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THESIS

EFFECTIVENESS OF THE INDIVIDUAL RIFLEMEN IN AN INFANTRY SQUAD

by

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December 2017

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Our research establishes a decision-making framework for use during the acquisition of the next individual combat rifle system. We utilize four possible courses of action to display the decision-making model. The four primary evaluation factors to optimize the squad are lethality, accuracy, mobility, and interoperability. The first part of the model is a value approach that normalizes these four different performance factors for system comparison. The second part of the model is a qualitative approach that examines other potential risk factors. We analyze, normalize, and weigh the performance factors for comparison of each course of action against programmatic, political, and international risks.

Program risks focus on the cost, schedule, and performance of each potential course of action, while maintaining the best interest of our soldiers and American taxpayers. Political risks are uncertain based on the stakeholders involved within Congress and military’s leadership. International risks are primarily concerned with the North Atlantic Treaty Organization (NATO). The 5.56mm caliber is the NATO standard, and any adaptation of a new weapon and caliber may invoke criticism from our NATO allies. In the end, our research provides senior leaders with an initial recommendation for gaining overmatch capability against our peer and near-peer adversaries.

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EFFECTIVENESS OF THE INDIVIDUAL RIFLEMEN IN AN INFANTRY SQUAD

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LIST OF ACRONYMS AND ABBREVIATIONS

AAO	Army Acquisition Objective
AO	Area of Operations
AUSA	Association of the United States Army
CBA	Capabilities Based Assessment
CDD	Capability Development Document
COA	Course of Action
COTS	Commercial-off-the-Shelf
DOTMLPF-P	Department of Defense Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, Policy
FOIA	Freedom of information Act
GWOT	Global War on Terror
IC	Individual Carbine
IC AS	Individual Carbine Acquisition Strategy
IPT	Integrated Product Team
KPP	Key Performance Parameters
LCC	Life Cycle Cost
MCOE	Maneuver Center of Excellence
NATO	North Atlantic Treaty Organization
NDI	Non-Developmental Item
PEO	Program Executive Office
PM SW	Project Manager Soldier Weapons
RDT&E	Research Development Test and Evaluation
SME	Subject Matter Expertise
TDP	Tech Data Package
USA	United States Army

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Major Michael Martin would like to thank God for the opportunities that have been provided to his family. He would also like to thank his wife, Christina Martin, for her patience and understanding during this graduate school experience. He would also like to thank his son, Christopher Martin, for being such an amazing person, and for giving him the motivation to study so his prayers that I "make an A or a B on all my tests" come true.

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I. INTRODUCTION

The infantry squad is a lethal, versatile, and capable warfighting organization. Wartime necessity gave birth to squad maneuver concepts unheard of before World War I, and transformed the infantry on the battlefield. The history of the modern United States (U.S.) Army infantry squad lies in the lessons learned by the German *Stroβtruppen* of WWI (Lupfer, 1981). German Storm Troopers were specially trained soldiers versed in siege warfare and the attack. Integration of multiple skillsets increased the versatility and effectiveness of the squad. No longer were riflemen only carrying rifles, and grenadiers' only carrying grenades. *Stroβtruppen* were cross-trained on multiple weapon systems to increase their effectiveness and reduce their reliance on other units (Cardona, 2014).

The U.S. Army observed and recorded lessons learned from the German *Stroβtruppen* during WWI, and captured the effectiveness of these new combat units. The 1946 Infantry Conference transitioned lessons learned into doctrine to shape the future fighting force (Doughty, 1979). Here the rifle squad was defined as "a group of enlisted men organized as a team," and the "smallest tactical unit consisting of only as many men as a leader can direct easily on the field" (Department of the Army [DA], 1946). Although squad organization varied over time, the combat effectiveness of the squad remained central to the organizational plan (Karcher, 2002).

The U.S. Army's new doctrine required cross training infantry squads for combat in WWII. (Hughes, 1995). Squad weapons comprised of a mixture of small arms and other weapons. Rifles, submachine guns, automatic rifles combined with grenades and anti-tank rockets maximized lethality of the infantry squad (Hughes, 1995). Squad formations morphed over time from WWII through the Korean War, Vietnam, the Cold War, and our current Global War on Terror (GWOT). Squad size has changed from a 12-man squad in WWII to a 9-man squad after WWII.

"The Infantry is an all-weather, all-terrain unit. Its mission is to close with the enemy by means of fire and maneuver to destroy or capture him, or to repel his assault by fire, close combat, and counterattack" (DA, 2006b). Once complete, the infantry squad will prepare to repel an enemy counterattack or proceed with close combat attack operations required for dominance throughout an Area of Operations (AO). An infantry squad is made up of nine Soldiers who each have responsibilities and individual jobs ranging from leadership to rifleman. Each position has a particular purpose with a collective end result being mission accomplishment. An Army infantry squad is controlled by the squad leader (DA, 2006b). The squad can be broken further into two four-man fire teams, controlled by a fire team leader (DA, 2006b). Figure 1 displays the distribution of weapon systems within the squad. The squad leader and fire team leaders are equipped with the M4A1 weapon system. The remaining members of the squad consist of two grenadiers carrying an M4A1 weapon system with a 40mm grenade launcher attachment, two riflemen equipped with a M249 squad automatic weapon (SAW) and two riflemen only carrying the M4A1 weapon system. There are other variations of a squad within a platoon, such as the Weapons Squad, however for purposes of this research our focus is solely on the basic infantry squad.

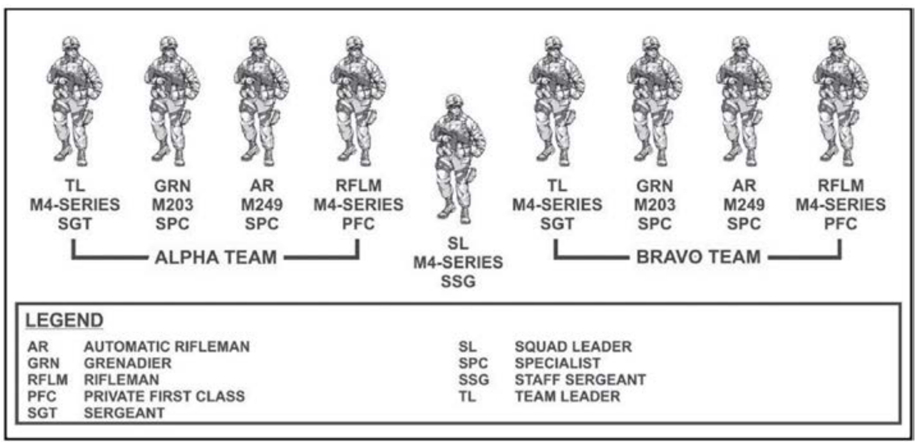

Figure 1. Breakdown of Nine-Person Infantry Squad. Source: DA (2016c).

The diversity of a squad gives it the ability to conduct offensive, defensive, stability and support missions (DA, 2006b). The composition and capability of a squad allows it to establish its own base of fire, maneuver, ambushes, security, indirect fire and other battle drills to defeat the enemy.

In order to defeat the enemy, a squad must employ fire and maneuver as shown in Figure 2. Where one fire team provides suppressive fire allowing the other fire team to maneuver itself to a position of tactical advantage. Since the infantry squad is broken down into two fire teams, either one can be used as a suppressing force or assaulting force. “The fundamental considerations for employing infantry units result from the missions, types, equipment, capabilities” (DA, 2006b).

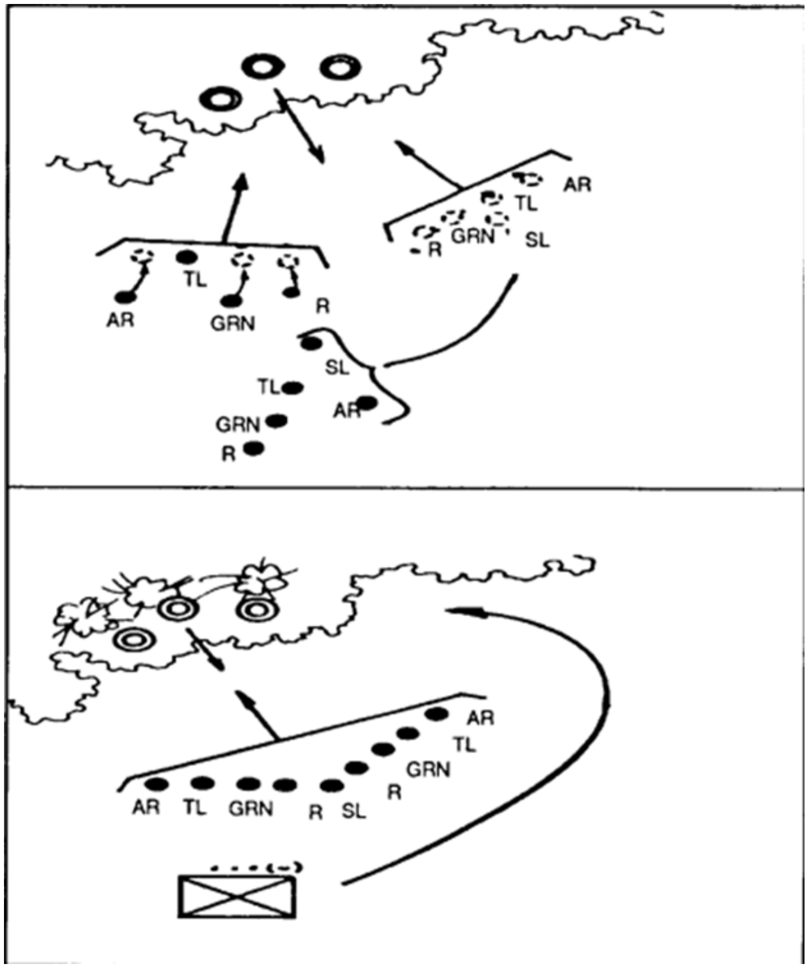

Figure 2. React to Contact. Source: DA (2016c).

The infantry squad is a powerful force on the battlefield, but does not have overwhelming firepower compared to enemy infantry supported by an armored or motorized assets (DA, 2006b). In order to achieve overmatch capability, the United States Army must invest in research and development to ensure overmatch.

The readiness of an infantry squad requires qualified personnel, consistent quality training, and cutting-edge equipment. Equipment provides Soldiers with a technology advantage and acts a combat multiplier. These technologies range from clothing, electronic warfare hardware, as well as weaponry. During GWOT, weaponry has been the major concern of many Congressional leaders.

Congressional leaders have proposed Commercial-off-the-shelf (COTS) solutions but do not understand the United States Army's total systems acquisition approach concept. This concept uses the doctrine, organization, training, materiel, leadership, personnel, facilities, policy (DOTmLPF-P) process to address capability gaps after effective analysis. A currently identified gap within the infantry squad is individual lethality (DA, 2006a).

Lethality is a constant theme from our current battlefields to Army doctrine. Lethality applied during direct and immediate contact will be the focus of this thesis. The United States Army is moving forward to develop the correct combination of DOTmLPF-P solutions. The United States Army is currently engaging the firearm/ammunition industries to capitalize on current firearm technology. For example, SHOT Show, Association of the United States Army (AUSA) and other tradeshows are prime sources for developmental or current products for both commercial and military applications. These industries have revolutionized the manufacturing processes and possess the subject matter expertise (SME) to provide the individual rifleman with an effective materiel fix. This materiel fix provides technology overmatch through the procurement and fielding of updated weaponry.

Requirements assist acquisition program managers in selecting the appropriate acquisition strategy. The acquisition strategy ensures all user requirements are encapsulated within the materiel solution. This thesis examines the overall relationship between the costs, performance, and schedule of delivering these materiel solutions. Costs, performance, and schedule are the major factors which drive programmatic expenses. This acquisition strategy will focus on courses and actions (COAs) ranging from status quo, status quo with product improvement, COTS and non-developmental item (NDI) materiel solutions. These COAs are compared using metrics and provide information to Army leadership and defense acquisition authorities.

A. RESEARCH QUESTIONS

The following research questions are addressed and analyzed in this thesis:

1. What performance attributes contribute to operational effectiveness within an infantry squad?

2. What role does small arms lethality play in the operational effectiveness of the infantry squad?

3. Within the constraints of cost, schedule, and performance, what course of action best supports an acquisition strategy to increase operational effectiveness within an infantry squad?

B. SCOPE

This thesis utilizes unclassified documents gathered through historical references and literary review. The individual carbine (IC) capabilities development document (IC CDD) was initiated in 2008 as a requirement to improve the current M4 weapon system. IC CDD required the weapon system to integrate and accept the M320 40mm grenade launcher, mount visual aiming devices and include a system of modular accessories (i.e., lights optics) and a bayonet. The IC CDD also required that the weapon system be chambered in either 5.56mm or 7.62mm NATO standard munitions (live, training, blank, and dummy) (DA, 2011a).

Advancements in polymer technology, composite durability, and a significant reduction in weight have placed large caliber ammunition in reach of the 5^{th}– 95^{th} percentile male and female Soldiers (Textron, 2017b). These vast improvements in technology have resulted in affordable, highly reliable, and effective weapon systems.

COAs proposed in this thesis provide information to either continue with the M4 weapon system or another COA.

C. BACKGROUND

The M4 was incorporated into the Army during the mid-1990s as a replacement for the aging M16 (Jenzen-Jones, 2016). Both systems utilized many of the same parts, maintained similar operational features, and maintenance requirements allowing for a seamless system transition. Figures 3 and 4 display the commonality between the systems.

Figure 3. Accessories for M16. Source: Hammack (2008).

Figure 4. M4 Accessory List. Source: Hammack (2008).

M4 is suitable for the 5th - 95th percentile Soldier due to its reduced length (M16 39 inches versus the M4 33 inches). Figure 5 demonstrates the size differences between the 5th – 95th percentiles. The M4 also incorporated a flat top receiver with a M1913 Picatinny Rail to easily accept optics and other lethality devices. Despite the improvements of the M4 over M16 variants, there were numerous complaints about the operational effectiveness and reliability of the M4 (Ehrhart, 2009). For example, during the battle of Wanat, Afghanistan, Battle Company 173rd Airborne Brigade experienced multiple M4 weapon failures and malfunctions stemming from extended firefights (DA, 2010b). Complications from environmental conditions and system reliability exacerbated the M4s problems and plagued operational effectiveness. This was not an isolated event as many Soldiers in Iraq and Afghanistan experienced similar problems with the M4 in combat (DA, 2006a).

