughout the platoon.

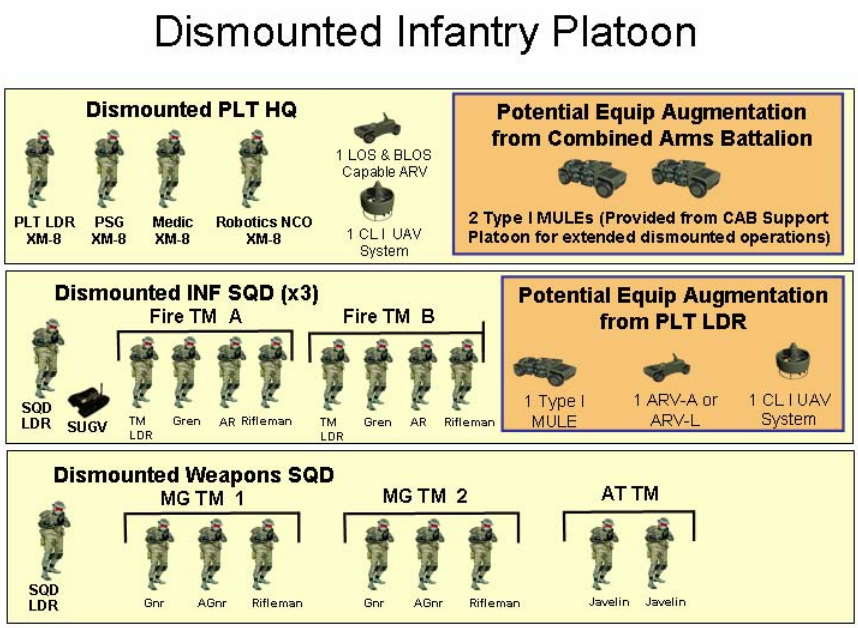

Figure 19. FFW Platoon Organization with Potential Augmentations[83]

[81] Capabilities Development Document for Ground Soldier Systems: ACAT I, p. 8.

[82] Booz Allen Hamilton, p. 3.

[83] OFW MAPEX MOUT Vignette Description, Annex A (DRAFT), (OFW ATD Integration Analysis and Simulation Team), p. 37.

C. POTENTIAL AUGMENTATION EQUIPMENT

While unmanned systems (briefly described below) are anticipated to be an integral piece to the FFW SCU, the exact configuration, distribution, and performance of these potential augmentations are not known at this time. As such, these augmentations are explored in MAJ Alt's research and not included within this NLW exploration.

Aerial Robotics[84] – Unmanned Aerial Vehicles (UAVs) are flown to observe areas of interest beyond direct observation of the SCU. A Soldier is required to monitor the UAV's video feed in order for it to be used by the SCU.

Unmanned Ground Vehicle (UGV)[85] – A family of systems that include Armed Robotic Vehicles (ARVs) (Light, Assault, and RSTA), Multifunction Utility/Logistics and Equipment vehicle (MULE) and small UGV (SUGV).

- ARVs are self-employed robotics used to investigate features to gain and sustain information dominance. ARV-A and -RSTA used provide force protection that enhances operational and tactical flexibility. The ARV-Assault (Light) will be used for security and assault support missions where a lighter weight vehicle is required.
- MULEs provide transport of equipment and/or supplies in support of maneuver.
- Small UGVs (SUGV) provide the ability to deploy sensors, detect and neutralize obstacles, and detect subterranean avenues of approach.

D. FFW CAPABILITY INCREASES

Capability increases described below are intended to provide a brief background on equipment/capabilities used in this research's limited FFW modeling. These technology advancements are not intended to reflect the comprehensive suite of weapons, equipment, and sensors that are anticipated to be integrated into the FFW SCU.

Helmet Mounted Sensors: Fused sensor technology allows images from various sensors to be electronically merged and displayed. FFW is integrating Near Infrared (NIR) and Long-Wave Infrared (LWIR, i.e., Thermal) sensors mounted on the helmet to fuse images based on visual contrast in low-light conditions with images based on thermal contrast. This technology promises an enhanced ability for an observer to understand a scene, with resulting advances in several areas including target detection and enhanced mobility during periods of limited visibility. Leaders and Grenadiers have the helmet-mounted fused sensor; others have PVS-14 night vision goggles (NIR).

