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NATO Infantry Weapons Standardization: Ideal or Possibility?

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NATO Infantry Weapons Standardization: Ideal or Possibility?

by

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Abstract

This thesis examines the efforts that the North Atlantic Treaty Organization (NATO) has taken regarding the standardization of rifles and small arms ammunition from the Cold War to the present day and the limitations of these standardization efforts. During the Cold War, NATO was unsuccessful at standardizing a common rifle and its member states only agreed to standardize ammunition calibers. This thesis will discuss the factors that prevented all of the alliance's militaries from adopting the same rifle models and the problems associated with NATO's ammunition standardization efforts. Many NATO members intend on procuring new small arms during the 2020s period but there are no plans for the adoption of a common NATO rifle. In the absence of a common rifle for the future, NATO needs to undertake efforts that would both modernize its small arms capabilities and improve the degree of standardization within the alliance.

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List of Abbreviations

2-325 AIR	2nd Battalion, 325th Airborne Infantry Regiment, 82nd Airborne Division
ACR	Advanced Combat Rifle
ADE	Armament Design Establishment
AOA	Angle of Attack
AOP	Allied Ordnance Publication
AP	Armour Piercing
APG	Aberdeen Proving Ground
ARDEC	Armament Research, Development and Engineering Command
ARPA	Advanced Research Projects Agency
ATK	Alliant Techsystems
BAe	British Aerospace
BAR	Browning Automatic Rifle
BC	Ballistic Coefficient
BGS	Boarder Guard
BRL	Ballistics Research Laboratory
BTB	Blind to Barriers
CC	Compact Carbine
CHF	Cold Hammer Forged
CNAD	Conference of National Armaments Directors
CNS	Central Nervous System
COIN	Counter Insurgency

CONARC	Continental Army Command
CQBR	Close Quarters Battle Receiver
CTA	Cased Telescoped Ammunition
CWO	Chief Warrant Officer
CZ	Ceska zbrojovka
DMAR	Designated Marksman/Automatic Rifle
EPR	Enhanced Penetration Round
FMJ	Full Metal Jacket
FNH	FN Herstal
fps	Feet per second
FTE	Failure to Extract
GPMG	General Purpose Machine Gun
GWOT	Global War on Terror
HK	Heckler and Koch
IAR	Infantry Automatic Rifle
IOFS	Interior Operating Floating System
ISAF	International Security Assistance Force
IW	Individual Weapon
JHP	Jacketed Hollow Point
JSP	Jacketed Soft Point
JSWB-IPT	Joint Services Wound Ballistics Board- Integrated Product Team
LMG	Light Machine Gun
LSAT	Lightweight Small Arms Technologies

LSW	Light Support Weapon
MAS	Manufacture d'Armes de St-Etienne
MMG	Medium Machine Gun
MOPI	Manual of Proof and Inspection
MOS	Military Occupational Specialty
MOU	Memoranda of Understanding
MPa	Megapascal
MRBEFF	Mean Rounds Between Essential Function Failure
MRBS	Mean Rounds Between Stoppages
MSBS	Modular Small Arms System
MSW	Medium Support Weapon
NAAG	NATO Army Armaments Group
NATO	North Atlantic Treaty Organization
NL	Neck Length
NNW	NATO Nominated Weapon
NSMATCC	NATO Small Arms Test Control Commission
OICW	Objective Individual Combat Weapon
ORO	Operations Research Office
OSD	Office of the Secretary of Defense
OTM	Open Tip Match
PEO Soldier	Program Executive Office Soldier
pH	Hit Probability
P(i)	Probability of Incapacitation

PSI	Pounds per Square Inch
RPM	Rounds per Minute
RSAF	Royal Small Arms Factory
RSI	Rationalization, Standardization and Interoperability
SAAC	Small Arms Ammunition Configuration
SARP	Small Arms Replacement Program
SAW	Squad Automatic Weapon
SCHV	Small Caliber High Velocity
SDM	Squad Designated Marksman
SMG	Submachine Gun
SOST	Special Operations Science and Technology
SPIW	Special Purpose Individual Weapon
STANAG	Standardization Agreement
STTE	Spare Tools and Test Equipment
TA/FCS	Target Acquisition and Fire Control System
TOTM	Tactical Open Tip Match
USAIC	United States Army Infantry Center
USGI	United States Government Issue
USMC	United States Marine Corps
Vol.	Volume