> Operations in Afghanistan frequently require United States ground forces to engage and destroy the enemy at ranges beyond 300 meters. These operations occur in rugged terrain and in situations where traditional supporting fires are limited due to range or risk of collateral damage. With these limitations, the infantry in Afghanistan require a precise, lethal fire capability that exists only in a properly trained and equipped infantryman.

> While the infantryman is ideally suited for combat in Afghanistan, his current weapons, doctrine, and marksmanship training do not provide a precise, lethal fire capability to 400 meters and are therefore inappropriate. (Ehrhart, 2009)

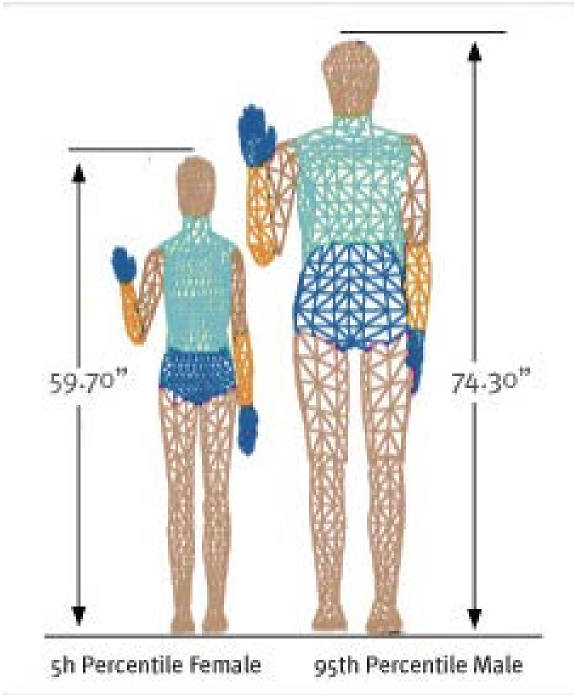

Figure 5. 5th–95th Percentile. Source: El Creative Advertising and Design (2007).

Complaints from Soldiers over the lethality, effectiveness, and reliability of the M4 system resulted in the adoption of the IC Program in 2011 (DA, 2011a). The IC sought a materiel solution to gaps identified during a 2008 Capabilities Based Assessment (CBA) that included the M4 rifle (DA, 2011a). Gaps identified within the M4 system were in the areas of lethality, accuracy, and reliability. Figure 6 represents thresholds and objectives for the IC to provide enhancements in accuracy, lethality, reliability, compatibility, and operational availability (DA, 2010a).

	Threshold	Objective
KPP 1. System Accuracy/ Dispersion (Precision)	5" mean radius @ 300 meters throughout barrel life (T)	5" extreme spread @ 300 meters throughout barrel life with .9 probability (O) 10" extreme spread @ 600 meters throughout barrel life with .9 probability (O)
KPP 2. System Reliability	• Reliability ≥ .94 probability of incurring no Class I or II (operator correctable) malfunctions during each individual wartime mission in which up to 209 rounds are fired (T) • Reliability ≥ .97 probability of incurring no Class III (non-operator correctable) malfunctions during each individual wartime mission in which up to 209 rounds are fired (T)	• Reliability ≥ .98 probability of incurring no Class I or II (operator correctable) malfunctions during each individual wartime mission in which up to 209 rounds are fired (O) • Reliability ≥ .99 probability of incurring no Class III (non-operator correctable) malfunctions during each individual wartime mission in which up to 209 rounds are fired (O)
KPP 3. Compatibility	The IC shall have accessory attachment points that provide compatibility for accessories made to attach to the MIL-STD-1913 (Picatinny Rail) with numbered attachment points (T). The IC shall provide sufficient MIL-STD-1913-compatible accessory attachment points/surfaces on the weapon receiver above and to both sides of the barrel to allow simultaneous mounting of standard U.S. military accessories (T). The IC shall have removable mounting surfaces below the barrel (T).	The IC shall provide for a MIL-STD-1913 compatible handguard, allowing for a free-floating barrel and a design/redesign of the underbarrel weapon systems/module interface to use the MIL-STD-1913 compatible rail surface on the handguard as the attachment point instead of the barrel (O).
KPP 4. Operational Availability	Ao ≥ .95 (T)	Ao ≥ .98 (O)

Figure 6. Key Performance Parameters (KPP). Source: DA (2011a).

The Individual Carbine Acquisition Strategy (IC AS) was developed to acquire and field an individual weapon system which would deliver the following KPPs. Figure 6 breaks down key performance parameters as follows: KPP 1 System Accuracy, KPP 2 System Reliability, KPP 3 Compatibility, and KPP 4 Operational Availability. Our analysis additionally accounts for the system's weight and range. Since the IC did not incorporate a new ammunition type, range and weight would remain similar to the M4 it was attempting to replace (DA, 2010a). To gain insight on COTS and NDI systems, the IC stakeholders, particularly PM Soldier Weapons, conducted market research on possible materiel solutions (DA, 2010a).

The IC AS budget and funding lines are analogous to previous programs that resulted in the M4 weapon system. The IC's life cycle cost (LCC) is based on a 20-year sustainment plan which includes slings, magazines, cleaning kits, and manuals etc. (DA, 2011a). The COAs rely on full and open competition, of GOTS, COTS, and NDI systems to leverage current technology and industry expertise (U.S. Government [USG], 2017).

The COAs are listed as follows

- COA1: M4A1 with M855A1 (5.56mm)
- COA2: Modified M4A1 with New Intermediate Caliber Ammunition (.264 USA)
- COA3: New Carbine with New Intermediate Caliber Ammunition (.264 USA)
- COA4: New Carbine with M80A1 (7.62mm)

D. BENEFITS

This thesis provides information to the Army and other interested parties. The thesis accomplishes this through analysis of criterion with measureable metrics to demonstrate possible COAs for future use. The objective of this thesis focuses on increasing the operational effectiveness of the individual rifleman, and recommends future areas for additional analysis.

II. REFERENCES

In the course of our research of this project, we used a series of documents, acquisition processes, Army field manuals (FM), and subject matter expert (SME) presentations to provide analysis for improving infantry squad lethality. The review and incorporation of material allows for a systematic approach for the necessary framework and discussion.

A. INCREASING SMALL ARMS LETHALITY IN AFGHANISTAN: TAKING BACK THE INFANTRY HALF-KILOMETER (2009)

Major (MAJ) Thomas P. Ehrhart (2009) researched and documented eyewitness accounts of M4 failures in Afghanistan. Ehrhart came to the conclusion that infantry squad weapons do not provide lethality at extended ranges. He also recommends changes to squad structure, doctrine, and improved marksmanship training. MAJ Ehrhart’s report is used to provide background to the current lethality problem.

B. DEPARTMENT OF DEFENSE INSTRUCTION 5000.02

The Department of Defense Instruction (DODI) 5000.02 is the instruction guide for all materiel acquisition development. Figure 7 outlines procedures and steps required for all materiel acquisition.

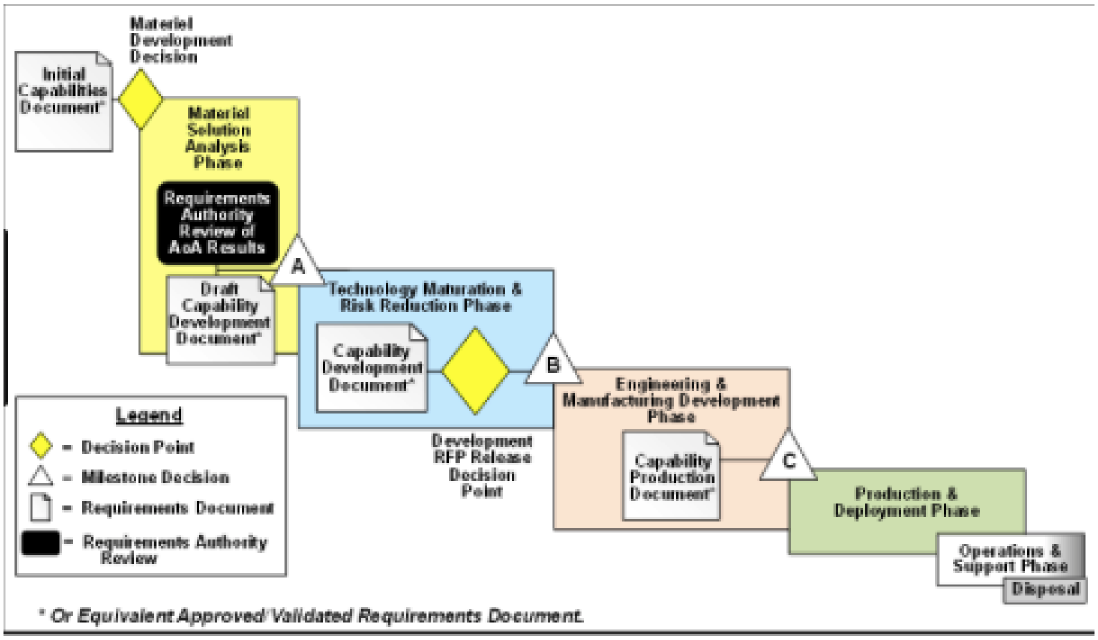

Figure 7. DODI Framework. Source: Defense Acquisition University (2017).

This thesis does not showcase a step by step process for procurement when providing a recommended COA. However, the COA must follow rules and policies that all programs must adhere too. Senior leadership must take into account the above framework when selecting a COA. Each COA has a different time line, but must follow the same DODI. The ability to tailor or streamline a COA depends on the availability, reliability, and manufacturability of the prescribed material solution. The COA's discussed during this thesis are a mixture of COTS and NDI's.

C. AN ARMY OUTGUNNED: PHYSICS DEMANDS A NEW BASIC COMBAT WEAPON

An article by Joseph P. Avery (2012) is used as background information for COA's. Avery's article suggest that the battlefield is a dynamic evolution of events. For example, during operation Gothic Serpent, Task Force Ranger experienced many problems with target interdiction. These problems were associated with body density (very thin stature of Somali combatants) and narcotic inhibitors (kaht) ingested by the general Somali population. This combination of body density and drug use prevented instant incapacitation of Somali combatants by Task Force Ranger using 5.56mm munitions.

The evolution from terrain to combatants has changed. To maintain pace with change, the combat basic weapon has to evolve. Incremental improvements only stymie the evolution of the combat basic weapon.

As shown in GWOT, the individual rifleman is not able to effectively engage and kill targets beyond 400m. This unforeseen consequence is not exclusive to GWOT but was recorded during World War II (WWII), Korea, and Vietnam. For example, Joseph P. Avery Ph.D. author of "An Army Outgunned" states:

> In the World War II Pacific Theater, shooting at the enemy was a major problem because camouflaged Japanese forces hid in jungle growth or in caves and fortifications and were difficult to target/hit. The same issue arose in the jungles of Vietnam, where the enemy was frequently unseen. Today, the combat environment is very different, and the enemy is frequently quite visible at all ranges from close quarters to over 1,000 yards. The M14's maximum effective range was a respectable 400 meters with the sniper version having a range of 600 to 800 meters. (Avery, 2012)

The thesis will use the article's information to reinforce the need for change. The change should initially improve the lethality of the individual rifleman. This improvement will have a cascading effect into the lethality of the infantry squad.

D. ARMY DOCTRINE PUBLICATION (ADP) 3-0 UNIFIED LAND OPERATIONS

ADP 3-0 is the United States Army doctrine when conducting Unified Land Operations (ULO). ULO focuses on the Army's ability to gain and retain area within a congested battlespace. Figure 8 presents the ULO concept focuses on full spectrum military operations comprised of offense, defense, and stability and support operations along with supporting tenets; depth, lethality, adaptability, flexibility, synchronization, and integration (DA, 2011b). ADP 3-0 provides a common operating picture for all organizations.

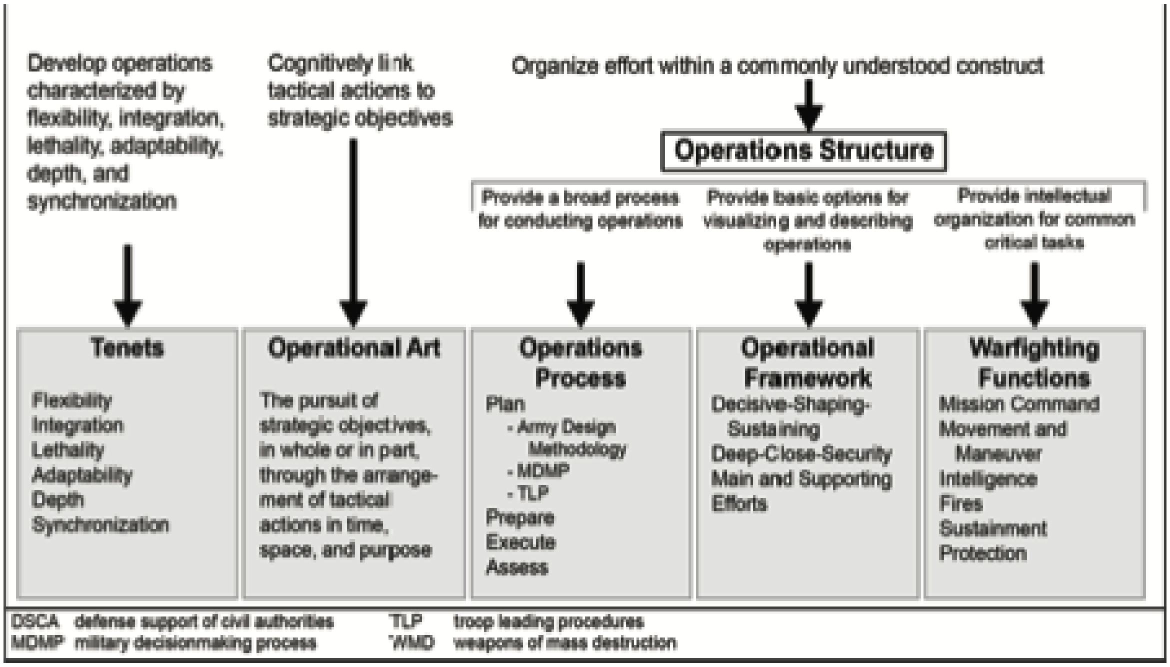

Figure 8. ADP 3-0 Common Operational Picture for All Organizations. Source: DA (2011b).

