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HUNTING THE GHOST GUN: AN ANALYSIS OF THE U.S. ARMY INFANTRY RIFLE

March 2016

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Like many other nations, the United States was born of war. The freedom sought by our founding fathers was not free; it was paid in patriot blood during the American Revolution. No matter the reason—the preservation of democracy, liberation of the oppressed, or revolution—the United States has been no stranger to the battlefield. Through deserts, jungles, and grassy plains; in brick buildings, straw huts, and log cabins; by mountains, ditches, and the oceans, the infantry soldier has relied on one key tool to accomplish the mission: his weapon. Indeed, among the many characteristics of war, the infantry rifle has remained a critical battle component throughout time.

The purpose of this study is to provide an analysis of the U.S. military's usage of various small arms and their associated cartridges from WWII to current day. The primary objective centers on an analysis of the driving factors and decisions used in military cartridge selection and development. The expected product will be a reference document to aid in the decision-making process for future small arms cartridge/weapon selection and development.

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HUNTING THE GHOST GUN:
AN ANALYSIS OF THE U.S. ARMY INFANTRY RIFLE

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ABSTRACT

Like many other nations, the United States was born of war. The freedom sought by our founding fathers was not free; it was paid in patriot blood during the American Revolution. No matter the reason—the preservation of democracy, liberation of the oppressed, or revolution—the United States has been no stranger to the battlefield. Through deserts, jungles, and grassy plains; in brick buildings, straw huts, and log cabins; by mountains, ditches, and the oceans, the infantry soldier has relied on one key tool to accomplish the mission: his weapon. Indeed, among the many characteristics of war, the infantry rifle has remained a critical battle component throughout time.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAI	Aircraft Ammunition Incorporated
ACR	Advanced Combat Rifle
AOA	angle of attack
ARDEC	Armament Research Development and Engineering Center
ARL	Army Research Laboratory
BAR	Browning automatic rifle
BRL	Ballistics Research Laboratory
CONARC	Continental Army Command
COTS	commercial off the shelf
CQB	close quarter battle
DOD	Department of Defense
DPS	Development and Proof Services
ECP	engineering change proposal
EPR	enhanced performance round
FM	field manual
GWOT	global war on terrorism
IPT	Integrated Product Team
JHU	Johns Hopkins University
JSWB	Joint Service Working Board
LOF	line of fire
NATO	North Atlantic Treaty Organization
OAL	overall length
OCS	Office Chief of Staff
OICW	Objective Individual Combat Weapon
ONR	Office of Naval Research
ORO	Operations Research Office
OT	Operational Testing
POI	point of impact

R&D	research and development
SAAMI	Sporting Arms and Ammunition Manufacturers Institute
SAW	squad automatic weapon
SCHV	small caliber high velocity
SOCOM	Special Operations Command
SPC	Special Purpose Cartridge
SPIW	Special Purpose Individual Weapon
STANAG	(NATO) Standardization Agreement
TM	technical manual
USMC	United States Marine Corps

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I. INTRODUCTION

This chapter describes general information, objectives, scope, methodology, benefits, and organization of the project.

A. GENERAL INFORMATION

Taken directly from the United States Army Field Manual (FM) 7-8, "the mission of the infantry is to close with the enemy by means of fire and maneuver to defeat or capture him, or to repel his assault by fire, close combat, and counterattack" (Headquarters Department of the Army [HQDA], 2001, p. 18). The infantry's primary means of accomplishing this mission is the service weapon. The current weapon and cartridge used by the U.S. Army to accomplish this mission is the M4A1 assault carbine chambered for the 5.56x45 mm North Atlantic Treaty Organization (NATO) cartridge.

As the battlefield setting for the U.S. has changed from conflict to conflict, so, too, has the service rifle. This study will follow the evolution of the U.S. Army infantry weapon/cartridge and determine if the selection has historically satisfied battlefield requirements. Finally, this study will attempt to answer the question: "Has the U.S. Army provided its infantry with the optimum cartridge and weapon throughout history?"

B. OBJECTIVE

The objective of the study is to determine whether or not the U.S. Army has provided its infantry with the optimum cartridge and weapon throughout history.

In general, the U.S. Army has managed to maintain a top ranking regarding infantry weapon technology. Seldom has the U.S. Army suffered defeat due to the adversary's superior infantry technology. From this, one may be tempted to come to the conclusion that, if we are on top and winning, then we must be making the correct decisions regarding the proper infantry weapons and cartridges. If this were the case, why then do some officials claim that the current system is sufficient as for the current battlefield, yet others claim that the current system is lacking in many ways? Is there historical evidence that supports that the U.S. has been using the optimum infantry weapon and cartridge? Is there research to suggest that this optimum combination is within reach? Why are we still using this technology? Is something better out there?

C. SCOPE

For the purpose of this project, the infantry weapon shall be defined as the small caliber service (combat) rifle used by the U.S. Army and U.S. Marine Corps infantry. This study focuses on the cartridge selections and infantry weapon of the following:

- 7.62x63 mm cartridge/M1 Rifle
- 7.62x51 mm cartridge/M14 Rifle
- 5.56x45 mm cartridge/M16 Rifle
- 5.56x45 mm cartridge/M4 Carbine

The time period covered by this study begins in the early 1900s and ends with the current year of 2016. Conflicts referenced by this study include:

- World War One and Two (WWI and WWII)
- Korean War
- Vietnam War
- Persian Gulf War
- Afghanistan War

D. METHODOLOGY (COMPARATIVE ANALYSIS)

This study defines an optimum weapon/cartridge as one <u>that satisfies the requirements as found on the battlefield at the time</u>. In order to gauge whether or not a selection was optimum, this study will compare the weapon/cartridge selected for use against the actual battlefield applicability and effectiveness during a particular time period. Measures of effectiveness will include:

- weapon type and design
- ammunition caliber and design
- system-level performance on the battlefield

E. BENEFITS OF THE STUDY

This study serves as a basis for future research, analysis, and discussion for determining optimal weapon systems for the infantry members in the Department of Defense (DOD). This document will serve as an aid to the DOD decision makers in making the next cartridge/weapon selection by offering a summary of past successes and failures.

F. ORGANIZATION OF THE STUDY

Chapter I: This chapter provides general information, objectives, scope, methodology, benefits, and the organization of the study.

Chapter II: This chapter establishes a baseline of terms used in this study. This chapter provides a brief technical background of projectiles, cartridges, and U.S. small arms types. The terms and concepts in this chapter are also used in the analysis portions of subsequent chapters.

Chapter III: This chapter is separated into three sections and briefly describes the history of the U.S. Service Rifle from WWII to Afghanistan. The first discusses infantry weapons and ammunition during the Second World War as well as during the Korean War. The first segment focuses on the impact made by the M1 rifle. The second segment discusses infantry weapons and ammunition during the Vietnam War. The second segment focuses on the impact made by the M16 and M14 rifles. The third segment discusses infantry weapons and ammunition during the Persian Gulf War and the war in Afghanistan. The third segment focuses on the impact made by the M4 carbine.

Chapter IV: This chapter will compare and contrast the Infantry weapon/cartridge capabilities against the actual battlefield requirements during the time periods discussed in Chapter III. The comprehensive analysis seeks to reveal whether or not the U.S. Army has provided its infantry with the optimum cartridge and weapon throughout history.

Chapter V: This chapter provides an opportunity to draw conclusions and afford options for improved decision making during the U.S. Army's evolution of the infantry weapon and ammunition programs.

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II. AMMUNITION AND SMALL ARMS WEAPONS

A. AMMUNITION

Ammunition is a broad, generic term for all projectiles used for offense and defense. For the purpose of this study, ammunition will refer to the sub category of small arms ammunition. The first example of an integrated firearms cartridge was developed by Jean Samuel Pauly in 1808 (Wallace, 2008). Pauly, a Swiss gunsmith, sought to increase firearm effectiveness by means of decreasing time to reload. To do so, he integrated the projectile, the propellant, and the ignition system into something that resembles the modern day cartridge. By the mid-1800s, Pauly's concept had evolved into what is known today as the centerfire cartridge. By the late 1800s the U.S. Army was using centerfire cartridges in their rifles ("Small arms and light weapons," n.d.).