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[84] Robert S. Alexander, "Future Force Warrior: Exploratory Analysis Phase II Report," Future Force Warrior ATD, Fort Benning, GA, 2005.

[85] Wexford Group International, Inc., p. 117.

Figure 20. Helmet Fused Sensor[86]

Weapon Mounted Sensors: All Soldiers have medium-range thermal weapon sights. Automatic riflemen have heavy thermal sights.

Network/Communications Distribution: Platoon Leader and Plt HQs have the Joint Tactical Radio System (JTRS); Squad Leaders and Team Leaders have both JTRS and Soldier Radio Wave (SRW, small form-fit radios) network; Team Leader and below have SRW. This network is an essential piece to the FFW SCU to share information continuously and near instantaneously. It includes embedded navigation systems, blue force tracking (BFT), cooperative engagement and handover (not modeled) and physiological/health status monitoring (WPSM).

Figure 21. Warfighter Physiological Status Monitor (WPSM)[87]

Survivability: Integrated battle ensemble with body armor, improved ballistic protection will afford soldiers individual levels of protection beyond systems currently fielded.

[86] "Future Force Warrior Engineering Design Evaluation (EDE) #4 Report," p. 68.

[87] "Future Force Warrior Engineering Design Evaluation (EDE) #4 Report," p. 13.

Figure 22. FFW Uparmor and Integrated Battle Ensemble[88]

[88] "Future Force Warrior Engineering Design Evaluation (EDE) #4 Report," p. 8.

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APPENDIX G – BUILDING THE SCENARIO IN PYTHAGORAS

Disclaimer: The information provided in this appendix is intended to introduce the reader to some of the data used to model the specific scenario used for this research. Implementation and model details are provided by the Pythagoras Users Manual. Appendix sections correspond to Pythagoras GUI tabs.

A. TERRAIN MODELING

The features comprising the urban environment were attributed in Pythagoras (Table 1) to allow for general movement, protection, and cover:

Feature	Movement Factor	Protection Factor	Concealment from		
			Visual	IR	Thermal
General Urban	1	0.4	0	0	0
Road	1	0	0	0	0
Building	0.2	0.9	0.9	0.8	0.7

Table 1. Terrain Feature Attributes used for Pythagoras Scenario

Buildings were subjectively degraded to approximate windows and doors, thereby allowing movement (in and out), observation, and engagement from openings typical to a structure.

B. WEAPONS MODELING

The below listed direct fire weapons performance data (Table 2) was obtained from AMSAA. Probabilities were generalized according to family of weapons (i.e., 5.56 munitions for M16A2, M16A3, M4, etc.). Classified incapacitation data can be obtained though AMSAA. Indirect systems (to include M203 and Javelin) were not modeled in this scenario to reflect a stricter ROE due to civilians in close proximity. This ROE also limits the maximum range use by the weapon systems to 200 meters (600 pixels).

	Basic	Shots per	Max	Suppression	Probaility to Hit at Range (meters)						
Weapon	Load	Time Step	Range	Duration	75	150	300	600	900	1200	1500
M4	210	0.5	600	1	0.75	0.63	0.47	0.3	0.22	0.15	0.11
M240	1000	3.33	600	5	0.74	0.61	0.43	0.25	0.17	0.11	0.08
M249	1000	2.83	600	5	0.74	0.61	0.42	0.24	0.16	0.1	0.07
NLW	5	0.25	150	1	0.95	0.95					
AK47	1000	3.33	600	4	0.75	0.63	0.46	0.3	0.21	0.14	0.1
RPK74	1000	3.33	600	5	0.74	0.63	0.46	0.29	0.2	0.14	0.09
RPG-7	1	0.07	600	10	1	1	1	0.99	0.92	0.81	0.69

Table 2. Weapon Attributes (Converted) for Pythagoras Scenario

C. Sidedness Modeling

As referenced and explained in chapter 5, colors are used to capture allegiance. Table 3 reflects (not inclusive) the methodology used to capture unit, friend, neutral, and enemy relationships (associated with a high misidentification level, other 2 misidentification levels use slightly different values). Table 4 reflects the range (captured as tolerance in Pythagoras) of color values assigned to agents in order to utilize an identification/ misidentification framework (associated with High Misidentification level, other levels use slightly different values). The resulting identification/misidentification probabilities for all levels are displayed in Table 5.