ADP 3-0 is used in this thesis as a reference for lethality. Lethality serves as a tenet in offensive and defensive operations.

E. CHAMBERING THE NEXT ROUND

A research paper by N.R. Jenzen-Jones takes an in-depth view of factors facing the modern-day infantryman. Experiences from Afghanistan and Iraq have been complied, processed, and analyzed; this compilation of information led to the development of new small arms munitions (Jenzen-Jones, 2016). Examples of this new ammunition are displayed in Figures 9 and 10. These new munitions have become a priority of industry and of interest to Congress. The author of “Chambering the Next Round” identifies current deficiencies within U.S. and allied nation munitions. The report focuses on combinations of technology that will improve allied standardization, logistical constraints, cost, lethality, and future munition requirements.

Figure 9. Comparison of Polymer versus Brass-Cased Ammunition. Source: Baker (2014).

Figure 10. From Left to Right: Traditional Brass-Cased Ammunition versus Case-Telescoped Ammunition. Source: Mizokami (2016).

"Chambering the next round" is used in this thesis as a reference for munitions development. Munitions support the tenet of lethality in offensive and defensive operations.

F. BITING THE BULLET

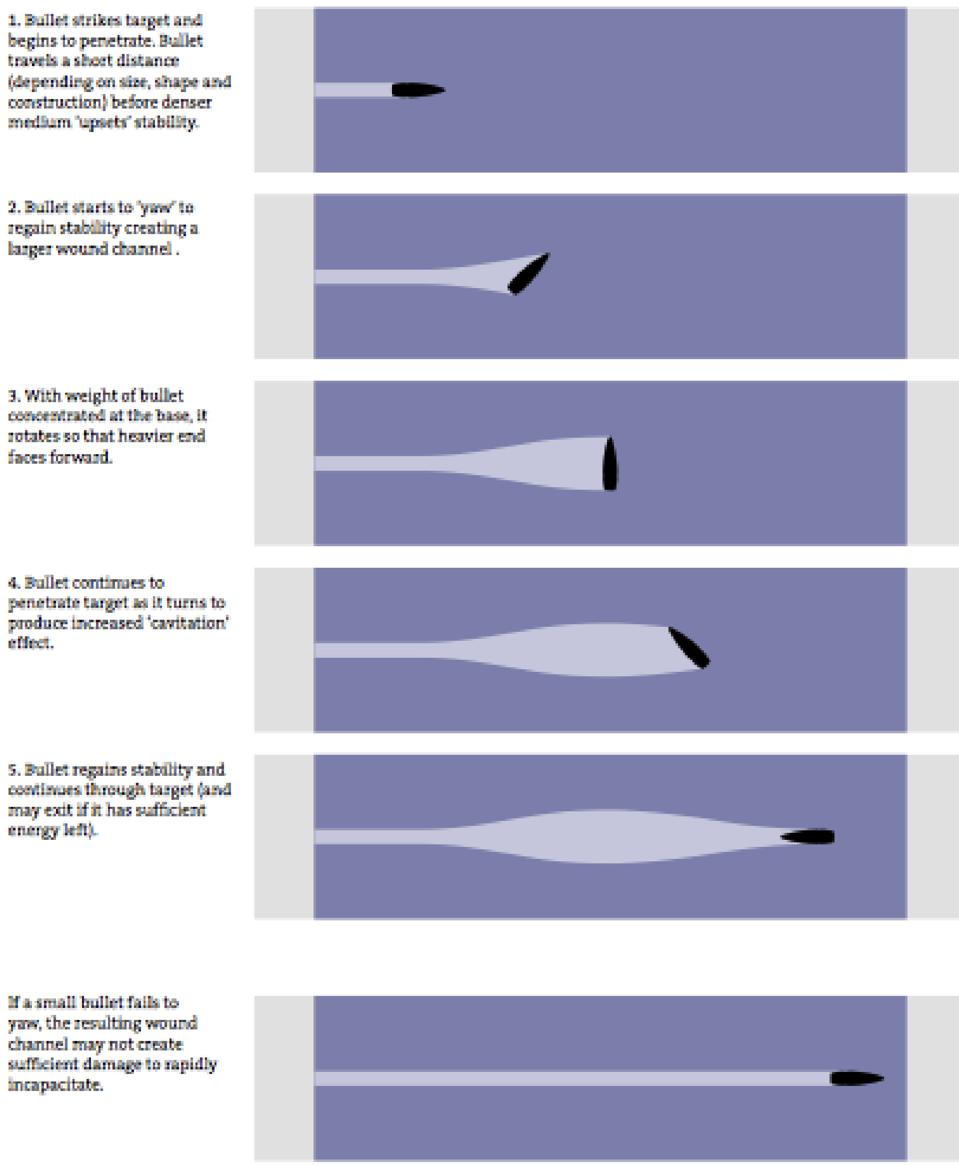

Figure 11. Demonstration of a Yawing Round upon Target Impact.
Source: Drummond and Williams (2009).

A research paper written by Nicholas Drummond and Anthony Williams for the British Ministry of Defence on 5.56mm inadequacies. Drummond’s paper focuses on the NATO 5.56mm round and its lack of lethality beyond 400 meters. The yaw in particular, demonstrated in Figure 11, has a significant effect on target lethality. **“**Biting the Bullet” is used in this thesis as a reference for 5.56mm ineffectiveness beyond 400 meters and its operational contrast against 7.62mm. The paper highlights the need for an improved lightweight munition of a larger caliber than 5.56mm.

G. WHERE TO NOW?

A presentation given by Jim Schatz to the NDIA Armaments Small Arms Forum in Whippany, NJ on 3 June 2015 outlined requirements for small arms overmatch. Capable forces such as Russia, China, and North Korea possess the ability to out range U.S. forces. Schatz sums up his presentation in a dynamic response to the lack developmental progress within U.S. small arms weaponry munitions.

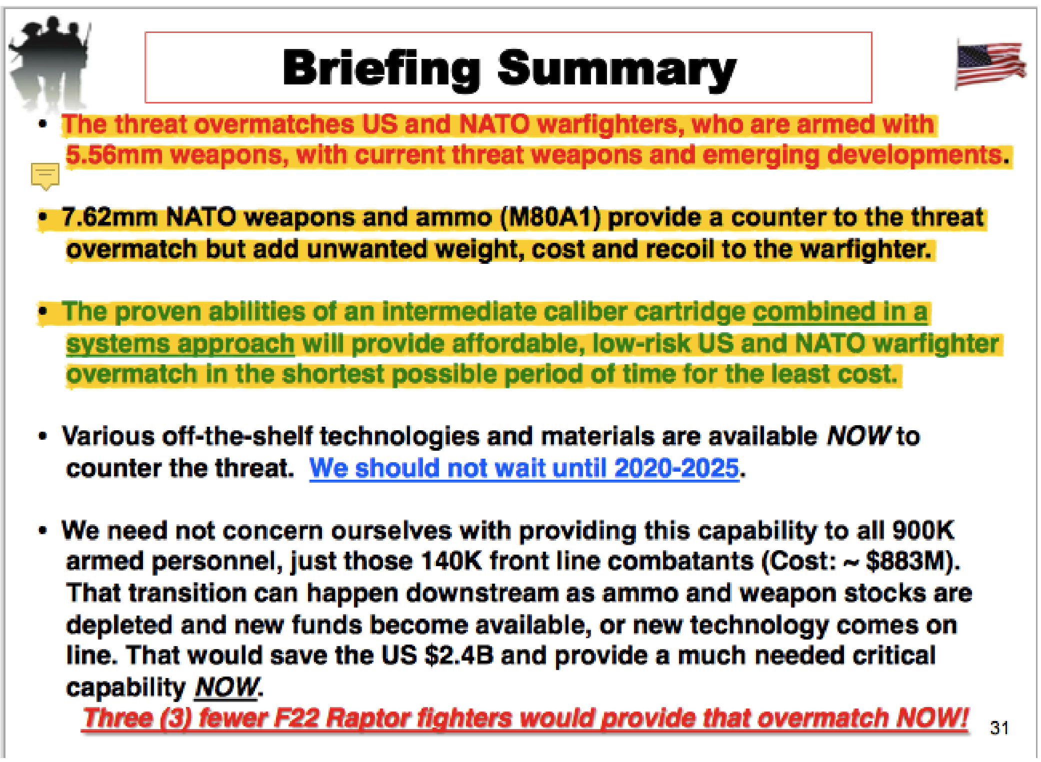

Figure 12. Overmatch Inferiority of Current NATO Ammunition. Source: Schatz (2015).

H. DO WE NEED A NEW SERVICE RIFLE CARTRIDGE?

The article "Do we need a new service rifle cartridge" by Jim Schatz reflects on 5.56mm operational effectiveness. Throughout the article, Schatz demonstrates the ineffectiveness and lack of lethality of the 5.56mm cartridge. For example, during a Special Forces mission in Afghanistan, an insurgent was shot 7–8 times before falling to the ground. That same insurgent then somehow regained consciousness to reengage the Special Forces soldier. Problems with 5.56mm were accounted for during Operation Gothic Serpent and have not been remedied. Schatz then goes on to say that the U.S. should lead ammunition development, and not NATO. "Do we need a new service rifle cartridge" is used in this thesis as reference for growth within infantry munitions.

I. HORNADY HANDBOOK

The *Hornady Handbook of Cartridge Reloading* focuses on the development of munitions. The book presents calculations and measurements required for optimal ammunition effectiveness. It outlines the ballistic coefficient and sectional density required for target accuracy and defeat. Hornady defines ballistic coefficient, shown in Figure 13, as "the measure of a bullet's relative ability to overcome air resistance. Each bullet can be assigned a numerical value expressing this efficiency. The basis of this value is a ratio comparing the performance characteristics of a particular bullet against the known trajectory characteristics of a standard projectile. The ratio compares the drag of a bullet (loss of velocity caused by air resistance encountered in flight) to the drag of the standard projectile" (Emery, 2012).

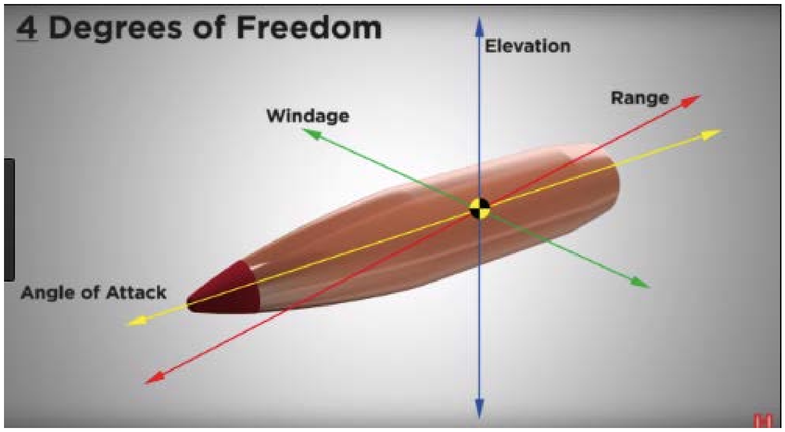

Figure 13. Ballistic Effects on a Projectile. Source: Emery (2012).

According to Hornady, sectional density "affects the amount of damage a bullet can cause" (Emery, 2012). Sectional density is defined as "a bullet's weight in pounds divided by its diameter squared which describes a bullet's length for its diameter: The higher the number, the longer the bullet. Generally speaking, the larger a bullet's sectional density, the deeper it will penetrate" (Emery, 2012). Figure 14, demonstrates the penetrative capability of a projectile in 20% ballistic gelatin. Measuring the distance traveled provides the evaluator with better data on the potential lethality of a projectile.

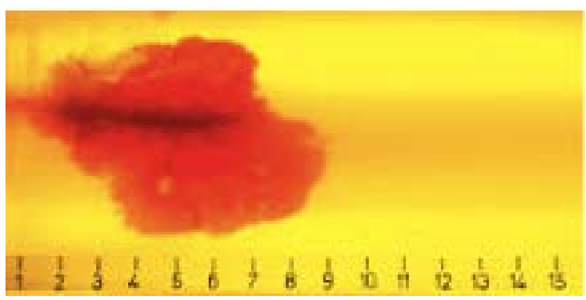

Figure 14. Ballistic Characteristics upon Entry. Source: Emery (2012).

J. M-16 RIFLE CASE STUDY

The author Richard R. Hallock is a retired U.S. Army officer specializing in the history of the M-16 from cradle to its relevancy today. The author outlines the M16 development and controversy stemming from reluctant commanders to politicians. The establishment of NATO also played a significant role in the adoption of the 5.56mm round. This ensured that the caliber was consistent among all NATO forces in times of war. The author outlines the debate between accuracy vs. volume of fire and its presence on the battlefield. This debate has caused a divide in military and political arenas. The "M-16 Rifle Case Study" is used in this thesis as a reference for the acceptance of change in the military, political arenas, and NATO.

III. HISTORY OF THE MODERN INFANTRY SQUAD

Modern warfare found the infantry squad as a servile unit incapable of independent thought or action. The stagnated eastern front of WWI led to a revolution in the arming of the infantry unit, and paved the way for the combined arms concept (Fitzsimons, 1973).

Infantryman were often conscripts, because it was cheaper to equip and train them then other types of Soldiers like the cavalry or artillery (Bull, 2007). Being conscripts, their trust and courage under fire was questionable. Officers required the ability to issue voice orders to their respective formations in-masse. Noise from gun fire and artillery explosions would often mask these orders if the infantryman were arrayed too far apart from one another. Additionally, the tactics were reliant of mass fire from the unit at large, and not individual action or marksmanship from the individual infantryman (Cardona, 2014).