The centerfire cartridge was a giant leap forward for the ammunition industry. It was a reliable, inexpensive, and convenient way to feed weapons. The centerfire cartridge worked on a simple yet effective process, a process through which every infantry firearm since then has utilized. The process: When the percussive primer is struck, ignition of the propellant occurs. The combustion of the propellant creates gases that begin to expand inside the case of the round. These expanding gases force the bullet out of the neck of the cartridge and into the throat and bore of the weapon's barrel. After passing through the throat, the bullet then engages the spiral-shaped lands and grooves of the barrel.

These parallel lands and grooves, commonly referred to as "rifling," extend from the throat to the muzzle and impart spin onto the bullet as it travels down the length of the bore. By spinning the projectile, the rifled bore provides the necessary stability for the projectile to follow a predictable trajectory to the target.

The 100-year-old centerfire cartridge design is still used for today's small arms ammunition. The proliferation of the design on the battlefield is signified by the fact that small arms ammunition continues to be the most commonly encountered type of ammunition in conflict areas across the globe (United Nations General Assembly [UN], 1999).

This study will primarily focus on three small arms cartridges used by the U.S. Army. The nomenclatures of these cartridges are given as:

- 7.62x63 mm
- 7.62x51 mm
- 5.56x45 mm

The nomenclature of the cartridge consists of two parts, both given in millimeters. The first part of the nomenclature is the *projectile component*, and denotes the nominal diameter or caliber of the projectile (7.62, 5.56, etc.). The second part of the nomenclature is the *cartridge component* and denotes cartridge-case length e.g., 63, 51, 45. Depending on the context, one may find the caliber of small arms and associated ammunition primary described in inches, as in .22 Caliber (5.56 mm), .27 Cal (6.8 mm), .30 Cal (7.62 mm).

Projectile: Small arms projectiles, often called bullets, are comprised of several basic designs. Various features may be incorporated into a single design including hardened penetrators, tracer elements, ballistic tips, sabots, and others. This research will focus on only those projectiles that are in compliance with the 1899 Hague Declaration concerning expanding bullets: “The Contracting Parties agree to abstain from the use of bullets which expand or flatten easily in the human body, such as bullets with a hard envelope which does not entirely cover the core, or is pierced with incisions” (Scott, 1908, p. 82).

Cartridges: The cartridge or “case” for ammunition is the portion of the round that contains the propellant and the primer. Cartridge cases tend to be made of brass, although other materials are used such as aluminum, steel, or polymers. The primer is typically a percussive device, which is used to ignite the propellant. Atop the case, the bullet is seated. When the percussive primer is struck, ignition of the propellant occurs.

B. U.S. SMALL ARMS WEAPONS

The term “small arms” generally refers to non-crew served weapons up to .50 Cal (12.7 mm), although some references cite weapons calibers up to 20 mm (UN, 1999). Weapon models in the small arms category vary in each of the DOD branches and can even differ depending on which subcommand is being referenced.

With the intention of simplification, “small arms,” as mentioned in this research, will refer to the following five infantry weapons:

- M1 Rifle
- M1 Carbine
- M14 Rifle
- M16 Rifle
- M4 Carbine

These infantry weapons can further be separated into one of two categories: rifle or carbine.

Rifle: The definition of a rifle is a shoulder firearm which can discharge a bullet through a rifled barrel 16 inches or longer (“Small arms and light weapons,” n.d.). Examples of rifles discussed in this study are the M1 Garand, the M14, and the M16.

Carbine: A carbine is a rifle-styled firearm that generally has a barrel under 16 inches in length (“Small arms and light weapons,” n.d.). Examples of carbines discussed in this study are the M1 Carbine and the M4.

C. DISCUSSION

The data in Table 1 is derived from U.S. Army publications. The table shows a standard M1 rifle against a standard M1 carbine.

Table 1. M1 Rifle versus M1 Carbine

	Rifle	Carbine
Weight in pounds (lbs.)	9.5	5.5
Barrel length in inches (in.)	24	18
Overall length (OAL) in inches (in.)	43	35.58
Muzzle velocity in feet per second (fps)	2750–2800	2000
Max. effective range in meters (yds.)	500	300

Data from Department of the Army.

From the data in Table 1, we can make two general observations from an operational perspective:

Carbines tend to provide increased mobility: Simply stated, carbine weapons provide increased user mobility. Due to its shorter barrel length, and thus lighter weight, the carbine is more suited to self-defense situations, close quarter battle (CQB), and other maneuvers where smaller sized weapons are appropriate. Despite this advantage, carbines tend to exhibit accuracy and ballistics inferior to that of the full length version of the rifles from which they are adapted ("Small arms and light weapons," n.d.).

Rifles tend to have better downrange performance: The rifle's superior downrange performance (exterior ballistics), is a direct result of its ability to generate a higher muzzle velocity. For this particular analysis, consider muzzle velocity as a measurement of internal ballistic performance; whereby an increase in internal ballistic performance, yields an increase in muzzle velocity.

The basic parameters used to describe internal ballistics are pressure, distance, time, and velocity. These parameters can be varied for better performance in a particular weapon system by changing ammunition components. Additionally, weapon components can be changed or modified to accommodate a particular ammunition type. The optimal result being: a weapon that will consistently and effectively fire a projectile out of the muzzle at optimum velocities and with the proper stabilization.

Barrel length is a critical factor when computing internal ballistics. In terms of barrel length, optimization occurs when a cartridge provides a projectile with the proper acceleration along the distance of the bore, ending at the muzzle (Kasper, Downey, Myer, & Kimball, n.d.).

Assuming the same ammunition is used for both weapons, from Table 1 one can deduce that the ammunition used for the comparison is better matched to the longer barreled rifle. Later in the project, we confirm this to be the case. The ammunition used for the comparison in Table 1 was the M855, a cartridge optimized for use in the M16 and M249 (long barrel) platforms.

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III. INFANTRY RIFLES ON THE BATTLEFIELDS

In my opinion, the M1 rifle is the greatest battle implement ever devised

~ LTG G.S. Patton, Jr.

A. EUROPE AND THE GARAND

1. Background

The bolt action M1903 rifle, chambered in .30-06 Springfield (7.62x63 mm), was the infantry weapon of WWI. Following the end of World War I, the U.S. Army then began efforts to modernize its infantry arsenal and replace the bolt actioned M1903 Springfield. The successor to the M1903 would be a rugged, semi-automatic rifle of high reliability, and be chambered in .30-06 Springfield. In 1919, John C. Garand was hired by Springfield Armory in Massachusetts to orchestrate the designing of the new weapon system for the U.S. Army. In January of 1936, the Army adopted the new .30 caliber rifle from Springfield as the M1 rifle, better known as the Garand ("M1 Garand," n.d.). The specifications for the M1 rifle, derived from the *Army Technical Manual* (TM), are shown in Table 2 (HQDA, 1969).

Table 2. M1 Rifle Specifications

	M1 rifle
Weight (lbs.)	9.5–10.5
Length (in.)	43
Muzzle velocity (fps)	2,750–2,800
Maximum effective range (yds.)	500
Maximum effective rate of fire	16–24 aimed rounds per minute
Cartridges per clip	8 rounds

Source: Headquarters, Department of the Army (1969), *Rifle Caliber .30: M1, M1C (Sniper's), M1D (Sniper's),* Technical Manual No. 9-1005-222-12, Washington, DC: U.S. Government Printing Office.

The rifle was lauded as a magnificent weapon and the most deadly rifle in the world by many users. As a testament to the popularity and success of the M1 Garand rifle, by the end of WWII, more than 4 million rifles had been produced and the M1's influence on weapon design continued to spread globally ("M1 Garand," n.d.).