Introduction

Standardization for a coalition means that member states "adopt the use of common or compatible operational, administrative, and logistics procedures along with common, compatible, or interchangeable supplies, components, weapons, or equipment and common or compatible tactical doctrine."[1] When the North Atlantic Treaty Organization (NATO) was formed in 1949 to deter Soviet aggression, the alliance wanted to pursue weapons standardization in order to improve its military effectiveness. Standardization meant that it was ideal for the alliance to adopt common weapons and at the very least, alliance members should have interoperable systems.[2] "Interoperability refers to compatibility of equipment and interchangeability of parts, fuel and ammunition."[3] In terms of small arms and their associated ammunition, NATO sought a common rifle model and caliber in the 1950s and 1970s. While NATO has standardized small arms calibers, the alliance's efforts towards the adoption of a common rifle ended in failure and it is unlikely to standardize a single rifle model for all its military forces in the future. Due to the unlikelihood that a common rifle will be procured, NATO needs to take other measures to improve the degree of standardization in the field of small arms compared to their standardization efforts in the 1950s and 1970s.

The topic of NATO rifle and ammunition standardization during the 1950s was primarily discussed in detail in Edward Ezell's thesis "The Search for A Lightweight Rifle: The M14 and M16 Rifles" and his various publications on post-war small arms developments.[4] Ezell argued

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[1] Douglas M. Turner, "A Systems Engineering Approach to NATO Standardization" (Masters Thesis: Naval Postgraduate School, 1979).

[2] Shannon Marie Leslie Hurley, "Arms for the alliance: Armaments cooperation in NATO," *Comparative Strategy* 7 (1988): 377, 378.

[3] Philip Taylor, "Weapons Standardization in NATO: Collaborative Security or Economic competition?," *International Organization* 36 (1982): 95.

[4] Edward Clinton Ezell, "The Search for A Lightweight Rifle: The M14 and M16 Rifles" (PhD Thesis: Case Western Reserve University, 1969).

that the US Ordnance Department's conservatism towards rifle design was focussed on minimizing disruption to production, which required new designs to be based heavily on their predecessors and the use of existing manufacturing methods. Hostility towards new concepts was also evident in the Ordnance Department's design philosophy for rifle ammunition, which rejected the concept of lower recoiling intermediate cartridges in favour of a new full power rifle round.[5] Since previous US service rifles fired full power cartridges, the Ordnance Department and many US military leaders "wanted new weapons and ammunition that conformed to old doctrine" rather than newer concepts that were developed from experience in modern warfare.[6] Ezell explained that American conservatism in small arms design along with national pride led to the rejection of new foreign rifles and intermediate rounds for US service and forced NATO to accept the standardization of the American 7.62mm full power cartridge.[7] R. Blake Stevens has written on the history of the FAL rifle, which was adopted by numerous NATO states such as Canada, Britain and Belgium while Robert Dale Hinrichs composed a thesis on the history of the M14 and M16 rifles. Although Stevens and Hinrichs discussed NATO standardization in their works, they were heavily reliant on Ezell's writings as sources and shared a common consensus that national pride doomed the effort to field a common NATO rifle.[8] Also, Stevens emphasized

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[5] Ibid, 6, 17.
[6] Ibid, 19.
[7] Edward Clinton Ezell, *The Great Rifle Controversy: Search For The Ultimate Infantry Weapon From World War II Through Vietnam and Beyond* (Harrisburg: Stackpole Books, 1984), 135.
Edward C. Ezell, "Cracks in the Post-War Anglo-American Alliance: The Great Rifle Controversy, 1947-1957," *Military Affairs* 38 (1974): 139, 141.
[8] Robert Dale Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967" (Masters Thesis: Iowa State University, 2009), 99.
R. Blake Stevens, *UK and Commonwealth FALs-Volume Two of the FAL Series* (Cobourg: Collector Grade Publications Incorporated, 1980), 41, 42.

Ezell's explanation that the American preference for a rifle design based on previous US rifle models was responsible for the failure of the US and UK to adopt a common rifle.[9]

From 1976 to 1979, NATO held trials to select an intermediate caliber for standardization. Ezell has been the only historian to have reviewed those trials and their conclusions. The NATO trials attempted to avoid the influence of national prejudice during the evaluation process by standardizing testing procedures and terminology and through independent testing by "a NATO body composed of military personnel from participating nations."[10] Ezell explained that the Belgian 5.56mm SS109 cartridge was best suited for NATO's performance criteria and was chosen for standardization. But some alliance members had different military requirements than those of the NATO evaluators and Ezell believed that those states might adopt alternative ammunition technologies rather than the SS109 after those developments become mature in a few years.[11] Since Ezell's coverage of the 1976-1979 NATO trials was written shortly after its conclusion, he was unable to examine the more significant limitations of the alliance's standardization of the SS109 cartridge.