Repeating rifles and machine guns at the turn of the 20th century catapulted change within the infantry unit at a remarkable rate (Zapotoczny, 2006). European warfare evolved out of necessity and curiosity as military theorists experimented with the effectiveness of differing maneuver tactics to compensate for capability increases from rival nations, as well as exploit the strengths of their own materiel ingenuity (Widder, 2002). The lethality of modern weapon systems outpaced the military tactics of the day, and a change was necessary if the infantryman was to have any chance of survival on the battlefield (Fitzsimons, 1973).

Skirmish lines were brought to Europe by military observers studying the American Civil War. Jefferson Davis, then Secretary of War, commissioned a new infantry tactics manual be written to account for the increased capability of the “rifled musket.” This new Infantry manual included the concept of “comrades in battle” which consisted of four Soldiers who relied upon one another while performing skirmishing actions. These battle buddies were self-reliant, and entrusted to take appropriate action in the face of the enemy, and then rejoin the larger unit once complete with skirmish line duties (Kerr, 1990).

In the German Army, these forces were routinely placed under command of an *Unteroffizer* or Noncommissioned Officer. The NCO would receive orders from his officer, and was then left to interpret and act on them as he saw fit. Skirmish lines relied on strong NCO leadership to be effective. They had to fire at a much larger force who was continuously closing in on their position, and determine when to fallback to join their larger force and continue the attack (Widder, 2002).

Linear tactics of the day did not take into account the devastating firepower of small arms and artillery. For example, over 6,000 German Soldiers were killed or wounded in just the first 30 minutes of the battle of St. Privat (Cardona, 2014). Such carnage could not be tolerated, and a change in tactics across Europe was necessary. To achieve this, skirmish lines operated as decentralized “knots” of Soldiers in depth rather than large bodies of infantry in depth moving in mass (Bull, 2007). This change was seen as a way to inflict casualties on the enemy while preserving combat power, and limiting a friendly forces exposure to enemy troops.

Skirmish lines became squads, and squad leaders were expected to control the fire of their squad (Bull, 2007). The necessary decentralized movement from the skirmish lines impeded direct control from the officers, and NCOs became responsible for their respective formations. They were entrusted to support one another through fire and maneuver techniques to enable the platoon to reach its objective while supporting other adjacent units attempting to reach their own (Bull, 2007).

World War I introduced new maneuver techniques to the German Army. During the pre-war years, an infantry unit consisted solely of riflemen, which are men carrying rifles. Squads were referred to as rifle squads for the same reason, and the squad consisted only of riflemen. The nomenclature continued upward through the rifle platoon, rifle company, and rifle battalion. Once at the regimental level, diversity in organization and equipment appeared. Each regiment contained 1 machine gun company consisting of 3 machine gun platoons with 2 machine guns apiece (Cardona, 2014).

The Rifle Squad was unable to advance on the attack without suffering high numbers of casualties from the enemy in prepared defensive positions (Cardona, 2014). Before the attack, troops on either side would prepare for the assault using the same basic formula. Field Artillery would fire into "no man's land" to create craters for the infantry to take cover, destroy or disrupt obstacles, and target enemy strongpoints or artillery positions (Cardona, 2014). However, the same lack of communication and coordination often left enemy positions undestroyed. It also failed to provide the infantry with the support they needed, resulting in higher casualty rates (Bull, 2007).

Decentralized maneuver relied on trusting subordinate leaders, due to the difficulty commanders faced controlling them on the battlefield. The Germans referred to it as *Auftragstaktik*, the idea of individual action and initiative in the face of uncertainty but within the commander's intent (Widder, 2002). Previously, the infantryman marched in formation, and fired volleys in mass as they closed with the enemy to deliver the final bayonet charge (Kerr, 1990). Skirmish lines had the liberty and flexibility to utilize terrain to their advantage. Rifle squads were trusted to take advantage of their modern firearms and engage the enemy from more advantageous positions to inflict casualties on the enemy and remain protected (Bull, 2007).

Auftragstaktik, was born from German experiences in battle with Napoleon, and carried through the 19th and into the 20th century (Widder, 2002). Skirmishers, lines of troops forward of the main body, were a standard affair in European warfare, and were tasked with making precision shots at approaching enemy forces to exact casualties before the main body of the enemy could effectively range the German Army's main body (Cardona, 2014).

The German High Command realized this problem, and experimented with different techniques of equipping their Soldiers with multiple weapons like rifles and hand grenades (Cardona, 2014). The German Army sought a method to break through the stalemate on the Western front. Experimentation led to the development of the *Sturmbattalion* (Storm Battalion) and *Stroßtruppen* (Storm Troopers) which relied on competent small unit leaders, capable of conducting independent maneuver in support of an overall objective (Cardona, 2014).

Stroβtruppen were specially trained Soldiers optimized in siege warfare and the attack (Bull, 2007). Integration of multiple skillsets increased the versatility of the squad. No longer was the squad comprised of riflemen carrying rifles, and grenadiers carrying grenades. *Stroβtruppen* were cross-trained to employ multiple weapon systems to magnify their effectiveness and reduce their reliance on other units for support (Cardona, 2014). The *Stroβtruppen* concept was initially a goal for all German Soldiers, but continuous combat operations prevented it from becoming a reality (Cardona, 2014). It did, however, became the model for future infantry units to emulate.

The U.S. Army witnessed the effectiveness of the *Stroβtruppen* first hand during WWI. In turn, they used those experiences to design infantry squads for WWII (Hughes, 1995). Normally, infantry squads were equipped solely with rifles. However, the modern squads were equipped with a mixture of rifles, submachine guns, and automatic rifles combined with grenades and anti-tank rockets which maximized the lethality of the infantry squad (Hughes, 1995).

Cross training within the squad became the norm; all Soldiers are expected to be familiar with all of the weapons in the squad. As they become available, new technologies and capabilities are integrated into the squad, in an effort to continually maximize the squad's effectiveness. Not only did weapon systems change, but squad formations morphed over time from WWII to our current war on terror. Squad size was based on a dual function of personnel availability and a desired effectiveness level (Karcher, 2002). Squad size changed over time from its peak at 12-men during WWII down to a low of an 8-man after the introduction of the Bradley Fighting Vehicle to our current 9-man squad across all infantry organizations (Hughes, 1995).

What did not change however, was the role of the squad leader within the squad and platoon. Squad leaders are expected to execute their mission in support of the overarching Commander's Intent for the operation through mission command (DA, 2007). Infantry squads are expected to utilize "mission oriented command and control to lead the squad, and complete their mission (DA, 2007). Mission command teaches the empowerment of subordinate leaders at each level (Deparment of the Army [DA], 2012a). A leader is empowered to accomplish his mission based on his understanding of his mission's task and purpose and the mission(s) of other adjacent units. Leaders are expected to seize the initiative and exploit gains won from the enemy. The infantry squad leader is a trusted NCO who is expected to use his experience and tactical knowledge to lead his squad and close with and destroy the enemy (DA, 2012a).

Integration of new technologies continue to increase the effectiveness of the infantry squad. More powerful small arms and other weapon systems coupled with day and night optics provide the infantryman with unparalleled effectiveness on the battlefield. Infantry squads continue to increase their autonomy in current Counter Insurgency (COIN) operations. Often squads conduct independent patrols from fire bases in the mountains of Afghanistan. Squad leaders are expected to maintain communications with their higher headquarters while coordinating with air and other combat multipliers to defeat the enemy and accomplish their mission.

Infantryman will always be relevant on the battlefield. The U.S. Army Operating Concept: Win in a Complex World characterizes that "future armed conflict will be complex…because threats, enemies, and adversaries are becoming increasingly capable and elusive." (DA, 2014b). The Air Force may be able to bomb an objective, and the Navy may be able to launch cruise missiles from hundreds of miles away. But it is the infantryman who is required to hold the ground, and his success rests in part on the effectiveness of his rifle.

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IV. OPERATIONAL EFFECTIVENESS OF THE INFANTRY SQUAD

The mission of an infantry squad must be considered early in the acquisition process. Greater comprehension of the elements for operational effectiveness will lead to the procurement of more suitable systems. There are different explanations used for describing operational effectiveness. Defense Acquisition University explains operational effectiveness as the ability to accomplish a mission with a specific system and representative personnel (Defense Acquisition University [DAU], 2017). An effective infantry squad is capable of projecting its military capability among adversaries.

There are a diverse number of variables, both qualitative and quantitative needed to create a potent combat-ready force. The qualitative variables, such as training, leadership, demographics, and comradery are extremely important with any unit. However, these variables are influenced by the unit, and are dependent on different personalities, culture, which contribute to the organizational climate. Tactical and technical proficiency, on the other hand, are quantitative variables which can be shaped through the acquisition process. Understanding the squad and correctly distinguishing these factors are fundamental during the design and development of systems, which support the rifleman.

The ability to conduct fire and maneuver is dependent on the quality of equipment developed for the infantry squad. Organic systems like the rifle and machine gun as well as the Bradley Fighting Vehicle and Stryker Combat Vehicle were developed based on how the Army defined operational effectiveness early in the acquisition process. Therefore, equipment designed to produce greater effective fires to support maneuverability will produce overmatch capability in comparison to our adversaries.

Decomposition of an infantry squad allows us to break it into two distinct components, personnel and equipment (DA, 1946). Increasing the potential of personnel is essential in the maximizing squad effectiveness. However, as mentioned above, this can only be achievable at each individual organization. These unmeasurable elements consume characteristics which cannot be evaluated during the early design phase of a system. Consequently, our focus on achieving maximum effectiveness is based on measureable elements—equipment, specifically the rifle and ammunition.

A powerful force on the battlefield, the infantry squad alone does not have overwhelming firepower compared to peer and near-peer adversaries. In order to achieve overmatch against the enemy we must invest in research and development to ensure the best systems are in our soldiers' hands. The rifle is the most important system an infantryman has at his disposal.

Analysis of alternatives are conducted on different avenues, research into amplifying the fundamental qualities must be explored. Small arms fire superiority is achieved through a rifle that can deliver high volumes of accurate fire at the enemy. Comparatively, the rifle should not reduce the mobility of the rifleman or hamper the functionality of the entire squad.

Using a holistic approach to view operational effectiveness drives the dynamics of the study to a different spectrum. Hence, the application of the following evaluative criteria during the acquisition process is a measurement for operational effectiveness: lethality, accuracy, mobility, and interoperability.

V. METHODOLOGY

This chapter discusses the procedures used in our decision-making process. An upfront explanation of the courses of action, criteria, and risks provides a familiarization prior to comparison. Our explanation is followed by an analysis of the raw, normalized, and weighted data. Evaluating each factor systematically provides a thorough comparison for a potential solution. We conclude the chapter by completing a sensitivity analysis to reveal possible trends in the data or factors which could arbitrarily skew the results.

A. COURSES OF ACTION

Our research will focus on four distinct courses of action (COAs). These COAs are not intended to lead directly to a specific materiel solution. Instead, they will lead to an acquisition strategy to determine the optimal COA to follow. Our recommended acquisition strategy accounts for lessons learned from both the Individual Carbine (IC) and Modular Handgun System (MHS) Acquisition Strategies.

The considered COAs leverage COTS/NDI systems which will include the weapon and ammunition optimized to meet the user's requirements. Evaluation of the COAs ensures their ability to meet the user's requirements in an operational environment while providing a best value to the government. Our intent is not developing a system, but evaluating the systems based on performance specifications. This methodology reduces the risk to the government, and encourages innovation within the small arms industry to meet the Army's requirement (DA, 2014a).

Courses of Action:

- COA1: M4A1 with M855A1 (5.56mm)
- COA2: Modified M4A1 with New Intermediate Caliber Ammunition (.264 USA)
- COA3: New Carbine with New Intermediate Caliber Ammunition (.264 USA)

- COA4: New Carbine with M80A1 (7.62mm)

COA1: Course of Action 1 is basically the status quo and is a baseline for the purposes of this study. COA1 does not provide any enhancements or increase to the lethality of the system. Instead COA1 anchors the remaining COAs against an objective to attain. If the M4A1 with M855A1 ammunition meets the user's current requirement, then the other COAs must outperform COA1 in order to represent a better value to the government.

The M4A1 is a current system, and has minimal planned additional research and development funds to maintain currency. We assumed that additional functionality could be added to rifle at a cost of $2million in overall R&D funds.

COA2: Course of Action 2 represents an increase in capability through the adoption of an intermediate caliber ammunition type (Jenzen-Jones, 2016). This COA balances the cost associated with the type classification of a new ammunition type. The M4A1 is a trusted, versatile, and battle proven platform and has served the U.S. military in various forms since the Vietnam War. The M4's versatility comes from its ability to be easily reconfigured to meet different mission requirements. M4A1's utilizes an upper and lower receiver group which are easily separated and interchangeable between weapons. Weapons can be easily modified with accessories or other parts to meet different mission requirements.

Course of Action 2 would involve modifying the M4A1 to fire a new ammunition type. The modification would come from changing the necessary parts in the upper receiver group to accept a new ammunition type that would be compatible with the M4A1 upper (Griffin, 2015). Preferably, the conversion would require changing the barrel, bolt, and maybe a few other small items but would not require a change to upper receiver housing. The program may not see a significant reduction in test and evaluation cost, but the relatively low prices of these parts could significantly reduce the procurement costs.

COA3: Course of Action 3 would include both a totally new weapon system and a new ammunition type. Similar to COA2; COA3 would utilize an intermediate round to bridge the gap between the M855A1-5.56mm and M80A1- 7.62mm rounds. However, unlike COA2; COA3 would invest in an entirely new small arms weapon (different than the M4A1) (Skovand, 2017). Input from the Army's Small Arms Ammunition Configuration Study (SAAC) will undoubtedly inform the requirements for the next weapon system (Dawson, 2014). This COA represents a full-up test and evaluation plan for both a weapon and ammunition to achieve an increased capability. COA3 will seek a COTS/NDI system solution to meet the requirement, and reduce risk to the program.

COA4: Course of Action 4 is a new weapon system with a currently type classified ammunition type, M80A1-7.62mm. This COA represents a balance between COA1 and COA3 by mating a new weapon system with a current type classified ammunition type. COA4 mitigates risk to the program by reducing cost below COA3 through the use of a current ammunition type, and increasing the capability to the warfighter as in COAs 2 and 3.