				Unit				Friendly				Enemy			
Agent	**Red**	**Grn**	**Blue**	**Radi**	**Red**	**Grn**	**Blue**	**Radi**	**Red**	**Grn**	**Blue**	**Radi**	**Red**	**Grn**	**Blue**
1st Sqd	0	21	254	0	0	0	1	15	1	0	0	239	1	0	0
3rd Sqd	0	21	248	0	0	0	1	15	1	0	0	239	1	0	0
HQ	0	21	244	0	0	0	1	15	1	0	0	239	1	0	0
Insurgent	230	0	70	10	1	0	0	30	1	0	0	170	0	0	1
Hostile Civ	225	2	101	0	0	0	0	5	0	1	0	16	0	1	0
Neutral Civ	190	2	130	0	0	0	0	5	0	1	0	20	0	1	0

Table 3. Sidedness Attributes for Pythagoras (High Misidentification Level)

Agent	**Red**	**Green**	**Blue**
1st Sqd	0	21	254
3rd Sqd	0	21	248
HQ	0	21	244
Insurgent	215 – 245	0	60 – 80
Hostile Civilian	205 – 245	2	101
Neutral Civilian	125 – 255	2	130

Table 4. Range of Color Values to be used for Misidentification Probabilities

	Correct Identification		
	High MisID	**Mid MisID**	**Low MisID**
U.S. to Insurgent	0.20	0.50	0.80
U.S. to Hostile Civilian	0.15	0.43	0.71
U.S. to Neutral Civilian	0.88	0.92	0.96

Table 5. Identification Probabilities associated with each MisID Level

For example, in Table 5, U.S. forces have a 20% chance of correctly identifying an Insurgent under the High MisID (misidentification) level and an 80% chance of identifying the Insurgent as a neutral (and therefore not to be engaged with lethal means. The rationale is the same for hostile civilians. Neutral civilians are viewed as neutral 88% of the time but will be incorrectly identified as an enemy (and engaged with lethal) 12% of the time. Insurgents and civilians (hostile and neutral) can clearly identify U.S. forces (by uniform and tactical movements) and therefore no not have imperfect identification.

D. SENSOR MODELING

Sensors were modeled within three signature bands/categories: unaided vision, IR (infrared), and thermal. Agents are then assigned devices that have specific range dependant probabilities of detection within each signature band. For example, U.S. soldiers equipped with helmet sensor fusion (HSF) have fields of view and detection probabilities associated with the integrated night vision (IR) and thermal sensors (using existing equipment capabilities combined to represent the future HSF anticipated capability). The actual performance data was obtained through AMSAA (who used the ACQUIRE algorithm for calculating the probability of detecting a man-sized target in southwest Asia). This unclassified data is available upon request (from AMSAA) and is too extensive to include in this appendix.

E. COMMUNICATION MODELING

Communication is modeled in Pythagoras the same way as sensors. For purposes of this research effort (communication is not a research concern), this feature/functionality was bypassed with an agent communication attribute that allows team members to always know about other unit members.

F. AGENT MODELING

Perhaps the most extensive modeling effort involves assigning equipment (weapons, sensors, and communication devices) and attributing individual characteristics to each agent in order to represent actions, behaviors, desires, and reactions. All agents must be assigned at least one weapon, one sensor, and communication device (see Chapter V, Table 1 for assignments). The ability to use their assigned equipment can be varied, but this research effort did not investigate these impacts and therefore did not degrade any agent's performance. In order to capture a randomly timed attack by hostile civilians, they were assigned a desire to hold fire (0.9).