The largest improvement over the M1903 was the semi-automatic operation of the M1 rifle. By sheer increase in volume of fire, the gas operated, air cooled M1 became an instant force multiplier on the battlefield. This increased rate of fire, coupled with the large muzzle energy values made the infantryman armed with the M1 a formidable opponent to any adversary. The high downrange energy is a result of pairing a bullet of relatively large caliber, with a cartridge case capable of containing enough propellant to accelerate the bullet to high velocities. The .30-06 cartridge was designed to do just that.

The most common ammunition during WWII was M2 ball ammunition. M2 ball ammunition fired a 150 gr. projectile at velocities of approximately 2700 fps (HQDA, 1994).

This combination of projectile weight and muzzle velocity generates approximately 2,400 foot-pounds of muzzle energy. This level of muzzle energy is the source of battlefield reports attesting to the M1 rifle's firepower advantages that claim the M1 has the power to penetrate up to three enemy combatants with a single shot in close battle (George, 2012).

Killing three enemy combatants with a single shot, while being advantageous to the shooter, could be considered a ballistic overmatch in terms of firepower. Infantryman could indeed appreciate the M1 rifle's power at long engagement ranges of Eastern Europe's countryside during WWII. These distances proved too much for the M1 carbine. As one soldier reported, The M1 carbine lacked the power of the M1 rifle on the battlefield, and hauling the extra ammunition to feed the Browning Automatic Rifle (BAR) was too much work. The M1 rifle was a good fit (LeMaster, 2009). This advantage of firepower declined rapidly as engagement distances shortened to urban combat ranges; to include CQB. Here, the M1 rifle's recoil, weapon length, and weight, turned to disadvantages for the infantry.

2. Discussion

Why did the Army choose the .30-06 cartridge when combat experience from WWI showed the caliber to be overmatch at closer ranges? The answer to that question is: They did not choose the .30-06 caliber, at first.

Prior to the adoption of the .30 caliber M1 rifle in 1936, the U.S. Army had selected the .276 Pedersen caliber as a "best choice" for a new service rifle.

This choice was based on studies and trials done by the Joint Ordnance Board in the 1920's (Riling, 1951). The favor toward the smaller .276 Pedersen cartridge stemmed from its smaller size, lighter weight, reduced chamber pressure, and inherent increase in accuracy due to recoil reduction. When compared for terminal ballistics, the .30-06 Springfield cartridge remained superior to the .276 Pedersen at long ranges; however, the Army saw the trade-off savings of weight and accuracy as more valuable. Thus, during the late 1920s, John C. Garand was required by the Ordinance Board to also add to his original design for a .30 caliber weapon, an additional version, that would accommodate the now preferred .276 caliber (Canfield, 2009).

A "limited procurement" of John C. Garand's M1 rifle chambered in .276 Pedersen, was moving forward but soon found resistance from one General Douglas MacArthur (Canfield, 2009). In 1932, MacArthur, then Army Chief of Staff, recommended against the new caliber. In his letter to the adjutant general, he stated: "To make this change will introduce an element of chaos, confusion and uncertainty which, magnified under war conditions, would more than counteract the beneficial effect of any semiautomatic rifle" (Canfield, 2009, p. 6). In his letter, MacArthur also mentions utilizing the existing .30-06 stockpile from WWI. At the time, the U.S. Army stockpile of "Caliber .30 M1 ball" (.30-06) ammunition was at an all-time high. These factors proved too much for the Garand's M1 rifle design chambered for .276 Pedersen. Approximately a month after MacArthur's letter was received by Adjutant General Shuman, Shuman ordered all work stopped toward the .276 caliber M1 rifle (Riling, 1951).

Against its own best recommendations, based on technical performance, the Army was going to chamber the new M1 rifle in .30-06 Springfield.

To analyze why the .276 Pederson was a better choice, one needs to look no further than the tests that the Army performed in 1925 at Fort Benning, Georgia on developmental small arms. These tests furthered the mission of searching for an *ideal* rifle caliber. The Army's 1929 conclusion that "a rifle of caliber .276 is preferable to one of caliber .30 for use as the basic Infantry weapon" although valid, would not be proven out for more than 25 years (Canfield 2009, p. 5). The Department of the Army Reports of Hall, Hitchman, and Davis, published in the 1950s each contributed to the conclusion that a caliber smaller than the .30-06 Springfield would not only be more effective in battle, but would also likely have superior logistics supportability due to decreases in weapon and ammunition size and weights (Canfield, 2009). These conclusions were made based on current knowledge of internal and external ballistics, battlefield engagement distances, and terminal performance of projectiles.

B. SOUTHEAST ASIA, THE M14, AND THE M16

The cost of freedom is always high, but Americans have always paid it. And one path we shall never choose, and that is the path of surrender, or submission

~ John Fitzgerald Kennedy

1. Background

At the close of the Korean War in 1953, the U.S. Army eagerly pushed the development for a new infantry weapon that would satisfy a requirement that had surfaced from the battlefield cries of Europe. The new requirement was to provide the infantry serviceman with a rifle that was of reduced weight but, maintained current accuracy levels, incorporated a select-fire mechanism, and reduced supportability requirements when compared with the current infantry weapons. Up until the middle of the Twentieth Century, U.S. Army infantry rifles generally included: Ml rifle, M1 carbine, M3Al submachine gun, and the M1918 Browning Automatic Rifle (BAR). The large logistical footprint for these weapons was gaining attention as an area that needed improvement. The Army's challenge then became to develop a "one size fits all" rifle. The solution to this challenge manifested itself as the Army's adoption of the M14 rifle chambered for 7.62x51 mm on May 1, 1957 (Emerson, 2006). The 7.62x63 mm and 7.62x51 mm cartridges are almost identical except for the overall length (OAL) of the case. Although the reduction in OAL is approximately 20%, changes from the familiar ballistics of the M1 were minimal. The specifications for the M14 as found in TM 9-1005-223-10 are displayed in Table 3.

Table 3. M14 Rifle Specifications

	M14 Rifle
Weight (lbs.)	9.1
Length (in.)	44.3
Muzzle velocity (fps)	2,800
Maximum effective range (yds.)	500–875
Maximum effective rate of fire	16–24 aimed rounds per minute Or 700–750 rounds per minute auto
Magazine capacity	20 rounds

Source: Headquarters, Department of the Army (1972), *Operators Manual: Rifle, 7.62 mm M14, Rifle, 7.62 mm M14A1, Bipod Rifle, M2*, Technical Manual No. 9-1005-223-10, Washington, DC: U.S. Government Printing Office.

Shortly after the Army adopted the M14, a more radical rifle concept emerged from the private sector. This rifle, designed by Eugene Stoner of ArmaLite, was the AR-10 (Watters, 2009). The rifle was originally developed for use with the 7.62x51 mm NATO cartridge, however due to influence from the Army's Research and Development (R&D) community, the rifle was subsequently chambered in 5.56x45 mm and formally adopted by the Army as the M16A1 in 1967 (Woods, 2010). The data given for the M16 as selected from the U.S. Army's FM 3-22.9 are found in Table 4.

Table 4. M16A1 Rifle Specifications

	M16A1 Specifications
Weight (lbs.)	8.06
Length (in.)	39.0
Muzzle velocity (fps)	3,250
Maximum effective range (yds.)	460–600
Maximum effective rate of fire	45–65 aimed rounds per minute Or 700–800 rounds per minute auto
Magazine capacity	20-30 rounds

Source: Headquarters, Department of the Army (2008), *Rifle Marksmanship M16A1, M16A2/3, M16A4, and M4Carbin*, Field Manual No. 3-22.9, Washington, DC: Government Printing Office.