Similar to COA3, the SAAC Study will inform the requirements for a new weapon system. M80A1 will increase the lethality, but a new weapon will seek to increase functionality. 7.62mm ammunition can be utilized in a number of different firearm platforms, and may represent a viable alternative to intermediate caliber options.

B. PROCESS

Our methodology is based on four performance factors to maximize the operational effectiveness of the infantryman. Each criterion must assess the critical component's intended use. These components consist of both performance and risk factors. Performance factors are important since they become part of the infantry squad capabilities following the successful selection and procurement of the system. Performance factors are, in order of importance: lethality, accuracy, mobility, and interoperability. Risks are both internal to the project and external. Internal risks are cost and schedule as both are drivers to a course of action and an acquisition strategy to deliver a capability for the warfighter. Other risks factors such as political and international, where Congress and NATO may play into the adaptation of a new small arms capability for the infantryman.

1. Performance Criteria

a. Factor 1: Lethality

Increasing Soldier lethality is a high priority for the Army. The first objective in the 2015 modernization strategy is the investment in systems (weapons, optics, and etc.) which provide Soldier and Squad with improved lethality (U.S. Army, 2015). Presently, the new Army Modernization Priorities signed in 2017 has Soldier lethality as one of its six priorities (Judson, 2017).

Lethality is the ability of the weapon system, rifle and ammunition, to inflict wounds on the enemy and incapacitate him. Incapacitation is defined as the inability of the enemy combatant to conduct military tasks. Lethality is comprised of multiple facets that each affect the ability of the weapon system to achieve its goal of incapacitating the enemy. The military defines lethality as the Probability of Incapacitation Given a Hit ($P_{I/H}$) (Minisi, 2016). Our thesis will focus on the Sectional Density (SD) of the projectile to determine lethality.

Sectional Density: Sectional Density is an attribute of a projectile which determines the efficiency of the projectile. The *Hornady Handbook of Cartridge Reloading* defines it as “the ratio of a bullet’s weight in pounds to the square of its diameter in inches.” In other words, “bullets of the same shape, but with more weight in relation to their diameter will retain their velocity and energy better” (Emery, 2012). For example, a 7.62x51mm caliber rifle is capable of firing cartridges loaded with different bullets of varying weights and lengths intended for that caliber. As the weight of the bullet increases, so does the sectional density (Emery, 2012).

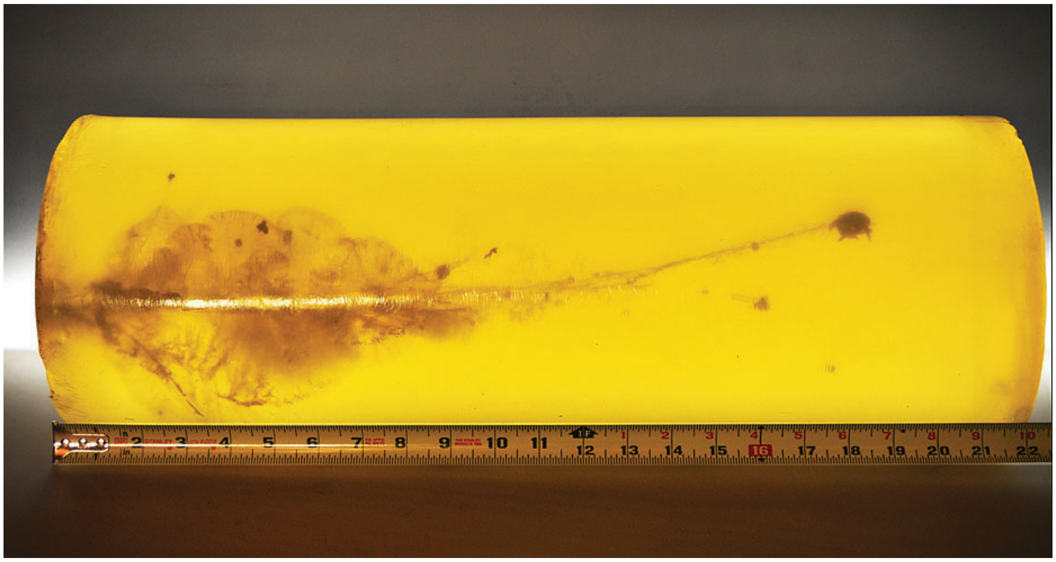

Figure 15. Penetration of a 7.62 Round in a Gelatin Substance.
Source: Minisi (2016).

b. Factor 2: Accuracy

The IC AS states the next generation rifle must provide accurate engagements from 0 to 600 meters throughout the range of military operations and environments (DA, 2011a). System Accuracy is listed as KPP 1 in the IC CDD, and the MHS CPD (DA, 2008, 2011a).

Weapon accuracy encompasses several factors that will affect the weapons at greater ranges. Our study focuses on Ballistic Coefficient (BC), which is a measure of the aerodynamic drag on a bullet. A higher BC retains its velocity greater during flight (Griffin, 2015). Generally, longer, tapered rounds are more aerodynamic, resulting in a higher BC (Emery, 2012). Exploiting the combination of these elements help maximize target effectiveness at ranges beyond 300 meters.

c. Factor 3: Mobility

A Key System Attribute (KSA) of the Squad Designated Rifle CPD is system weight (DA, 2016b). System weight adversely affects an infantryman's ability to maneuver on the battlefield and pursue the enemy (Bernton & Nowlin, 2003). Mobility for our study is the combination of weapon and 210 rounds of ammunition as carried by the rifleman. Figure 16 depicts the individual and cumulative weight an infantryman can expect to carry during an approach march as well as actions on the objective.

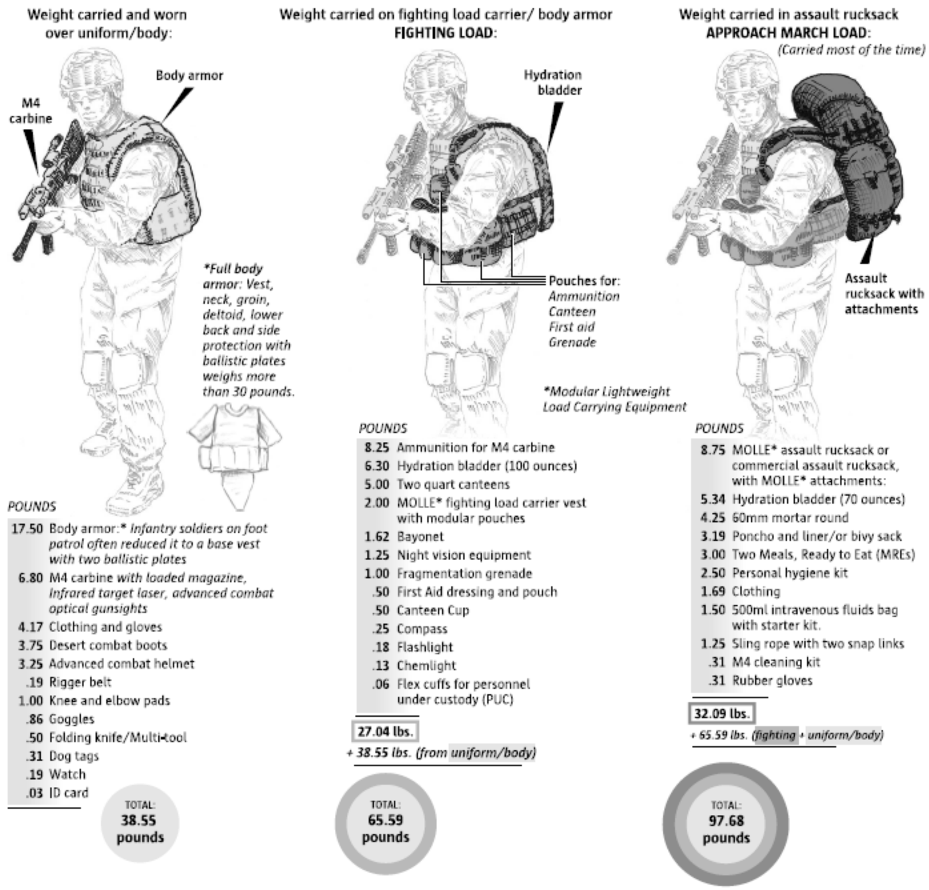

Figure 16. Equipment Weight Carried by the Average Infantryman.
Source: Bernton and Nowlin (2003).

Infantryman throughout history have carried between 50 and 60lbs on their backs while marching to battle (DA, 2009). Tests conducted by the Army found that as carried weight decreased, small arms accuracy increased (DA, 2009). A larger round will increase the weight per round and decrease a rifleman's mobility and effectiveness.

d. Factor 4: Interoperability

Interoperability within an infantry squad refers to the ability of squad members to exchange magazines and ammunition between one another. For our assessment we measure interoperability as the percentage of infantryman in a 9-man squad utilizing the same ammunition type, and can then cross load as needed.

The necessity for members to operate as a cohesive unit with common equipment is indispensable. A small arms survey conducted in 2016 stated a standardization of calibers within an infantry squad provides a tactical advantage via the interoperability of ammunition (Jenzen-Jones, 2016).

2. Program Risks

a. Risk 1: Cost

Cost risk associated with a program can result in program cancellation if costs rise beyond projections or if the capability seems unaffordable. It can be argued that costs should not be evaluated as part of COA analysis. However, all acquisition programs must compete for the same resources. Showing cost savings while providing for an increased capability to the Service will help achieve program success.

b. Risk 2: Schedule

Similar to cost, schedule can be an important element to a program's success. Some acquisition programs require extended schedules due to intense development required to fully deliver the capability. In this case, a rifle is a very mature technology, and would not require an extended Engineering and Manufacturing Development phase to validate whether the requirements are attainable. To reduce schedule risk, we anticipate the COTS/NDI nature of our program to enter acquisition process at pre-milestone C like MHS program and reduce the overall schedule (DA, 2014a). For our assessment, an extended schedule is disadvantageous to the program's success.

3. Other Risk Factors

a. Political Risk

Political risk is an important factor, but does not weigh as heavily as cost, schedule, or performance. Politicians wield power within the acquisition domain, and can affect the decision makers within the Services. Requirements must have traceability to higher level documents such as the National Security Strategy or the National Defense Strategy as well as map to the priorities of the respective Service Chief. Inability to do this places increased risk on the program by Congress and other elected officials.

Congress has the ability to defund programs that it feels are unnecessary or are not being managed to produce the capability required of the military. Political risk cannot be quantified numerically in the same manner as other types of risk. However, it is important and must be discussed with respect to any course of action.

b. NATO Risk

NATO risk, much like political risk, cannot be quantified because neither concurrence nor support are sought from NATO before determining a small arms path. NATO played a critical factor in deterring Soviet aggression during the cold war (B. Halpern, interview with authors, August 2017). However, since the fall of the USSR, NATO small arms interoperability has assumed a less prominent role.

The U.S. military has effectively established NATO small arms standards since the late 1940s (Hallock, 1970). NATO and other partner nations will accept U.S. small arms standards based on the R&D and testing conducted by the U.S. military. Therefore, there is minimal risk to NATO nonoccurrence affecting the outcome of the U.S. Army’s small arms program (Halpern, 2017).

To ensure NATO interoperability, European NATO partners provide a predetermined amount of ammunition to a NATO small arms test center on an annual basis for testing with other nation’s weapons. All of the NATO partners participate in this testing process except for the U.S. Although we utilize ammunition in a similar caliber we do not provide ammunition to NATO to ensure NATO partner interoperability. Therefore, just because the ammunition is the same caliber, it does not represent the same capability and is not guaranteed to be interoperable.

NATO small arms capabilities are influenced by U.S. research and development (Halpern, 2017). A meeting with the Chair of the NATO Weapons & Sensors Sub Group at Picatinny Arsenal, NJ revealed that several non-NATO partner nations are adapting their small arms fleet to fire NATO Standard ammunition (Halpern, 2017).

These nations are modernizing their Soviet Bloc weapons to show solidarity with the West (Halpern, 2017). Although based on speculation, it can be anticipated that these nations would be interested in purchasing our stock of 5.56mm ammunition and rifles. Purchasing our weapons and ammunition would provide them with a jump start to NATO standardization. Figure 17, depicts the future small arms plans for multiple NATO and non-NATO partner nations.