Initial positions (which were varied for all but U.S. forces) were then selected to each agent, along with a series of waypoints and terrain preferences/desires to model movement. Assigning movement desires enabled coordinated small team (tactical) movements. The speed at which the agent moves through the urban environment is calculated according to doctrinal movement rates (see Table 6). The Agents movement rates were converted to Pythagoras units with a corresponding degradation rate to approximate movement through an urban environment at night.[89]

[89] MAJ Jon Alt consolidated and shared movement calculation and degradation for base scenario.

Table IV-5. Unopposed Movement Rates

TYPE TERRAIN	DISMOUNTED INFANTRY	ARMORED/MECHANIZED
Unrestricted	4 kmph (Day) 3.2 kmph (Night)	24 kmph (Day) 24 kmph (Night with lights/passive)
Restricted	2.4 kmph (Day) 1.6 kmph (Night)	16 kmph (Day) 8 kmph (Night, blacked out)
Severely Restricted	1.0 kmph (Day) 0.1 to 0.5 kmph (Night)	1.0 kmph (Day) 0.1 to 0.5 kmph (Night)

Table 6. Unopposed Movement Rates[90]

Soldier Average Speed

1 timestep= 2 seconds

$$\frac{4.0\text{km}}{\text{hr}} * \frac{1\text{ hr}}{60\text{ min}} * \frac{1000\text{m}}{\text{km}} * \frac{1\text{ min}}{30\text{ timesteps}} = 1.48\text{km/time step}$$

Figure 1. Movement Rate converted to Pythagoras Units of Time

Unrestricted Night Degradation

$$\frac{4-3.2}{4} = 0.2$$

Normalized

$1 - 0.2 = 0.8$ movement factor

Figure 2. Normalized Movement Degradation to account for Night Movement

Attributes can be used to model vulnerabilities from lethal and non-lethal fire. Since FFW Soldiers wear improved body armor, their vulnerability to lethal fire was reduced over 11% (see calculations in Figure 3).

Vulnerability Reduction Based on Surface Area

(%Abdomen * % Coverage) + (%Thorax * % Coverage) + (%Head/neck * % Coverage) =

(10.6%*22%)+(13%*31%)+(6.5%*50%) = 9.6% Reduction in Vulnerability

FFW Armor 18% More Coverage Area

9.6% + (9.6%*18%) = 11.34% Reduction in Vulnerability

Figure 3. Vulnerability Reduction Calculations for Improved Body Armor[91]

Also within this tab is an agent's vulnerability to color changes. NLWs were modeled as a color weapon that essentially pains its targets with color. A threshold value (13) for a color (green) would trigger an agent hit/painted by an NLW to surrender. Each

[90] Headquarters, Department of the Army, FM 90-31, *AMCI Army and Marine Corps Integration in Joint Operations*, (HQ, Department of the Army, 2002).

[91] Actual values and calculations were obtained from Mr. Lew Farkas at AMSAA.

category of agent (insurgent, hostile civilian, and neutral civilian) was assigned different vulnerability values to capture a subjectively determined probability of surrender (see Table 7). If an agent did not surrender, it would attempt to return (lethal) fire (if the agent possessed a weapon) but would also be immediately targeted by lethal means from U.S. forces.

Agent	Surrender Probability
Insurgent	0.25
Hostile Civilian	0.75
Neutral Civilian	0.90

Table 7. Surrender Probability of Agents Hit with an NLW

G. BEHAVIOR MODELING

An agent's behavior can be programmed or changed though the use of triggers. Events that trigger behavior changes can range from detecting types and/or numbers of other agents, completing an action (arriving at an objective), to being shot at or running low on ammunition. This functionality allows for fairly complicated and robust set of interactions and coordinated operations. The process of modeling behavior is one of trial and error in order to approximate what the user believes to be realistic. The extent and description of all the behaviors and associated triggers used in this scenario, as well as additional details of this research can be obtained by contacting the author.

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