The M16 rifle was indeed a revolutionary step for infantry rifle technology. Developed as a lighter alternative to the 7.62 mm class of weapons, the M16 used the significantly smaller 5.56x45 mm cartridge, in hopes of reducing infantry combat ammunition load weight. Although noble in nature, this concept cannot prove valid in a situation where ammunition supply takes precedence over physical combat load capabilities, i.e. Infantry will just carry more ammunition at the same combat load weight. The M16 offered reduced overall weapon weight.

The design called for construction using lighter materials such as polymers and aircraft grade aluminum. The M16's polymer stock was lighter than the wood stocks used by previous service rifles. In addition to the polymer stock's lighter weight, polymer was not affected by environmental factors such as humidity and temperature. Known to cause swelling and shrinking of wooden parts, humidity and temperature can affect a weapon's point of impact (POI). The M16's polymer stock and forearm alleviated the issue with changing POI.

The M16 utilized a different gas operating system than previous infantry weapons such as the M1. Typically, gas operated systems use a gas cylinder, piston, and rod to cycle the weapon's action. Gases formed by the ignition of propellant are captured and made to move a piston, which thereby moves a rod, which causes the action of the weapon to cycle. Direct gas-impingement differs from the traditional system in that it does not require a piston and rod to cycle the weapon's action.

Direct gas impingement systems use a gas tube to divert propellant gases directly back onto the bolt carrier to cycle the action. Although the direct impingement system generally saves on weight, logistics, and manufacturing cost due to the reduction in number of components, the system can have severe reliability issues. Reliability issues, namely "jamming" issues, stem from the fact that the gases, which are forced back into the breech, are loaded with carbon, vaporized metals, and other undesirable materials that cause deposits which eventually foul the action until it cannot function (Smith & Ezell 1990). The residue would accumulate in the chamber of the weapon cause the fired brass cartridge to stick firmly in the chamber.

The resultant issue, known as a failure to extract (FTE), requires specialized tools to extricate the stuck cartridge. Depending on what tools are available, the stuck cartridge may also require weapon disassembly.

2. Discussion

Some U.S. Army weapon historians refer to the M14 as the "Shortest Lived" rifle in the Army's history. Why did the M14 see such little action after its battlefield debut? The answer is not a simple one. To begin with, the M14 was designed to be a "one-size-fits-all" replacement for a number of current battlefield weapons. As is typical with products that satisfy multiple roles and requirements, The M14 "covered the bases" but did not excel in any particular area or function. By referencing tables 2 and 3, one can determine that the M14 weapon itself did not offer much improvement over the M1 in terms of size and weight. A positive improvement in weapon design came in the form of a detachable box magazine capable of holding 20 rounds of ammunition.

The 7.62x51 mm cartridge selected for use with the M14 was an improvement over the 7.62x63 mm used by the M1. The exterior ballistics between the two cartridges were almost identical except for the higher velocity exhibited by the 7.62x63 mm.

Despite the reduced maximum range, the shorter 51 mm cartridge provided reduced weight and reduced recoil which translated into a smaller logistic requirement as well as increased accuracy from the M14. It should be noted that, although the 7.62x51 mm was an improvement over its predecessor, it was not readily accepted into the NATO standard. British weapon engineers favored a smaller caliber of .280 for use in infantry weapons.

Despite the test evidence that substantiated Britain's claim of the .280 caliber's superiority over the .30 caliber, it became clear to the NATO panel members that the Americans would not endorse any foreign cartridge design during this time period (Holland, 2009). In 1957, NATO panel members ratified Standard Agreement (STANAG) 2310, which officially accepted the 7.62x51 mm cartridge into the NATO family of cartridges (Pellegrino & Kirkman, 2011).

In May of 1957, Eugene Stoner of ArmaLite provided a demonstration of his prototype rifle for U.S. General Wyman, then Commander of the Continental Army Command (CONARC). Wyman, impressed with AR platform, formally requests the purchase of 10 of these prototype rifles to be tested by the Infantry Board. Ironically, the formal request to test the new rifle platform was made just five days after the U.S. Army's announcement to adopt the M14 rifle chambered in 7.62x51 mm NATO (Watters, 2009).

In 1958, the Powell Board convened to review the entire Army infantry rifle program. The board recommended no additional consideration be made toward the .22 caliber (5.56 mm). The board also recommended the developing AR15 platform to be chambered for a .258 (6.55 mm) caliber cartridge instead of .22 (5.56 mm) (OCS, 1968). Between the years of 1954 and 1963, Stoner's design was tested, modified, and refined to produce a truly state-of-the-art SCHV weapon. In 1964, The U.S. Army began purchasing the new SCHV weapon and cartridge combination, also known as the M16 chambered for 5.56x45 mm (Kern, 2006).

To better understand why the U.S. Army would make the decision to test a new prototype immediately following the adoption of the M14, one must start several years earlier in 1952. In March of 1952, U.S. Army Ballistics Research Laboratories (BRL) published a report entitled “An Effectiveness Study of the Infantry Rifle” authored by Donald L. Hall (BRL, 1952). Hall’s report studied the theoretical hit probability and expected number of kills for a variety of rifles and calibers. The study used the standard .30 caliber M2 Ball cartridge as a baseline for comparison. Multiple experimental calibers ranging from .30 to .21 were matched with varied propellant loads to produce the theoretical weapon cartridge loads. These loads were then combined with additional parameters, such as weapon and ammunition weight, muzzle velocity, muzzle energy, ballistics, wounding characteristics, etc., to produce tabular data of hit and kill probabilities for each load (BRL, 1952).

One of the major results obtained from the study was that a soldier’s hit and kill probability could potentially be improved by a factor greater than two by the simple adoption of small caliber high velocity (SCHV) projectiles. Hall’s results, although theoretical in nature, proved critical to the advancement of SCHV weapon studies.

Concurrent with BRL’s study, the Operations Research Office (ORO) of Johns Hopkins University (JHU) was working on project BALANCE (JHU, 1952). Working under contract with the U.S. Army, ORO’s project BALANCE sought to determine the desirable characteristics for the infantry weapon. In November of 1952 the ORO produced a report that proved central in SCHV development.

ORO’s Norman A. Hitchman produced a report entitled “Operational Requirements for an Infantry Hand Weapon” (JHU, 1952). Hitchman’s study was based on statistical data from combat casualty, terrain visibility, lethality, accuracy, and dispersion studies in order to answer the question of what an infantry rifle should be capable of on the battlefield today. The Hitchman study came to several significant conclusions, however two factors alone, proved to be monumental in defining the “operational requirements” for infantry weapons. Hitchman found that typical battlefield engagement distances for the infantryman did not exceed 300 yards. Additionally, average infantry marksmanship decreased exponentially beyond 100 yards due to battlefield terrain and visibility. Up until the publishing of these findings, Army authorities had little, if any, thresholds on which to develop solid ballistic performance parameters. Hitchman also found dispersion control to be critical in the effectiveness of salvo or automatic fire.

This point hinges on the effects of perceived recoil on the shooter. Perceived recoil is a direct result of the physical law of Conservation of Momentum (SAAMI, 1976). This law, simply stated, is that for every action, there is an equal and opposite reaction. To put this in perspective in regards to weapon recoil, a weapon firing larger propellant loads with heavier projectiles will produce greater recoil than that same weapon firing smaller propellant loads with smaller projectiles. Hitchman found that, for a given weapon, shot dispersion significantly increases as perceived recoil increases. The study was able to conclude that the low recoil of a SCHV weapon facilitated substantial increases in dispersion control, thereby increasing weapon effectiveness when used in a salvo or volley mode of function. Eventually this conclusion would become the basis for the three-round burst mode found on some modern-day weapon systems.