NATO OTAN

NATO Army Armaments Group

NATO Collaborative Opportunities

Assault Rifle Standard-Weapon (Caliber)

Number of Countries Planning to Upgrade – 22

Number of Countries with TBD Plans – 7 (GE, ES, GR, NO, PO, SWE, TU)

13- 5.56mm Caliber Variants

4- 7.62 x 51 Caliber Variants

2- 7.62 x 39 Caliber Variants

M4/M4A1

Country	Current Weapon/Sensor	Future Weapon/Sensor
AUS	F88 AUSTEYR family of weapons, including the F88SA1 and F88SA2. Recent release of the EF88 (enhanced F88, aka the F90). Australian variant M4A1 for SOCOMD users.	The F90 will be the enduring service rifle well past the 2021 SARP.
AUT	STEYR AUG - A1, (STG 77) 5,56mm	STEYR AUG A1 - Carbine, 5,56mm
BE	FN SCAR-L (5.56 NATO) & FNC M3(5.56 NATO)	
CA	C7A2 (M16 Variant) 5.56mm	C7A2 until 2030+ Future Small Arms Research (FSAR) on the way to define the replacement weapon after that
SWI	5,56mm (SG 551)	5,56mm
CZ	CZ 805 Bren A1/A2-Assalut Rifle 5,56 mm	CZ 805 Bren A1/A2-Assalut Rifle 5,56 mm
DE	Colt canada C8IUR (monolithic rail system and 16 inch barrel) with slimmed sides, STANAG 4694 rails and MAGPUL Furniture, Colt Canada C7A1 and C8A2	Fleet renewal til C8IUR standard
GE	G36, G36A1, G36A2, G36A3 5,56 mm x 45	tbd
SP	G36 E, 5,56 x 45 mm	G36E Improved, 5,56 x 45 mm
ES	5,56 mm Galil; 7,62 mm AK-4	Replacement from 2017
FIN		
FR	FAMAS F1 cal 5,56 Nato and FAMAS G2 cal 5,56 Nato (marines) FAMAS Infanterie cal 5,56 Nato (F1 with Nato interface) FAMAS FELIN cal 5,56 Nato (=FAMAS VALORISE with Felin system) FAMAS VALORISE cal 5,56 Nato (with MIL-STD-1913 rail)	AIF (Arme Individuelle Future) cal 5,56 Nato
UK	L85A2 SA80A2 HK (5.56mm) ISD: 2001	L85A3 SA80 ETF OSD:2025
GR	CALIBRE 7,62 mm and 5,56mm	5,56mm will be the main calibre
HU	AK-63 (7.62 mm)	
IT	Beretta 70/90 5,56 mm x 45, ARX 160 5,56 mm x 45	"Soldato futuro" weapon (ARX 160 5,56 mm x 45)
LI		
NL	COLT Canada C7-/C8NLD; HK-416A2 (5,56 mm x 45)	HK-416A5 (11" and 14,5" barrels) (5,56 mm x 45) (to replace A2 version)
NO	HK 416 5,56 x 45 mm	To be defined
NZL		
PL	BERYL 5,56x45 mm MSBS 5,56x45 mm	MSBS 5,56x45mm
PR	G 3 rifle 7,62 x 51 mm	Acquisition process (NSPA) starts 2017. (5,56x45 mm NATO, STANAG 4172)
SK	Sa-v2 58 (7.62 x 39)	
SN	M 70 AB2 (Kalashnikov type) 7,62x39	5,56x45
SWE	ak 5C and D (FN FNC), ak 4 (HK G3)	New carbine
TU	G3 A3, G3 A4, (7,62 mm. X 51) - HK 33 E (5,56 mm X 45)	to be defined
US ARMY	M4/M4A1 5.56mm x 45	M4/M4A1 5.56mm x 45. The M4A1 program is introducing an enhanced performance magazine to improve the interface between the weapon and the enhanced performance magazine. Results of caliber study will inform the material solution to the future carbine.
USMC	M-16A2/A4, M-4 5.56mm x 45, M27	M-16A4, M4A1

NATO UNCLASSIFIED rel to PfP, Australia, New Zealand and Singapore 35

Figure 17. NATO Future Small Arms Development and Integration Plans. Source: Halpern (2017).

4. Raw Data Analysis

Analyzing the raw data does not provide a clear view of which COA is superior across the board. Each COA presents merits within the different evaluation metrics. Table 1 provides the raw data for each factor.

Table 1. Raw Data Associated with Performance Factors, Program, and International Risks.

Raw Data Table					
Performance Criteria		COA 1	COA 2	COA 3	COA 4
	Lethality	0.178	0.252	0.252	0.196
	Accuracy	0.151	0.260	0.260	0.189
	Mobility	13.28	16.70	16.70	24.75
	Interoperability	9-0	7-2	7-2	7-2
Performance Values					
	Cost[a]	$ 2,000,000	$ 20,000,000	$ 25,438,000	$ 23,438,000
	Schedule (months)[a]	12	24	32	18
Other Criteria					
	Political	-	+	+	+
	NATO	+	-	-	+

[a] DA (2011a).

a. Performance Criteria

Lethality: Using SD as the evaluation factor, COAs 2 and 3 are superior to COAs 1 and 4. Surprisingly, COA4 with its larger ammunition type did not present a higher lethality rating. COAs 2 and 3 both utilize an undetermined intermediate caliber cartridge which is understood to have a higher SD than COA1 (Emery, 2012). The 7.62x51mm ammunition normally exhibits a higher SD, however the use of the M80A1 cartridge reduces SD in an effort to prioritize other ammunition characteristics (DA, 2012b).

Accuracy: Once again, COAs 2, 3, and 4 outperform COA1 on accuracy. This is not surprising since COA1 utilizes the smallest and lightest projectile of the four COAs. COA4 utilizes the Army's new 7.62x51mm round, the M80A1 which is a lighter projectile than the previous generation M80. The two rounds are 131, and 147 grains respectively. Reducing the weight of the cartridge reduces the amount of propellant required to achieve a desired muzzle velocity (Nathaniel F., 2016).

Intermediate caliber cartridges normally bridge the gap between 5.56mm and 7.62mm. They offer a longer projectile with a smaller diameter to perform efficiently at longer ranges (Jenzen-Jones, 2016). We selected the .264USA as our intermediate caliber of choice for this analysis, however, other intermediate caliber cartridges can be expected to perform similarly (Griffin, 2015).

Mobility: COA1 is clearly superior in this category. COAs 2, 3, and 4 all represent a heavier weapon and ammunition combination than the M4A1 with 210 rounds of M855A1 ammunition. COA4 is the least desirable at almost 25 pounds. 7.62mm rifles are normally heavier than their small caliber counterparts due to the increased velocity and chamber pressure exhibited on the firearm (Emery, 2012).

COAs 2 and 3 tie for 2nd place behind COA1. These two COAs represent only a slight increase in weight over the status quo. This weight increase is less than 3.5lbs, and could be considered negligible over COA1. However, any increase in weight decreases mobility, and this must be taken into consideration when selecting a COA (DA, 2009).

Interoperability: COA1 is superior when evaluated against interoperability. The M249SAW fires the same ammunition type as the M4A1; allowing for riflemen to cross load ammunition as needed during combat. COAs 2, 3, and 4 utilize a separate ammunition type than the M249. In these COAs, only the 7 riflemen are interoperable with each other; leaving the 2 SAW gunners interoperable.

However, the marginal benefit of 9 rifleman versus 7 riflemen and the 2 SAW gunners is low. All squad members are interoperable with another squad member who utilizes the same ammunition type. Also, even though the M4A1 and M249 utilize the same ammunition type, they are not perfectly interoperable. The M4A1 fires from a magazine, and the M249 is primarily a belt fed weapon. The M249 can accept a 30 round M4A1 magazine, however, the weapon is much more prone to malfunction and would only fire from a magazine in emergency situations.

Risk can be mitigated with these performance factors through adoption of a new Squad Automatic Weapon chambered in a similar round. The Army's Next Generation Squad Automatic Rifle and Ammunition Capability Decision Document will seek ammunition compatibility within the family of weapons (carbine, squad designated marksman rifle) (DA, 2016a).

Similarly, adoption of the Mk48 lightweight machine gun chambered in 7.62x51mm from USSOCOM would mitigate interoperability between weapon systems. This would, however, required increased time and funding to ensure interoperability exists and to type classify the weapon system for the Army (Johnson, 2011).

b. Program Risks

Cost: Cost is an inevitable factor associated with any acquisition program. COA1, is clearly the favorite in this category. However, it is only the favorite because of the sunk costs and timeline of previously developing the system to meet the needs of the Vietnam War and continuously modifying it since its adoption. The Army's Individual Carbine (IC) program sought to increase the effectiveness of the individual rifleman's rifle with a new system. The failure of this program led to the adoption of the M4A1 (Shinkman, 2013). Failure to account for this would increase risk of making the same mistakes as the IC.

COA2 is promising when comparing the raw data. These costs depict an estimation of funds needed to test the M4A1 modifications to meet the user's requirements. Both this COA and COA3 require a new ammunition type, and the critical path of these schedule would follow the time necessary to qualify and type classify a new ammunition type.

COA4 splits the difference between COAs 2 and 3. Cost risks associated with COA4 stem from testing and validation of a new rifle. The new weapon system will constitute a one for one swap within the infantry squad. Thereby, increasing squad lethality through the individual rifleman. COA4 is more expensive than COA1, however COA4 has the ability for future upgrades while COAs 1 and 2 do not.

Schedule: COA1 is preferred in this category, but only because it is a legacy system that is currently fielded across the entire DOD. COA4 is second with an estimated 18 months to validate the system's performance with M80A1 ammunition.

COA2 and COA3 are substantially longer because they both require a new ammunition type. Type classifying ammunition requires roughly 1 year to complete all the tasks. Propellants and primers are tested to ensure the safety and stability of the materials. Propellants are also artificially aged to 20 years to ensure the propellant will retain the required energetics and perform properly through proper storage of the war stock.

c. Other Risks

Political: COAs 2, 3, and 4 achieve the political desires of the Army and Congress. They each increase the lethality of the rifleman. Lethality is a key driver in the Chief of Staff of the Army's modernization plan (Tucker, 2017). Congress is showing reluctance to fund major Army programs which show little promise in successfully placing capabilities in Soldier's hands (Myers, 2017). A low risk program such as this would encourage the Army to tackle other modernization programs.

COA1 does not increase the capability of the rifleman on the battlefield. COA4 provides an increase at an acceptable cost and schedule. COAs 2 and 3 provide an opportunity for a bridging strategy to deliver an increased capability to the rifleman rapidly through COA2, and then following up with a completely new platform for the rifleman under COA3.

NATO: COAs 1 and 4 are acceptable to NATO since they both utilize a NATO standard caliber. As discussed earlier however, the U.S. military does not provide ammunition to NATO for interoperability testing with NATO small arms. Although, they are the same caliber, they are not the same ammunition. COAs 2 and 3 are unfavorable, because they represent an entirely new ammunition caliber. In a Cold War-esque battle, NATO forces could not resupply ammunition to U.S. forces as they would be completely inoperable. However, the British Army has a similar desire to upgrade its small arms weapon system to a larger and more effective caliber (Drummond & Williams, 2009). The British Army has similar lessons learned from battles over the years. Developing a common ammunition type along with the Brits may be a viable solution which could encourage NATO to follow suit (Halpern, 2017).

d. Summary

At a cursory look the raw data initially points toward COA1 with superior raw data ratings across four of the criteria. Figure 18, depicts the system level improvements of the M4A1 from 1991 to the present. However, COA1 is inferior to the other three COAs in the two most important criteria; lethality and accuracy. These criteria rate higher than the others because they represent the increased capability to the rifleman. Any COA that does not improve lethality or accuracy cannot be considered as a viable COA. Depending on the factor or risk category, any of the other COAs or combination of COAs can present a viable option to the warfighter. Normalization of the data may provide more insight into the data, and provide a clear trend to a particular COA.

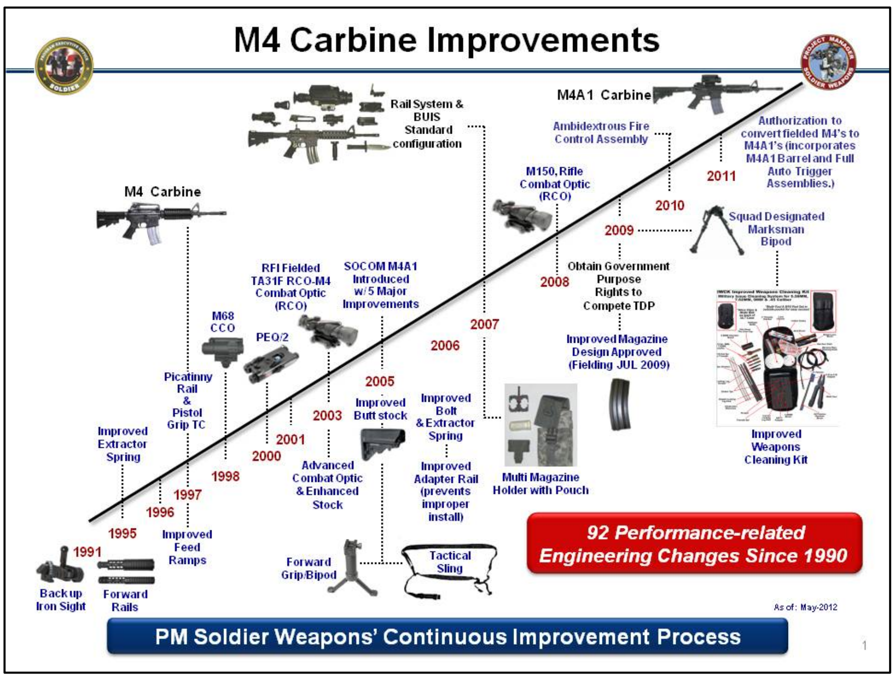

Figure 18. Linear Timeline of Small Arm Improvements.
Source: Dawson (2012).

5. Normalized Data Comparison

Analyzing the raw data did not present a clear winner amongst the COAs. In an effort to further distinguish them from one another, we normalized the data within the value models on the previous page. The performance factors are given a value score based the value of the raw data for each respective value model. Raw data is valued from 0 – 1, with 1 being the best. These scores are summarized in Table 2 and the corresponding value curves shown in Table 3.