There has been little written about NATO small arms and ammunition standardization in the post-Cold War era. An Institute for Defense Analysis Paper written by Christina Patterson et al had examined weapons manufacturing in the Czech Republic, Poland and Hungary and gave recommendations on how those states could transition to the "production of NATO-compatible armaments."[12] The authors argued that "ensuring safety, quality, compatibility and interoperability of ammunition and weapons could prove vital to the new member countries'

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[9] R. Blake Stevens, *North American FALs-NATO's Search for a Standard Rifle* (Cobourg: Collector Grade Publications Incorporated, 1979), 106.
[10] Edward Clinton Ezell, *Small Arms of the World*, 12th ed. (Harrisburg: Stackpole Books, 1983), 57.
[11] Ibid, 63.
[12] Christina M. Patterson, David R. Markov and Karen J. Richter, *Western-Style Armaments for New NATO Countries* (Alexandria: Institute for Defense Analyses, 1999), iii.

performance in NATO operations."[13] The Czechs' exportation of commercial ammunition to developed countries "has forced them to closely followed Western manufacturing standards and practices" while Poland is "implementing European and NATO standards" for its defense industry.[14] Due to these factors, Patterson et al believed that the Czech Republic and Poland would be capable of manufacturing ammunition that complies with the alliance's standards.[15]

Existing literature on NATO rifle standardization has argued that national pride was an important barrier towards a common rifle for NATO in the 1950s and was primarily focussed on the Anglo-American states. Similar to previous works on rifle standardization during the 1950s, this thesis will cover the Anglo-American developments and the use of nationalism to support indigenous rifle designs. But compared to the existing historiography on NATO weapons standardization, this thesis will examine rifle procurement in other NATO states and alternative reasons that prevented the standardization of a common rifle. National desire to maintain domestic industries, the unwillingness of states to rely on foreign exports and the availability of new designs that were less expensive than existing rifle models were all major reasons that NATO members did not agree on a common rifle. Analyzing all of the factors that impeded the adoption of a common NATO rifle will facilitate assessment of whether some obstacles towards rifle standardization could in principle and even practice be overcome and those that would nonetheless still remain. Another limitation of the current historiography on NATO infantry weapons standardization is the lack of coverage of the challenges of ammunition standardization and interchangeability. Unlike the works of other academics on weapons standardization, this thesis will examine the procedures that NATO uses to determine ammunition interchangeability

[13] Ibid, 2-2.
[14] Ibid, s-3, 3-19.
[15] Ibid, 3-6, 3-20.

and why some NATO standard ammunition designs do not function reliability in certain NATO weapons. As well, this thesis will present a contrary view compared to those of Patterson et al regarding Eastern European states' efforts in achieving NATO ammunition standardization and explain that financial constraints have significantly hindered ammunition standardization for new members. While historians have explained that different states wanted their own cartridge designs to be selected for standardization, they did not explain the technical characteristics required for an ideal infantry rifle cartridge. This thesis will explain the capabilities of NATO standard small caliber cartridges and whether they are suitable for current combat operations. Finally, this thesis will examine potential solutions that will improve standardization throughout NATO or within the alliance's national military forces. Political and economic factors along with the lack of coordinated weapons development are likely to prevent the adoption of a common NATO rifle while modernization efforts may lead member states to abandon NATO compatible weapons and ammunition. Standardization throughout NATO could be improved via new ammunition standards and common weapons interfaces while adopting a family of weapons with common parts would allow standardization within their own national militaries.

Chapter 1: Second World War Logistical Problems and Weapons Developments

1.1 Ammunition Supply Problems during the Second World War

During the Second World War, the Western Allies discovered that "ammunition supply was a nightmare."[16] Before the post-war era, many nations were proud of the fact that they were able to field their own calibers.[17] Accordingly, rifles, machine guns and some submachine guns (SMGs) of the US and British Commonwealth armies were not of the same caliber. For example, American rifles, automatic rifles and medium machine guns (MMGs) were chambered for .30-06, while British rifles, light machine guns (LMGs) and MMGs used .303 ammunition.[18] Also, a large variety of ammunition configurations, such as full metal jacket (FMJ), armour piercing (AP), incendiary and tracer bullets, were required for some of the same calibers.[19] In addition, rifle and belted machine gun ammunition of the same caliber were considered different types of ammunition during manufacture and transport for several militaries.[20] Infantry squads were equipped with SMGs and rifles, which were not of the same caliber. Major Godfrey, a graduate of the US "Quartermaster Officer Basic and Advanced Courses," explained that "ammunition was the hardest supply to push on the battlefield during the Second World War because of its various types and different configurations."[21]

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[16] Per G. Arvidsson, "Weapons and Sensors" (presented at National Defense Industrial Association Conference, Las Vegas, Nevada, May 18-21, 2009, http://www.dtic.mil/ndia/2009infantrysmallarms/wednesdaysessionvArvidsson.pdf), 3.