The Hitchman and Hall (1952) reports indicated that the Army did not have sufficient knowledge of SCHV projectiles and cartridges, thus warranting further research into the SCHV cartridge domain. The U.S. Army's Development and Proof Services (DPS), located at Aberdeen Proving Ground, published the Gustafson report in 1953 (DPS, 1953). The objective of the Gustafson study was to increase the effectiveness of the M2 carbine by adapting the cartridge to fire a .22 caliber SCHV projectile. The Gustafson report concluded that through testing, the .22 caliber carbines performed "markedly better" than the standard .30 caliber M1 rifle and recommended further investigation by the DPS into the applications of a .22 caliber cartridge (DPS, 1953). The results of the investigation were outlined in a subsequent report.

The report, titled "An Investigation of an Experimental Caliber .22 High-Velocity Bullet for Rifles" was authored by WM. C. Davis and published by DPS in 1955. The Davis report reinforced Gustafson's conclusions and recommended further engineering development for the next rifle cartridge. The aforementioned reports proved sufficient incentive for the Army's decision to move forward with the requirement for a new weapon that would fire .22 caliber projectiles.

During the same time-period, and based on the data coming in under project BALANCE, the ORO began a new effort to improve the infantry weapon named project SALVO (Watters, 2000).

Project SALVO was a joint effort involving BRL, Office of Naval Research (ONR), and the commercial entity Aircraft Ammunition Incorporated (AAI). SALVO was intended to develop an infantry weapon system that paired increased hit probability with increased lethality. During the mid-late 1950s many prototypes and concepts were proposed as solutions for SALVO's objective from multi-barrel weapons to weapons that fires cartridges containing multiple projectiles. As project SALVO lost momentum in the late 1950s, the Army refreshed the mission with the Special Purpose Individual Weapon (SPIW) program and again sought to produce a better infantry rifle (Stevens, 2014).

Seeing the potential to fulfill SPIW program requirements in the interim, and with the escalating conflict in Vietnam, the M16 program was pushed to the front of the line. The M16 found a solid niche in the infantry's inventory during the SPIW program. The SPIW program was expected to produce a new infantry rifle capable of firing exotic flechettes and exotic grenade munitions.

The M16 was a weapon to be used until the product of the SPIW was fielded. Unfortunately the SPIW program was cancelled after 7 years and $20 million of R&D efforts failed to yield a weapon system ready for production and use (Stevens, 2014). When compared to the more traditional Army acquisition process of the M14, the M16 was introduced into the jungles of Vietnam somewhat rapidly. This "rapid fielding initiative" type of acquisition represented what can be viewed as a culture shift within the Army. As with most shifts, there were those who did not feel comfortable with change and thus resisted it. Those who resisted change supported the traditional role of research and development in the Army acquisition process.

Those who supported the change sought to gain the benefits of reduced R&D by adopting platform that had its origins in the private sector. To complicate issues, the M14 was just recently been formally adopted and was starting to be fielded. In the end, the newly appointed Secretary of Defense Robert S. McNamara would provide the leadership necessary to improve the infantry rifle program that now was (Kern, 2006). McNamara made DOD-wide changes in an attempt to oust the failed traditional methods of small arms acquisition, and usher in a new process based on science and one that adapts to emerging and newer technologies. From his instatement through the mid-1960s it appeared as though McNamara was precisely what the infantry rifle program needed until reports from the battlefields of Vietnam citing M16 failures began making their way home to the US. One Marine, who was deployed to Vietnam, wrote home to his mother saying, "practically every one of our dead was found with his rifle torn down next to him where he had been trying to fix it" (Morgan, 2012, Para. 5).

When stories involving U.S. casualties and weapon malfunctions found their way to the public eye, Washington officials were forced to investigate. On June 1, 1968 the Army's Office Chiefs of Staff (OCS) published a report from the M16 Rifle Review Panel titled, *History of the M16 Weapon System* (OCS, 1968). The approximately 200 paged report detailed the many shortcomings of the M16's acquisition and development processes. Some of the major issues recommended by the report included a highly improved maintenance program, critical propellant changes for the ammunition, engineering changes such as chrome-lined barrel requirements, and the addition of a forward assist mechanism. Clearly both time and product improvement were needed to shape the final design for the M16 as an infantry weapon.

From a geographical perspective, the fight in Vietnam was waged under the canopy of densely vegetated jungle. Although the jungle was not unlike the Pacific Island battles of WWII, military planners soon realized that the current threat did not operate like those previously experienced in the Pacific or Western Europe. This threat was not the massive Soviet Army that was expected. The new threat consisted of a smaller, decentralized enemy that operated in the realm of guerilla warfare. The operational environment in Vietnam was that of a logistical nightmare. Unlike the ship-accessible supply chains that were created as islands were conquered in the Pacific during WWII, the supply chains of Vietnam were stymied with jungle terrain, few roads, and guarded waterways. These poor routes of supply sought to suppress vital logistic operations for the duration of the conflict.

Forces sustainment would have been unlikely if it weren't for the critical contribution of rotary wing logistic support. Compared to operations in Western Europe during WWII, enemy operations in Vietnam were on a small scale. Enemy in Vietnam often utilized raid-style or ambush techniques. Threats of this nature proved difficult to defeat, as U.S. operations had severely limited capabilities in the jungle terrain. This terrain and dense undergrowth often inhibited U.S. forces' ability to locate the enemy. As a result of not knowing the origin of fire, many U.S. troops adopted a "spray and pray" method of counter-fire. Unfortunately, this method did not result in increased lethality; U.S. soldiers just depleted precious ammunition supplies while firing on an enemy hidden in the jungle.

C. THE PERSIAN GULF, AFGHANISTAN, AND THE M4

You can't help but... with 20/20 hindsight, go back and say, "Look, had we done something different, we probably wouldn't be facing what we are facing today"

~ Norman Schwarzkopf

1. Background

Shortly after Iraq's invasion and annexation of Kuwait in 1990, the U.S. and other NATO backed allies began a campaign to support the Kuwaiti government and force Iraqi military withdrawal. The operation, designated Desert Storm, would pave the way for a second Gulf War, known officially as the Iraq War, in 2003.

Stemming from the September 11, 2001, attacks in New York City, the Iraq War was part of a larger effort known as the Global War on Terrorism (GWOT). GWOT's aim was to combating "terrorist" organizations such as Al Qaeda and other militant

Islamists, which posed a threat to the U.S. and its allies. Living up to its namesake, the GWOT would put U.S. troops in many countries spread throughout the globe. From the scorched deserts of the Middle East, to the snow-covered mountains of Afghanistan, to the Sahara/Sahel regions of Africa, to the tropical islands of the Philippines, the U.S. and Coalition forces launched efforts to hunt and eradicate “terror” wherever it is found.

In 1994, the U.S. Army officially adopted the M4 carbine as the newest infantry weapon. The M4 carbine utilized the same 5.56x45 mm cartridge as the currently fielded M16 rifle, while offering improvements in reliability as well as weapon size and weight reduction. The specifications for the M4 carbine derived from U.S. Army FM 3-22.9 are displayed in Table 5.

Table 5. M4 Carbine Specifications

	M4 Carbine
Weight (lbs.) (approximate)	7.5
Length (in.)	29.75
Muzzle velocity (fps)	2,970
Maximum effective range (yds.)	500-600 yards
Maximum effective rate of fire	45 aimed rounds per minute Or 700–900 rounds per minute auto
Magazine capacity	20–30 rounds

Source: Headquarters Department of the Army (2008), *Rifle Marksmanship M16A1, M16A2/3, M16A4, and M4Carbin*, Field Manual No. 3-22.9, Washington, DC: U.S. Government Printing Office.

The Iraq War provided the stage on which the M4 made its debut. Not long into the war, soldiers began to give reports of the 5.56x45 mm ammunition, hence forth designated as the M855, failing to adequately incapacitate enemy combatants. In August of 2003, a news correspondent for a U.S. media corporation reported that during one particularly fierce firefight, one insurgent sustained seven M855 hits but continued to fight ultimately killing 2 U.S. soldiers and wounding 7 more before being brought down by a pistol shot to the head (Pace, 2006).