Table 2. Normalized Values after Raw Data Is Applied to the Value Model

Normalized Data Table					
Performance Criteria		COA 1	COA 2	COA 3	COA 4
	Lethality	0.180	0.520	0.520	0.196
	Accuracy	0.150	0.260	0.260	0.189
	Mobility	1.00	0.825	0.825	0.153
	Interoperability	1.00	.750	.750	.750
Performance Values					
	Cost[a]	$ 2,000,000	$ 20,000,000	$ 25,438,000	$ 23,438,000
	Schedule (months)[a]	12	24	32	18
Other Criteria					
	Political	-	+	+	+
	NATO	+	-	-	+

[a.]DA (2011a)

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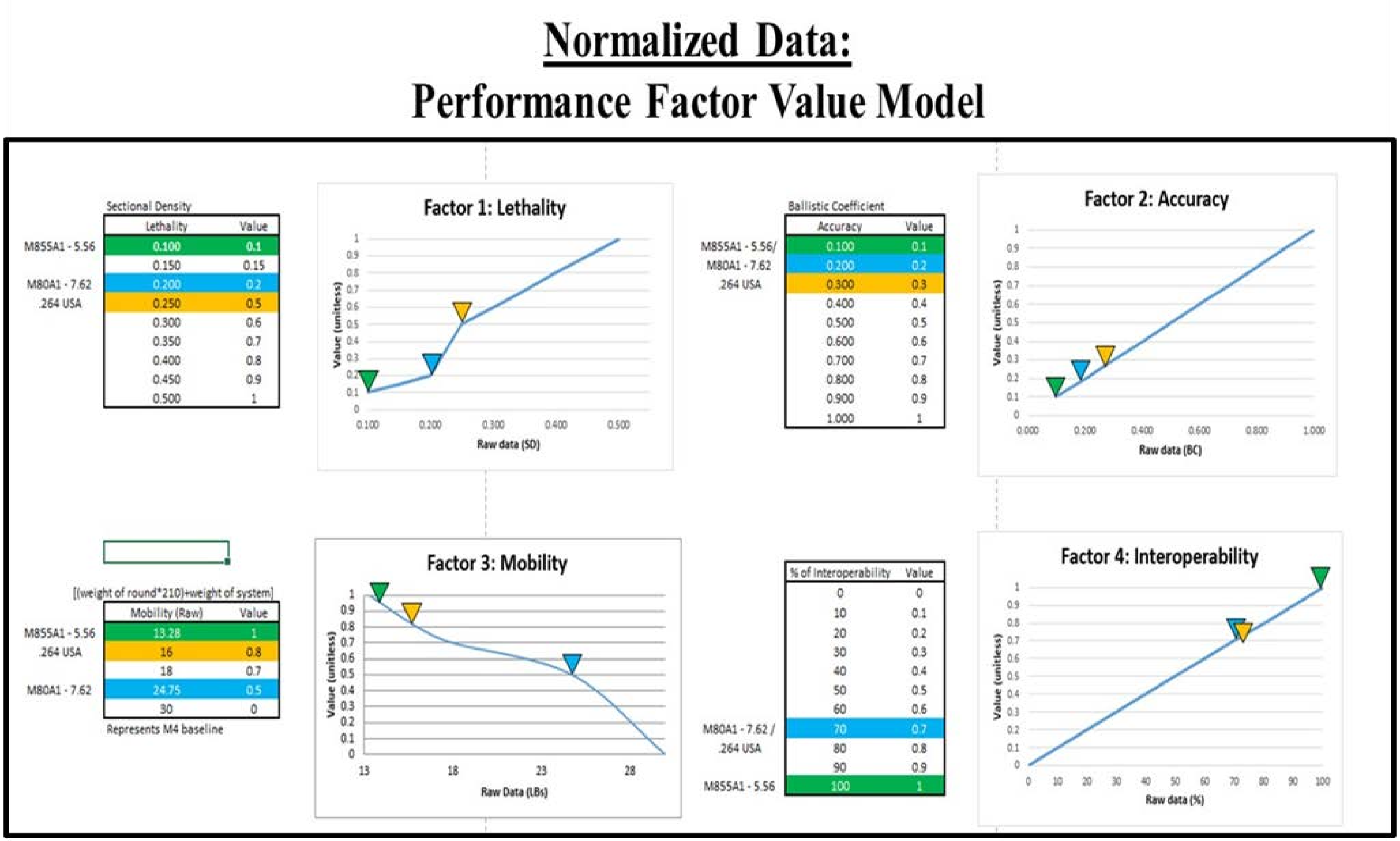
Table 3. Normalization of Performance Factors Using a Value Model.



Sectional Density

	Lethality	Value
M855A1 - 5.56	0.100	0.1
	0.150	0.15
M80A1 - 7.62	0.200	0.2
.264 USA	0.250	0.5
	0.300	0.6
	0.350	0.7
	0.400	0.8
	0.450	0.9
	0.500	1

Ballistic Coefficient

	Accuracy	Value
M855A1 - 5.56/	0.100	0.1
M80A1 - 7.62	0.200	0.2
.264 USA	0.300	0.3
	0.400	0.4
	0.500	0.5
	0.600	0.6
	0.700	0.7
	0.800	0.8
	0.900	0.9
	1.000	1

[(weight of round*210)+weight of system]

	Mobility (Raw)	Value
M855A1 - 5.56	13.28	1
.264 USA	16	0.8
	18	0.7
M80A1 - 7.62	24.75	0.5
	30	0

Represents M4 baseline

	% of Interoperability	Value
	0	0
	10	0.1
	20	0.2
	30	0.3
	40	0.4
	50	0.5
	60	0.6
M80A1 - 7.62 / .264 USA	70	0.7
	80	0.8
	90	0.9
M855A1 - 5.56	100	1

PERFORMANCE CRITERIA:

Lethality: After normalization the data, COAs 2 and 3 are superior to COAs 1 and 4. COA1 and COA4 employ a projectile with a lower SD than COAs 2 and 3. The intermediate caliber cartridge is still superior after normalizing the data (Jenzen-Jones, 2016).

Accuracy: COAs 2, 3, and 4 depict superior normalized data than COA1. COA 2 and 3 represent a projectile with a higher BC than COAs 1 and 4, which lends to their superior normalized rating. Normalized accuracy ratings trend similarly to the raw data ratings of the COAs.

Mobility: COA1 follows the trend set in the raw data assessment with COAs 2 and 3 trailing close behind. After normalization, COA4's additional weight greatly reduces its attractiveness as a viable solution and barely scores above a 0 rating.

Interoperability: There is no change to COA rankings after normalizing the interoperability ratings. Only COA1 offers 100% interoperability. Risk mitigation techniques must be employed to ensure that all ammunition in the squad are interoperable with one another. As with the raw data, the marginal benefit of increased interoperability does not increase the viability of COA1.

PROGRAM RISKS: N/A

OTHER RISKS: N/A

SUMMARY:

Program risks and other risks are not normalized in order to prevent skewing of the data. These factors are unable to be quantified in a similar manner as with the raw data. Additionally, these risk factors should not be normalized against the performance factors since they do not present factors that affect the lethality of the rifleman in the infantry squad.

6. Weighted Analysis Comparison

Normalization is the first step into understanding the data and eventually assessing results. The next phase of COA evaluation is dependent on the four weighted criterions and the selected weights. Table 4 depicts the weighted performance criteria.

Table 4. Weighted Quantity COA Totals

Weighted Data Table					
Performance Criteria		COA 1	COA 2	COA 3	COA 4
	Lethality	0.067	0.190	0.190	0.074
	Accuracy	0.051	0.088	0.088	0.064
	Mobility	0.21	0.173	0.173	0.104
	Interoperability	0.075	0.057	0.057	0.057
Performance Values					
	Cost[a]	$ 2,000,000	$ 20,000,000	$ 25,438,000	$ 23,438,000
	Schedule (months)[a]	12	24	32	18
Other Criteria					
	Political	-	+	+	+
	NATO	+	-	-	+

[a] DA (2011a).

Determination of proper weights are based on a swing weight breakdown. The use of swing weights vice preference weights are reflective of valid decision making. Swing weights were based on the variation and importance of each attribute. We concluded the following classification: 50% or below was **low variation**, 51%-75% **medium variation**, and 76% and above was **high variation**. User prioritization served as the determinant for the level of importance for each attribute.

Next, we placed each corresponding weight to a factor. Table 5, displays the location of each criterion on the swing weight table. Starting from the top-left (considered most important) to bottom-right (considered least important), each criteria receives a subsequent number and resultant location in our matrix. The most important value was given a numerical value of 100 and placed at the very top-left. Each additional attribute, as shown in Table 5, shall have a lesser value and location on the matrix. The swing weight values are computed together to obtain Total Swing Weight Value of 265.

Table 5. Swing Weight Table

variation in range	importance of value measure: High	Medium	Low
High	Lethality 100	Accuracy 90	
Medium		Mobility 55	
Low			Interoperability 20

Total Weight 265

Next, we divided each individual factor swing weight by the total swing weight to determine the measured weight. The Table 6 details the remaining values.

Table 6. Measured Weights Following Application of Swing Weights

Evaluation Measure	swing weight	Measure Weight
Lethality (Sectional Density)	100	0.38
Accuracy (Ballistic Coefficient)	90	0.34
Mobility [(wgt*210)+wgt of system]	55	0.21
Interoperability (% of similar ammo w/in sqd)	20	0.08
		1.00

Total criterion values are found by multiplying the measured weights by the value scores. If measuring lethality, for instance, we take 0.38 (measured weight) multiplied by the normalized data of one of the COA (COA1 = .180). Ensuring an accurate metric is crucial for comparison analysis.

PERFORMANCE CRITERIA:

Lethality: The weighted data revealed COA2 and 3 are still drastically superior to COAs 1 and 4. Lethality is the highest rated criterion compared to the other factors, and amplifies COAs with a higher sectional density.

Accuracy: Measured weight for accuracy equals 0.34. COA2 and 3 were best qualified in this area with a total of 0.088. COA4 is at .064, followed by COA1 with a weight of 0.051.

Mobility: Comparing mobility across each course of action was relatively closer. COA1 was the highest ranking with 0.21. COAs 2 and 3 are at 0.173. The marginal difference between COA1 and COAs 2 and 3 may be worth the investment in greater killing potential (lethality and accuracy).

Interoperability: The current program is the only system that reflects an optimum interoperability solution. Since all nine members of a squad are able to carry the same ammunition, results in COA1 ranked highest at 0.075. COAs 2, 3, and 4 all rate at 0.057. As with the raw data and normalized data analysis the marginal benefit of 7 and 2 versus 9 is negligible. However, changes in tactics and employment techniques of new weapon system would mitigate potential vulnerabilities with the squad.

PROGRAM RISKS: N/A

OTHER RISKS: N/A

SUMMARY:

In summary, the selection of a specific course of action can be skewed based on the individual weightings of the performance factors. Therefore, it is essential to understand the concept of operations and higher strategy. Additionally, the program manager must account for the underlying risks associated with each course of action. Accomplishing a qualitative analysis of the program risks (cost and schedule) gives a more well-rounded evaluation. Based on the resulting combination of both performance factors and program elements gives a balanced assessment for decision-makers.

7. Sensitivity Analysis

A sensitivity analysis allows us to test the feasibility of data. Selecting the right data is paramount for making informed decisions. Comparing multiple ranges develops a useful gauge to assess the corresponding outputs. Upfront identification of poor assumptions or insufficient inputs limit corrupted outputs and gives credibility to our selected methodology.

Our sensitivity analysis serves two purposes. First to provide the reader a realization that superficial weights are used to generate total scores. Second to verify that our weight selections are congruent with the current environment and leadership.

To provide realism in our study we conducted fifty valuations using different weighted trials. The corroboration of these different variations explains the diversity of our model, and observes the data behavior as the model changes. Table 7 shows a portion of these trial variations. The weights provided are the most prevalent for rationalizing our selected model weights. Initially, the attributes were tested with an equal weighting of .25 (highlighted in yellow). The total COA score resulted in the following: COA1 = 0.582, COA2 = 0.587, COA3 = 0.587, COA4 = 0.409. After further analysis of the volatility between each attribute, we weighted lethality extremely higher versus the other attributes. Weight 2 trial displays COA2 and 3 as glaring victors, defeating COA1 and 4.

Table 7. Sensitivity Analysis Trials

Weight 1	Attribute Weight	COA 1	COA 2	COA 3	COA 4
Lethality	0.25	0.045	0.126	0.126	0.049
Accuracy	0.25	0.038	0.065	0.065	0.047
Mobility	0.25	0.250	0.209	0.209	0.125
Interoperability	0.25	0.250	0.188	0.188	0.188
	TOTAL	0.582	0.587	0.587	0.409

Weight 2	Attribute Weight	COA 1	COA 2	COA 3	COA 4
Lethality	0.95	0.169	0.479	0.479	0.186
Accuracy	0.03	0.004	0.007	0.007	0.005
Mobility	0.02	0.020	0.017	0.017	0.010
Interoperability	0.01	0.005	0.004	0.004	0.004
	TOTAL	0.198	0.506	0.506	0.205

Weight 3	Attribute Weight	COA 1	COA 2	COA 3	COA 4
Lethality	0.500	0.089	0.252	0.252	0.098
Accuracy	0.400	0.060	0.104	0.104	0.104
Mobility	0.050	0.050	0.042	0.042	0.042
Interoperability	0.050	0.050	0.038	0.038	0.038
	TOTAL	0.249	0.435	0.435	0.281

Weight 4	Attribute Weight	COA 1	COA 2	COA 3	COA 4
Lethality	1.00	0.178	0.504	0.504	0.196
Accuracy	0.00	0.000	0.000	0.000	0.000
Mobility	0.00	0.000	0.000	0.000	0.000
Interoperability	0.00	0.000	0.000	0.000	0.000
	TOTAL	0.178	0.504	0.504	0.196

Weight 5	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.00	0.000	0.000	0.000	0.000
	1.00	0.151	0.260	0.260	0.189
	0.00	0.000	0.000	0.000	0.000
	0.00	0.000	0.000	0.000	0.000
	TOTAL	0.151	0.260	0.260	0.189

Weight 6	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.00	0.000	0.000	0.000	0.000
	0.00	0.000	0.000	0.000	0.000
	1.00	1.000	0.835	0.835	0.500
	0.00	0.000	0.000	0.000	0.000
	TOTAL	1.000	0.835	0.835	0.500

Weight 7	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.00	0.000	0.000	0.000	0.000
	0.00	0.000	0.000	0.000	0.000
	0.00	0.000	0.000	0.000	0.000
	1.00	1.000	0.750	0.750	0.750
	TOTAL	1.000	0.750	0.750	0.750

Weight 8	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.1	0.018	0.050	0.050	0.020
	0.1	0.015	0.026	0.026	0.019
	0.4	0.400	0.334	0.334	0.200
	0.4	0.400	0.300	0.300	0.300
	Total	0.833	0.710	0.710	0.539

Weight 9	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.1	0.018	0.050	0.050	0.020
	0.1	0.015	0.026	0.026	0.019
	0.5	0.500	0.418	0.418	0.250
	0.3	0.300	0.225	0.225	0.225
	Total	0.833	0.719	0.719	0.514

Weight 10	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.15	0.027	0.076	0.076	0.029
	0.15	0.023	0.039	0.039	0.028
	0.4	0.400	0.334	0.334	0.200
	0.3	0.300	0.225	0.225	0.225
	Total	0.749	0.674	0.674	0.483

Weight 11	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.2	0.036	0.101	0.101	0.039
	0.2	0.030	0.052	0.052	0.038
	0.3	0.300	0.251	0.251	0.150
	0.3	0.300	0.225	0.225	0.225
	Total	0.666	0.628	0.628	0.452