[17] Email communication from Per G. Arvidsson to author, March 27, 2015.

[18] Thomas B. Dugelby, *EM-2 Concept & Design: A Rifle Ahead of its Time* (Toronto: Collector Grade Publications, 1980), 2, 3.

[19] MAJ Danford Allan Kern, "The Influence of organizational culture on the acquisition of the M16 Rifle" (Masters Thesis, Fort Leavenworth: Command and General Staff College, 2006), 49

[20] Thomas L. McNaugher, *The M16 Controversies: Military Organizations and Weapons Acquisition* (New York: Praeger Publishers, 1984), 30.

[21] MAJ Frederick V. Godfrey, "The Logistics of Invasion," accessed March 18, 2015, http://www.almc.army.mil/alog/issues/NovDec03/Logistics_of_Invasion.htm.

In 1941, the UK started introducing the 9mm Sten SMG as a replacement for the .45 caliber US Thompson SMG but this prevented the standardization of SMG ammunition.[22] In the early years of the Second World War, the British did not have a viable domestic SMG design and had to rely on Thompson SMGs.[23] But the Thompson was expensive and time consuming to manufacture and the UK could not acquire enough Thompsons to equip all of their forces.[24] The British designed Sten was an inexpensive gun that used a receiver made of steel tubing (See Figure 1).[25]

Figure 1: US M1928A1 Thompson SMG (left) and British Sten SMG (right).

Sources: "Thompson M1921 M1928 M1 and M1A1 submachine gun / 'Tommy Gun' (USA)," accessed October 20, 2015, http://world.guns.ru/smg/usa/thompson-e.html .
"Sten Submachine guns (Great Britain)," accessed October 20, 2015, http://world.guns.ru/smg/brit/sten-e.html.

British and Commonwealth use of Thompsons during most of the Italian campaigns was advantageous from a logistical perspective because "the US had the supply lead and a plentiful quantity of .45 ammunition in Italy."[26] On campaigns where British forces were equipped with the Sten, they could not rely on US supply channels for ammunition. Thus, the lack of ammunition standardization among the Americans and British necessitated separate supply systems and was not as efficient compared to consolidated logistical systems.

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[22] Dugelby, *EM-2 Concept & Design*, 3.
"Sten Gun," accessed March 18, 2015, http://www.canadiansoldiers.com/weapons/smgs/sten.htm.
[23] Ibid.
[24] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 3, 2015.
[25] Dugelby, *EM-2 Concept & Design*, 3.
[26] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 3, 2015.

An example of significant operational problems caused by the Allies' lack of common logistics systems could be seen during the Battle of Anzio. The Battle of Anzio was an amphibious landing in 1944 intended to "break the stalemate on the Italian Front."[27] Unlike previous joint operations, where the Allies cooperated "above the corps level," the Battle of Anzio involved a consolidated corps that consisted of American and British soldiers.[28] Some of the consolidated corps' logistical difficulties stemmed from the lack of common ammunition, weapons, rations and petroleum, and oil and lubricants among US and British forces. With the exception of anti-tank and light anti-aircraft guns, there was a lack of ammunition interchangeability between US and British weapons.[29] Major Medve has argued that "the friction of war magnified during coalition warfare" due to logistical problems and the lack of common military doctrine "would contribute to the failure of the landings to accomplish their intended objectives."[30]

In addition to the failure of the joint British-American Corps at Anzio, the logistical problems during the early stages of the Normandy Invasion showed that a greater degree of ammunition commonality was desirable within a single national military. During the Allied landings, problems with the weather and heavy enemy fire hampered the initial plans for supplying Allied forces, which led to shortfalls in ammunition and required ammunition to be rationed. Another issue in Normandy was that the Allies had initially underestimated the

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[27] MAJ John P. Medve, "Integration, Interoperability and Coalition Warfare in the New World Order" (Monograph, Fort Leavenworth: Command and General Staff College, 1993), 13.