From 2001 to 2013 the U.S. Army was involved in the War in Afghanistan. In the early 2000s, reports were once again coming off the battlefields with soldiers stating that the M855 ammunition and M4 rifle were not lethal enough (Dean, 2011). The Army's response was to produce new ammunition. The new ammunition would not be susceptible to the shortfalls of the M855. The round would be specifically designed for use in the shorter barreled M4 carbine. Beginning in 2010, the Army began fielding the M855A1 Enhanced Performance Round (EPR) ammunition to service members in Afghanistan (Dean, 2011).

2. Discussion

The M4 was well adapted for use in tight quarters, such as those often encountered in the urban Iraqi environments. The smaller size of the M4 carbine also proved beneficial during vehicle ingress/egress operations as well as CQB. However, in the wide open spaces of the Iraqi desert, the M4 and its 5.56x45 mm (M855) ammunition played a limited role. U.S. field reports from Iraq reveal that engagements over 100 meters were rare, while most fell into the 20–30 meter range (USMC, 2003).

The battlefield in Afghanistan was not like that of Iraq. The geography of Afghanistan's battle fields is mostly described as mountainous terrain. This steep terrain posed a difficult challenge for U.S. forces coming from the deserts of Iraq.

Enemy combatants in Afghanistan often utilized high-ground tactics to observe and attack U.S. forces, while remaining just out of range of the soldiers' M4A1 carbines. U.S. soldiers returning from the battlefields of Afghanistan commented that approximately 50% of engagements occurred past 300 meters, which is at least 100 meters past the most effective range of the M855/M4A1 system (Dean, 2011). In the plateaus or southern regions of Afghanistan, engagements distances were much closer as patrols often had to pass through mud-walled villages, farms, and other areas lending to a more CQB style of operations.

The M855 was the primary cartridge use by the infantry during campaigns in Persian Gulf and Iraq. The rounds had been tested and used since its official adoption by the U.S. Army in 1982. The original purpose of the M855 was as a replacement for the M193 cartridge. The round was to offer increased performance against hard-targets at longer ranges when used in long barrel rifles (Woods, 2010), namely, the M16 and M249. Partly due to Special Operations Command (SOCOM) units' influence with the M4A1, the desire for shorter barrels became increasingly popular as soldiers found the smaller size to be more maneuverable in tight quarters. The shortened barrels proved deleterious to the ballistic performance of the M855. Recall that the M855 round was designed for use with a full length rifle barrel.

Thus, the shorter carbine-length barrel did not have sufficient length to allow for the complete combustion of propellant gases as the bullet traveled down the bore and out of the muzzle. Incomplete propellant combustion resulted in a reduction of muzzle velocity, as well as an increase in muzzle flash.

The reduction in muzzle velocity would lend itself to reduced downrange performance in the forms of decreased projectile energy, penetration, and maximum effective range. Also, the increase in muzzle flash of the weapon gave enemy combatants a larger advantage in that they could more readily identify U.S. firing positions in reduced light situations. Initially, Army ammunition developers were eventually able to rectify the propellant issues by incorporating a faster burning propellant in combination with a flash reducing agent to make the ammunition suitable for use in short-barrel carbines. The performance consistency issues with the M855, however, were not so easily solved.

Recall from Section II of this research that projectile designs vary greatly and are typically selected according to their application. Designs are based on a number of tradeoffs which all have in common, two goals. Goal number one is to deliver the projectile to the target (accuracy). Goal number two is to have the projectile perform as intended when it reaches the target (terminal ballistics). The first goal is achieved through the proper matching of projectile mass, projectile velocity, and projectile design with the appropriate weapon system. The second goal requires not only the parameters of the first, but also includes a bullet designed matched to defeat targets with particular characteristics.

For the purposes of this research, targets will be considered either hard (steel, armor) or soft (tissue, thin barriers). The angle of attack AOA is a result of two factors. The first factor is the target's obliquity to the line of fire (LOF). For the purposes of this analysis, targets will be forward facing at zero degrees obliquity. The second factor which determines AOA is due to a projectile flight characteristic known as yaw.

Bullet yaw, or "wobble," is the movement a projectile exhibits as it exits the muzzle and proceeds downrange to the target location. Yaw is not to be confused with instability. Yaw occurs naturally as a result of spin stabilized projectile motion (Dean & LaFontaine, 2006). The Hall, Gustafson, Davis, and Hitchman studies led scientists and engineers to the formal conclusion that a SCHV projectile, which begins to yaw soon after impact with a soft target, will result in greater kill probabilities. If the attitude of a projectile, at the moment of target-strike (due to its yaw), is sufficient, it may upset or "tumble" as it passes into the target material. A non-expanding, military-style bullet which upsets upon target-strike will have increased wound ballistic performance, thereby increasing the probability of a kill. When these types of bullets do not upset on target-strike, wound ballistic performance is reduced, thus the probability of kill is also greatly reduced. Typically, wounds created by bullets which fail to upset are referred to as "through and through," as they are characterized by wounds that pass entirely through a target in a straight line without causing significant damage. As a bullet upsets, it imparts energy into the target. Due to this energy loss, bullets that upset will have reduced penetration; however, as the bullet is losing energy by upsetting, it is creating greater tissue damage.

In 2003, the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) performed an updated analysis on rifle caliber selection. The findings assert that to date, caliber studies indicate the optimal caliber to be between the calibers of .256 (6.5mm) and .276 (7mm) (Spikert, 2003).

Also during the early 2000s, the U.S. Army Infantry Center asked the R&D community to explain the inconsistencies of the M855 as well as to investigate the feasibility of a COTS replacement. The Joint Service Wound Ballistics Integrated Product Team (JSWB-IPT) began investigations into the anomalous inconsistencies of U.S. small caliber ammunition performance. The JSWB-IPT comprised more than 40 professionals from backgrounds including engineers, combat veterans, joint service members, pathologists, ballisticians, and members of the ammunition manufacturing industry (Sanville, 2004). In May of 2006 the JSWB-IPT released a final report. The board published findings that favored calibers larger than .22 (5.56 mm), specifically selecting the 6.8 mm Special Purpose Cartridge (SPC) as a primary choice. The board also made three findings in terms of current M855 ammunition questions. The findings were:

- A COTS solution was not currently available. All eligible candidates exhibited yaw sensitivity.
- The anomalous behavior of terminal performance inconsistencies was explainable in terms of yaw dependency.
- There were close-range performance improvements that could be sanctioned immediately.

The JSWIB-IPT identified terminal performance inconsistencies with the M855, and attributed them to projectile design as well as caliber selection. The design of the M855 projectile falls into a category often titled "yaw dependent" or "yaw sensitive" projectiles. Yaw dependency translates into inconsistent performance.

The inconsistency is rooted in the low probability that each projectile will meet its target at precisely the same point in its yaw cycle. The subject matter experts at the U.S. Army's Army Research Laboratory (ARL) and Armament Research Development and Engineering Center (ARDEC) designed the M855A1 to solve the issue of inconsistent terminal performance with a breakthrough in projectile design. Instead of attempting to regulate or predict yaw, the new type of ammunition would incorporate a projectile design that performed consistently *independent* of yaw. This type of performance criteria is often referred to as "shot-to-shot" consistency and is the ultimate result of achieving the optimum ammunition and weapon combination. Per the ammunition portion, it is best understood where ammunition is viewed as a system including the components of cartridge, propellant, primer, and projectile. When the components are of the proper type and amount, one can say that the system is balanced. Balanced systems can then be expected to perform at the attributed level.