Weight 12	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.25	0.045	0.126	0.126	0.049
	0.25	0.038	0.065	0.065	0.047
	0.3	0.300	0.251	0.251	0.150
	0.2	0.200	0.150	0.150	0.150
	Total	0.582	0.592	0.592	0.396

Weight 13	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.3	0.053	0.151	0.151	0.059
	0.3	0.045	0.078	0.078	0.057
	0.3	0.300	0.251	0.251	0.150
	0.1	0.100	0.075	0.075	0.075
	Total	0.499	0.555	0.555	0.341

Weight 14	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.25	0.045	0.126	0.126	0.049
	0.25	0.038	0.065	0.065	0.047
	0.35	0.350	0.292	0.292	0.175
	0.15	0.150	0.113	0.113	0.113
	Total	0.582	0.596	0.596	0.384

Weight 15	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.19	0.034	0.096	0.096	0.037
	0.19	0.029	0.049	0.049	0.036
	0.31	0.310	0.259	0.259	0.155
	0.31	0.310	0.233	0.233	0.233
	Total	0.683	0.637	0.637	0.461

Weight 16	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.1	0.018	0.050	0.050	0.020
	0.1	0.015	0.026	0.026	0.019
	0.3	0.300	0.251	0.251	0.150
	0.5	0.500	0.375	0.375	0.375
	Total	0.833	0.702	0.702	0.564

Weight 17	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.15	0.027	0.076	0.076	0.029
	0.15	0.023	0.039	0.039	0.028
	0.3	0.300	0.251	0.251	0.150
	0.4	0.400	0.300	0.300	0.300
	Total	0.749	0.665	0.665	0.508

Weight 18	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.1	0.018	0.050	0.050	0.020
	0.1	0.015	0.026	0.026	0.019
	0.2	0.200	0.167	0.167	0.100
	0.6	0.600	0.450	0.450	0.450
	Total	0.833	0.693	0.693	0.589

Weight 19	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.25	0.045	0.126	0.126	0.049
	0.25	0.038	0.065	0.065	0.047
	0.2	0.200	0.167	0.167	0.100
	0.3	0.300	0.225	0.225	0.225
	Total	0.582	0.583	0.583	0.421

Weight 20	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.3	0.053	0.151	0.151	0.059
	0.3	0.045	0.078	0.078	0.057
	0.1	0.100	0.084	0.084	0.050
	0.3	0.300	0.225	0.225	0.225
	Total	0.499	0.538	0.538	0.391

Weight 21	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.25	0.045	0.126	0.126	0.049
	0.25	0.038	0.065	0.065	0.047
	0.15	0.150	0.125	0.125	0.075
	0.35	0.350	0.263	0.263	0.263
	Total	0.582	0.579	0.579	0.434

Weight 22	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.38	0.067	0.190	0.190	0.074
	0.34	0.051	0.088	0.088	0.064
	0.21	0.208	0.173	0.173	0.104
	0.08	0.075	0.057	0.057	0.057
	TOTAL	0.401	0.508	0.508	0.299

Weight 23	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.27	0.048	0.136	0.136	0.053
	0.19	0.029	0.049	0.049	0.036
	0.28	0.280	0.234	0.234	0.140
	0.26	0.260	0.195	0.195	0.195
	Total	0.617	0.614	0.614	0.424

Weight 24	Attribute Weight	COA 1	COA 2	COA 3	COA 4
	0.27	0.048	0.136	0.136	0.053
	0.2	0.030	0.052	0.052	0.038
	0.27	0.270	0.225	0.225	0.135
	0.26	0.260	0.195	0.195	0.195
	Total	0.608	0.609	0.609	0.421

We composed another test with lethality and accuracy ranked higher at 0.500 and 0.400 compared to 0.050 for both mobility and interoperability. Again, COA2 and COA3 prevailed.

Further insight into the behavioral patterns of the attributes were needed to determine if there were any scenarios where one attribute would make COA1 or 4 superior. We preceded by ranking each attribute equal 1.0 while zeroing out the other three. Lethality and accuracy did not result in any new changes (weights 4 & 5 records); both attributes clearly favored COA2 and 3 when ranked high. On the other hand, both mobility and interoperability logically favored COA1 (weights 6 & 7 records), since both these attributes are key advantages of the current weapon system.

Further sampling was performed to verify precision of our selected weights. We incrementally lowered the weights making sure mobility and interoperability were weighted heavier than lethality and accuracy. Then, we decided to switch and keep lethality and accuracy higher than the other two criterions which allowed us to identify any trends in our analysis. First, interoperability, is more sensitive to external adjustments. Therefore, weighting too high may skew the veracity of our model. This tendency is seen in weights 16 and 17 where interoperability is the highest. Second, mobility should not be greater than 25% of the overall measurements. This helps maintain a consistent relationship among the other variables. Thirdly, lethality and accuracy were major contributors when the results favored COA2 and COA3; whereas if mobility and interoperability are rated higher the results favored COA1. In the end, none of the factors were responsive to a scenario where COA4 won.

Table 8. Sensitivity Overview

	COA 1 Total	COA 2 Total	COA 3 Total	COA 4 Total
Weight 1	0.582	0.587	0.587	0.409
Weight 2	0.198	0.506	0.506	0.205
Weight 3	0.249	0.435	0.435	0.281
Weight 4	0.178	0.504	0.504	0.196
Weight 5	0.151	0.260	0.260	0.189
Weight 6	1.000	0.835	0.835	0.500
Weight 7	1.000	0.750	0.750	0.750
Weight 8	0.833	0.710	0.710	0.539
Weight 9	0.833	0.719	0.719	0.514
Weight 10	0.749	0.674	0.674	0.483
Weight 11	0.666	0.628	0.628	0.452
Weight 12	0.582	0.592	0.592	0.396
Weight 13	0.499	0.555	0.555	0.341
Weight 14	0.582	0.596	0.596	0.384
Weight 15	0.683	0.637	0.637	0.461
Weight 16	0.833	0.702	0.702	0.564
Weight 17	0.749	0.665	0.665	0.508
Weight 18	0.833	0.693	0.693	0.589
Weight 19	0.582	0.583	0.583	0.421
Weight 20	0.499	0.538	0.538	0.391
Weight 21	0.582	0.579	0.579	0.434
Weight 22	0.401	0.508	0.508	0.299
Weight 23	0.617	0.614	0.614	0.424
Weight 24	0.608	0.609	0.609	0.421

COA win %	
COA 1	0.5
COA 2	0.5
COA 3	0.5
COA 4	0

Table 8 is an overview table to give the reader a better idea of how sensitive the attributes are to random applications. Posted on the table are twenty-four of the weighted records used to conduct our analysis. COAs 2 and 3 are rated together since they are using the same caliber for this notional model. The items highlighted in green are the highest for a particular trial. Fifty percent of the time COA1 was considered a better fit for the performance factors. The other 50 percent of the time COA2 and 3 prevailed. This demonstrates the instability of weights if randomly selected. Furthermore, it reaffirms the prerequisite for properly decomposing the functional requirements to validate the needs of the infantryman. As mentioned previously, COA4 was not favored in any scenario.

This may be indicative of a potential caliber ceiling, which can be a major benefit when settling on capabilities and establishing acquisition strategies.

Our investigation allowed us to gauge the data points and create benchmarks. Conducting a sensitivity analysis exposed the accuracy of our outputs by displaying any vulnerabilities to our inputs. These vulnerabilities are knowledge points or critical junctures, which must be considered in the application of our model. Cognizance of the strategic guidance and requirements composition will help further define the correct weights for the value model.

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VI. CONCLUSIONS/RECOMMENDATIONS/AREAS FOR FUTURE RESEARCH

A. CONCLUSIONS

Each COA explored in this thesis represents a viable option to the procurement of a new or updated combat rifle for the infantryman. GEN Miley, Chief of Staff of the Army, rated Soldier Lethality as one of his top priorities for Army modernization during a recent Association of the United States Army (AUSA) speech (Lopez, 2017).

COA1 does not provide any increase in lethality. It may provide an increase in functionality with overall performance related improvements similar to the M4A1 and M4 Product Improvement Program (PIP) (Dawson, 2012). The M4/M16 family of weapons has been in the DOD's inventory since its debut in the Vietnam War (Scales, 2016). The Army has made over 100 improvements in the system since its adoption; with over 90 conducted since Operation Desert Storm (Dawson, 2012). However, peer and near peer adversaries have the capability to procure body armor, which can mitigate the effectiveness of our small arms and ammunition (DA, 2015a).

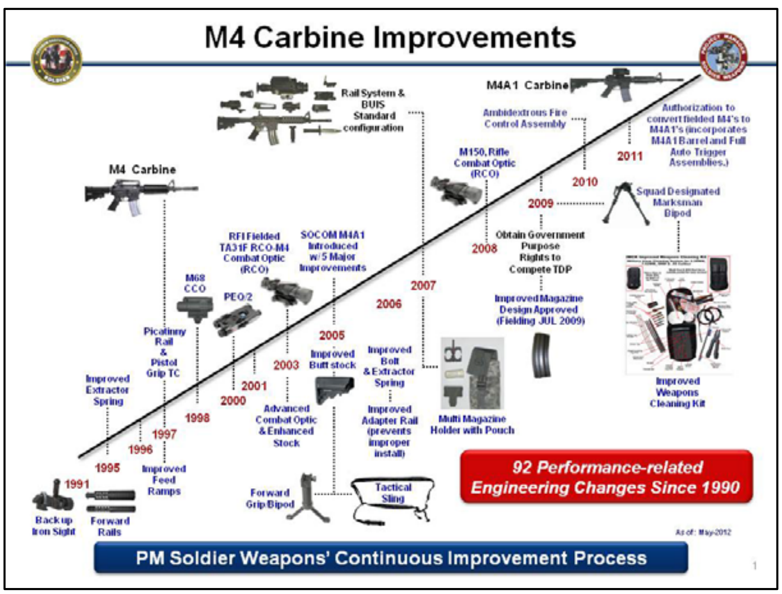

Figure 19. Linear Timeline of Small Arm Improvements. Source: Dawson (2012).

COA2 balances cost and capability. This COA is a compromise where increased lethality is desired, but within an affordable package. COA2 improves the ammunition and adapts the M4A1 platform to fire it effectively. It capitalizes on the continuous improvements to the M4 platform, but may not provide additional growth potential on an aging platform. The M4A1 is a legacy platform and every Soldier is familiar with it; therefore, new equipment training and fielding will be much quicker than on a brand-new system.

COA3 represents a dynamic shift in U.S. Army small arms development. It completely replaces all individual rifles with a new design, and integrates a new ammunition as a validated system. COA3 is the most expensive, but provides growth opportunities for decades to come. If COA3 were selected, we recommend a Squad Automatic Weapon program run parallel. Running a parallel program would ensure delivery of both systems in a relatively close period, and ensure magazines or other features could interface or be interchangeable with one another to maintain interoperability (DA, 2016a).

COA4 is a compromise similar to COA2, but does not expect to deliver a viable option. Although the ammunition is capable and accurate, weight is a key issue with this COA. Polymer ammunition or CT (Cased Telescoped) ammunition could offset the additional weight, which could make the weapon much more attractive (Textron, 2017a). However, type classifying a new ammunition type would increase the cost of the program comparable to COA3. If selected, COA4 would provide the Army with a viable solution to the M4A1, which could last for many decades.

B. RECOMMENDATIONS

The sine qua non of this thesis is the demonstration of an objective decision-making procedure for potential courses of action. The value-model validates and arranges in importance the main elements necessary for maximizing operational effectiveness through the combat rifle. This further enables greater understanding on part of the decision-maker to decide the most sensible course of action.

Based on the notional calibers in each course of action there are a couple recommendations we would propose. Overall, the best approach would be to pursue either COA2 or 3. Our goal of maximizing the effectiveness of the combat rifle will be achieved through two parallel approaches. We can split these approaches based on timeframes; short-term would be within 12–24 months and long-term would be greater than 24 months.

The short-term approach would be a stopgap in order to fill the lethality gap left by the 5.56mm caliber. Course of action two is considered our immediate solution. A modified M4A1 with a new intermediate caliber ammunition is a quick fix to bridge the capability gap. Our solution gives us a counterbalance between both type-classified rounds (5.56 and 7.62). Course of action two would drastically increase the lethality and accuracy, giving the soldier greater killing potential, but limits the total soldier weight. Lastly, maintaining a similar weapon style to the M4 reduces extensive additional training usually accompanied with a new weapon design. Thus, likely reducing cost and schedule to the program.

Simultaneously, a new program objective memorandum (POM) should be created for FY 19–23 for research and development into a new round. Our long-term solution supports course of action three. This approach would take several years to complete the development cycle, consisting of independent studies, evaluations and testing. We foresee the possibility of course of action three leveraging from the research and demonstrations from COA2, but would predominantly be a new, individual project. Finally, an acquisition strategy that emphasizes our critical performance factors and supports leadership's goal of increased soldier lethality will provide needed overmatch capability for the infantry squad.

C. AREAS OF FUTURE RESEARCH

Our thesis leaves room for areas of additional research. Our analysis pulls from multiple criterion in an effort to draw conclusions to increasing the operational effectiveness of the infantryman. A deep dive into one of the individual evaluation criterion of lethality, accuracy, mobility, and interoperability would provide greater insight into the research area. Greater research on interoperability is needed to study the effects between NATO partners and allies. Further research needs to be conducted on the maximum load, in both size and weight, a soldier should carry into battle. Additionally, a study on the average amount of ammunition expended during routine combat operations compared to direct fire engagements with the enemy should be included to optimize the infantryman's ammunition requirements. Reliability studies for the total system, rifle and ammunition, may improve system effectiveness by increasing operational availability. Additional studies should be conducted on improved marksmanship training, and the effects on the capability of the squad. Each topic could be explored further to provide additional methods to increase the effectiveness of the rifleman in the infantry squad.

An analysis of alternatives (AoA) should be conducted on future capability requirements of the infantryman. The AoA will provide decision-makers with credible information to assess future capability gaps to maximize the return on investment and maximize effectiveness (Air Force Material Command, 2013). Greater effects of how science and technology coupled with industry partners can improve the infantryman's primary combat weapon.

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