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IV. ANALYSIS

Failure is not a single, cataclysmic event. You don't fail overnight.
Instead, failure is a few errors in judgement, repeated every day

~ Jim Rohn

A. EUROPE

1. Weapon Type and Design

The M1 Garand was a technological improvement over its predecessor, the bolt actioned Model 1903 Springfield. Upgrading the bolt-actioned 1903 to the semi-automatic M1 resulted in an instant force multiplier on the battlefield. Very few field reports of weapon malfunction were noted, giving credence to the M1's reliability. The high reliability of the M1 was a result of superior design and development. The M1 rifle satisfied the infantry's requirements for engagements at long ranges as found in Eastern Europe's countryside during WWII. However, in urban or other CQB situations, the M1 rifle was ill suited at best due to its length and weight.

2. Ammunition Caliber and Design

The 7.62x63 mm ammunition used during WWII provided positive performance at extended ranges. However, the ammunition was a ballistic overmatch for enemy combatants at lesser ranges. The downrange energies associated with this ammunition far surpassed that which would be necessary for lightly or unarmored enemy combatants (George, 2012). Also, the recoil energy generated by this ammunition exceeded what is typically deemed as acceptable.

Logistically, the size and weight of the 7.62x63 mm cartridges proved burdensome. The size and weight hampered not only the infantry soldier, who was physically limited in the amount of ammunition he could carry, but also the supply chains that brought the ammunition to the battlefield.

3. System Performance

Overall, the M1 rifle chambered for 7.62x63 mm ammunition was a less than optimum system for issue to the general infantry. Except for usage at extended ranges, such as in a sniper role, the system was less than optimal. The ammunition selection is the cause for most of the system deficiencies. The selection was based on surplus inventory from WWI and sized the M1's chamber for 7.62x63 mm (Canfield, 2009). Plainly stated, the ammunition was too powerful. The ammunition was a logistical burden due to its size and weight. The ammunition required the rifle to be of heavier construction than if a smaller caliber had been selected. Garand himself was an advocate of chambering the M1 in a smaller caliber, namely the .276 Pederson (Canfield, 2009). Despite the weapon's increase in weight to accommodate the larger .30 caliber, the system remained less accurate due the heavy recoil from the 7.62x62 mm ammunition.

B. SOUTHEAST ASIA

1. Weapon Type and Design

The M14 rifle offered little improvement in terms of size and weight over the M1 Garand. However, the overall weapon design improved. The improvement was made by incorporating a detachable box magazine that enabled the M14 rifle to hold over twice the amount of ammunition as the M1 (HQDA, 1972). Not long after the M14 program began, then did it soon fade to the newly developed M16. The M16 rifle was a significant milestone for infantry weapon technology. The weight reductions achieved by the usage of polymers and aluminum were a significant advancement over the M14. In fact, materials used in the M16 such as polymer stocks and for-ends have remained with the infantry rifle to this day. The incorporation of the direct gas impingement system was a saving on weapon weight, manufacturing cost, and logistics. Under ideal conditions, the M16 was the weapon that supported the argument for small caliber high velocity (SCHV) rifles capable of high rates of fire. The length of the M16 rifle was a minor improvement over the length of the M14, only slightly aiding in infantry operations in thick jungle vegetation.

2. Ammunition Caliber and Design

The 7.62x51 mm ammunition used in the M14 offered vast improvement over the 7.62x63 mm used in the M1 in terms of logistics and accuracy. The reduction in case size offered weight and cost savings, reduced weapon wear, and less recoil.

From the Army reports under project BALANCE and project SALVO, less recoil translates into higher accuracy and hit probability (JHU, 1952). It is also from Project BALANCE that the small caliber high velocity (SCHV) concept is developed. Developers and proponents of the SCHV systems favored the .22 caliber (5.56 mm) projectiles and elected to develop the M193 5.56x45 mm ammunition for use with the M16 (Watters, 2000). The propellant used in the production of M193 ammunition significantly contributed to the poor performance of the M16 rifle. The M193 would undergo multiple product improvement programs before being phased out by the M855 in the early 1980s (Watters, 2000). The smaller 5.56x45 mm cartridges now allowed for a detachable box magazine that held thirty rounds. The minimal recoil produced by the smaller cartridge was complimentary to the lighter weight M16. The M193 projectiles performed well against lightly or un-armored threats at close to medium range (Watters, 2000). However, the small caliber selection was not optimal for use in the thick vegetation found in Vietnam. Here, the 5.56 mm caliber's tendency to deflect after striking vegetation was much greater than that of the 7.62 mm caliber projectile.

3. System Performance

Although the M14 was one step closer to an "all-purpose rifle," the M14 proved unwieldy in the dense jungle terrain of Vietnam due to its length. The M14 design however, was very well developed and offered much in the way of small arms advancements for the infantry soldier. In fact, the M14 is still found serving official military roles up to and including present day.

Though the M16 platform was originally developed to be chambered for 7.62x51 mm, adopting into the smaller 5.56x45 mm cartridge proved to be acceptable in terms of performance and weight under ideal conditions. Programmatically speaking, the M16 was complicated with issues from the beginning of its deployment (OCS, 1968). Many of the issues stem from lack of adequate comprehensive battlefield testing. Current Army acquisition terminology designates this as Operational Testing (OT). The M16 program had undergone development for years in the private sector in the forms of various calibers, yet saw little in terms of formal operational testing (Kern, 2006). This forced the program to follow a series of R&D “fixes” to keep the weapons operationally effective. The most notable deficiency of the M16 was reflected in some of the earliest field reports of failure to extract the spent casing otherwise known as “jamming.” The jamming issue primarily stemmed from improper maintenance that allowed for carbon and other residue to accumulate in the M16’s chamber (Smith & Ezell, 1990). The immediate and permanent fix was to implement a training program to familiarize soldiers with their weapon functions early on, as well as to provide a cleaning kit with weapon’s basic issued items. Other R&D fixes, such as the addition of the forward assist mechanism, were made later during the deployment of the M16 to further increase the reliability of the system (Kern, 2006).

C. THE PERSIAN GULF AND AFGHANISTAN

1. Weapon Type and Design

The M4 Carbine was well suited for CQB battle scenes experienced in the urban areas of Iraq and the villages of Afghanistan. The compact carbine platform aided ingress and egress maneuvers in tight quartered environments such as infantry carriers and other vehicles. The use of lightweight materials in the M4 was a technology that was carried over from the M16 program. The true advancement in technology for the M4 lies in its modularity. The M4’s design is similar to open architecture in the software realm. The ability to change and/or modify weapon configurations expanded the list of roles in which the carbine could perform. Since its debut in 1994 the M4 has undergone little change in design. It was not until 2014 that official conversions were made to convert the M4s into the upgraded M4A1 variants, which were developed due in part to SOCOM’s preferred usage of the short barreled configuration for Close Quarters Battle (CQB) such as entering the caves of Afghanistan after 9/11 (Dean, 2011). The shortened barrel length of the M4 carbine did not perform adequately at extended ranges found in the mountainous terrain of Afghanistan.

2. Ammunition Caliber and Design

During the early eighties, the U.S. Army adopted a new 5.56x45 mm cartridge designated the M855 as an ammunition improvement for use in long barrel rifles such as the M16 and the M249 (Dean, 2011). The ammunition performed adequately in long barrel rifles such as the M16.

By the time the U.S. Army becomes involved with Iraq in the early 2000s, the infantry “rifle” has now become the M4 carbine with a shortened barrel (Roberts, 2008). The reduced maximum effective of the M855 when used in the M4 carbine was not an issue during much of the battle in Iraq as engagement distances over 100 meters were uncommon. However, during this time period the reports of inconsistent terminal performance arose. As a result of the inconsistent behavior exhibited by the US’s small arms ammunition, the Joint Service Wound Board –Integrated Product Team (JSWB-IPT) was formed. The JSWB-IPT studied the field reports and pinpointed the terminal performance inconsistencies as having a root cause traced to the M855’s projectile design (Dean & LaFontaine, 2006). The M855 projectile design was found to be yaw *dependent*, which directed the development of a revolutionary projectile design that was yaw *independent* (Woods, 2010). That cartridge is known as the M855A1 enhanced performance round (EPR). The M855A1 EPR, also known as “green ammo” was a major improvement over the existing M855. The M855A1 ammunition had three primary areas of improvement over the M855. The new projectile design exhibits improved soft-target performance consistency of the current M855 round. The consistent performance was due in part to the projectile’s independent yaw design. The newly designed penetrator portion of the projectile increased downrange hard-target penetration. Also, the round utilized an improved propellant that was engineered to be effective in short barrel carbine weapons. In fact, the 5.56 mm cartridge’s performance now was more comparable to and sometimes exceeding that of the, larger, standard 7.62 mm ball ammunition (Woods, 2010).

3. System Performance

The newer versions of the M4 carbine did not perform adequately at the extended ranges found in the mountainous terrain of Afghanistan due to the weapon's barrel length and small caliber. Field reports indicate that enemy combatants in Afghanistan studied engagement distances and casualties, and analyzed them. Upon analysis, enemy combatants appear to have discovered a "zone" of operation that is within the maximum effective range of their 7.62 mm weapons but outside the maximum effectiveness of the US's 5.56 mm weapons (Ehrhart, 2009).

The enemy combatants then implemented doctrine to stay outside of the effective range of the 5.56 mm M4 whilst remaining inside the capabilities range of their own weapons, namely rifles of caliber 7.62x39 mm and 7.62x54 mm. With the advent of the M855A1, the U.S. Infantryman using the M4A1 Carbine has indeed become a formidable threat on the battlefield. This particular weapon system combines both some of the major benefits of carbines and rifles. When fed the M885A1 ammunition, the M4A1 carbine displays the weight savings and compactness found with the carbine platform as well as the enhanced accuracy and downrange performance typical of rifle-style platforms. This system did not, however, come about quickly or easily. The M4 carbine shares over 80% commonality with the M16. In this respect one can see that the M4 is essentially a down-scaled but upgraded M16. The M16 is not alone with this type of evolution. The Army has made over 90 engineering change proposals (ECP) to the M4 weapon since its introduction in 1994 (Military, n.d.).

In fact, the M855A1 that was specifically tailored for use with the M4 weapon was an engineering change proposal (ECP) to the existing M855 cartridge (DOTE, 2010).

V. CONCLUSION

Those who ignore history's lessons in the ultimate folly of war are forced to do more than relive them ... they may be forced to die by them.

~ Dan Simmons, *The Fall of Hyperion*

In conclusion, this study does not find sufficient evidence to support the claim that the U.S. Army has provided its infantry with the optimum weapon and cartridge throughout history. This study compared the weapon and cartridge selected for use against the actual battlefield applicability and effectiveness during deployment. The measures of effectiveness used in this study were weapon type and design, ammunition caliber and design, and system-level performance on the battlefield.

This study indicates that the general failure of the Army's mission is due to two primary factors. The first factor is the Army's requirement for a ubiquitous infantry weapon, and the second factor is the Army's failure to adopt the optimum caliber into the latest weapon platforms.

History has indicated that the concept for a ubiquitous weapon that satisfies all performance parameters is unlikely. The range of requirements concerning accuracy, size, weight, range, and precision is too great to be satisfied by a single weapon platform. Take, by example, the current GWOT mission.

GWOT demands that the infantry weapon systems must be able to satisfy the battlefield requirements in any geography, climate, terrain, altitude, etc., around the world. Afghanistan is a clear example where the range of performance requirements exceeds the capabilities of a single weapon platform.

During WWII, the Army recognized the requirement for two individual weapons of two different calibers. The requirement was satisfied by the M1 carbine paired with a small cartridge for close work and M1 rifle paired with a larger cartridge for engagements at extended range. Immediately following the Korean War, the U.S. Army began the hunt for a universal infantry weapon that would replace the Ml rifle, M1 carbine, M3Al submachine gun, and the M1918 BAR (Emmerson, 2006). This concept of an optimum weapon would prove elusive for the next 60 years, aptly earning the title of “the ghost gun.” The first major effort to develop the optimum infantry rifle began under the name of Project SALVO in the 1950s. SALVO’s mission was then cancelled, and the mission was replaced with the Special Purpose Individual Weapon (SPIW) program. The SPIW mission was later supplemented by another program called the Future Rifle Program (FRP) in the 1970s, which was cancelled under the justification of “waste of money.” The hunt for the ghost gun continued in 1980s by the Advanced Combat Rifle (ACR) program. The ACR program spawned yet another program known as Objective Individual Combat Weapon (OICW) that runs into current times (Watters, 2000). Thus, for over 50 years, the U.S. Army has failed to recognize the benefits of a purpose-driven design concept. Instead of identifying the large range of requirements and seeking to satisfy those requirements with multiple weapon platforms, the Army has chosen to pursue the elusive multirole single weapons platform for the infantry rifle.

The second factor that continues to hamper the infantry weapon’s development is caliber selection. The Army had multiple opportunities to develop or implement alternative calibers in the range between .22 (5.56 mm) and .30 (7.62 mm). Prior to the M16, the U.S. infantry caliber of .30 (7.62 mm) was the standard. Following the Army reports and studies with small caliber high velocity (SCHV) projectiles during the 1950s, the focus immediately went to the .22 (5.56 mm) caliber. The jump from a .30 caliber bullet to a .22 bullet, however, is not to be ignored, as it spans a number of alternative calibers in between. One of the first opportunities for the Army to recognize a caliber superior to that of the current .30 (7.62 mm) was in 1929. The U.S. Army War Department assembled a board of officers to determine the best choice caliber for the future infantry rifle. The board conducted tests to study the wounding effects that various calibers had on pigs. The board, aptly named “The Pig Board,” tested three calibers of .256 (6.5 mm), .276 (7 mm), and .30 (7.62 mm). The Pig Board concluded that the caliber of .276 (7 mm) should be used in what would eventually become the M1 rifle (OCS, 1968). The next opportunity came in 1950. The British 7 mm cartridge was tested against the United States' 30 caliber (7.62 mm) cartridge at Aberdeen Proving Grounds. While the small .22 (5.56 mm) caliber projectile showed great promise, it was dismissed by the Ordinance Department to bring the .30 (7.62 mm) caliber back to the forefront (Holland, 2009).

The next opportunity came in late 1958. The Powell Board convened to review the entire Army infantry rifle program. The board recommended no additional consideration be made toward the .22 caliber (5.56 mm). The board also recommended the developing AR15 platform to be chambered for a .258 (6.5 mm) caliber cartridge instead of .22 (5.56 mm) (OCS, 1968). In early 2003, the .268 caliber 6.8 mm Remington Special Purpose Cartridge (SPC) was introduced to the public and military communities (Watters, 2000). The next opportunity came from the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) in 2003. It asserts that to date, caliber studies indicate the optimal caliber to be between the calibers of .256 (6.5 mm) and .276 (7 mm) (Spikert, 2003). A more recent finding came from an analysis by the Joint Service Weapons Board-Integrated Product Team (JSWB-IPT) in 2006. The JSWB-IPT report published in May 2006 that the 6.8 mm SPC has the optimal characteristics for and intermediate caliber weapon. The board went as far to write: "The best performing systems emphasizing tissue damage, on the average, in this study were of larger caliber than 5.56 mm" (Roberts, 2008, slide 13). Thus, the U.S. Army has researched the optimum caliber for the infantry weapon for over 80 years and has not yielded to the historical research findings that indicate an optimal caliber for the infantry weapon being between the calibers of .256 (6.5 mm) and .276 (7 mm).

Takeaways:

- The quest for an optimum infantry weapon system (aka the ghost gun) requires both an optimum weapon and optimum ammunition.
- History indicates that small arms ammunition selection can be just as critical during the development process as the weapon platform itself.
- Generally speaking, as a product's range of applicability increases, the product's effectiveness and/or efficiency decreases.

Quote for thought … "If you refuse to change policy or your goals you are merely rearranging deck chairs on the Titanic."

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