[28] Ibid.

[29] Ibid, 18, 19.

[30] Ibid, 14.

MAJ Medve explained that "common practices between US and British units were not developed" and units in the integrated corps followed the "administrative procedures" of their respective national armies. For example, the UK "had a fixed replacement figure while the US expected replacements based on loss estimates, which meant that British units had a lower casualty threshold to continue operations." See Medve, "Integration, Interoperability and Coalition Warfare in the New World Order", 17.

consumption of small arms and mortar ammunition.[31] In hindsight, the reduction of different calibers and ammunition types within the squad would have allowed squad members to cross-load and use each other's ammunition.[32] Due to the plethora of ammunition calibers and types, it was sometimes "difficult to provide the correct ammunition during combat" and a greater degree of ammunition commonality could have better streamlined logistics.[33]

Although supply was problematic at times for the Allies, logistical problems were far more severe for the Axis Powers. The logistics problems of the Axis Powers were one of the reasons that Hitler and his allies were unable to wage war effectively as a coalition and their failures at coalition warfighting had significant repercussions on the Eastern Front.[34] The Eastern Front was significant because throughout the entire Second World War, no less than sixty percent of Germany's forces waged war against the Soviet Union and all of Hitler's allies fought on the Eastern Front.[35] The German Army "was a semi-motorized force and did not achieve the degree of motorization sufficient to carry on the war against the USSR by means of motor transport alone."[36] In part due to their logistical transport not being fully motorized, German forces were often unable to fulfill their own logistical needs.[37] Equally problematic was that the logistical capabilities of other Axis Powers were less capable than those of Germany and the Germans had to assist Axis "units with various supplies, including food, equipment, explosives,

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[31] Martin van Creveld, *Supplying War: Logistics From Wallenstein to Patton* (Cambridge: Cambridge University Press, 2004), 209, 212.
[32] "The Logistics of Invasion."
[33] Ibid.
[34] R. L. DiNardo, "The Dysfunctional Coalition: The Axis Powers and the Eastern Front in World War II," *The Journal of Military History* 60 (1996): 712.
[35] David M. Glantz and Jonathan M. House, *When Titans Clashed: How The Red Army Defeated Hitler* (Lawrence: University of Kansas Press, 1995), 283.
[36] van Creveld, *Supplying War*, 175.
[37] Lt COL John Hixon and Benjamin Franklin Cooling, *Combined Operations in Peace and War* (Carlisle Barracks: US Army Military History Publishers, 1982), 211.
Although Germany had some success with modifying Russian railway standards to be compatible with German trains, this was still insufficient to compensate for insufficient motorization. See Hixon and Cooling, *Combined Operations in Peace and War,* 211.

winter clothing and ammunition" for those allies who used German calibers.[38] In hindsight, "the standardization of equipment, weapons, ammunition and rations for the Axis Powers would have improved the efficiency of the available transport and provided greater operational and tactical flexibility in the employment of the available forces."[39]

In terms of small arms and machine guns, there was a lack of weapons standardization among the Germany military and their allies. Throughout the war, the Soviets generally produced the same type of SMGs, rifles, LMGs and heavy machine guns in volume and thus took advantage of mass production and long runs. In contrast, the Germans continued to manufacture several different models of SMGs throughout the conflict. During the later stages of the war, the Germans fielded the StG44 assault rifle, which used nonstandard 7.92x33mm ammunition and this led to problems with ammunition availability (See Figure 2).[40]

Figure 2: StG44 assault rifle.

Source: "Schmeisser MP 43 MP 44 Stg. 44, accessed October 20, 2015, http://world.guns.ru/assault/de/mp-43-mp-44-stg44-e.html.

For example, when the Germans first considered the large-scale fielding of assault rifles, there was only enough 7.92x33mm ammunition to completely equip infantry soldiers from the 1st Infantry Division of Army Group South with StG44s.[41] Although the StG44 had a significant

[38] Ibid, 210.
[39] Ibid, 212.
[40] Walter S. Dunn, Jr. *The Soviet Economy and the Red Army, 1930-1945* (Westport: Praeger Publishers, 1995), 96, 105.
[41] Leszek Erenfeicht, "Sturmgewehr: Hitler's Only True Wunderwaffe," *Small Arms Defense Journal* 5 (2013): 3, accessed March 20, 2015, http://www.sadefensejournal.com/wp/?p=2087.

tactical advantage over SMGs and rifles, those assault rifles were not produced in sufficient numbers to have a significant impact on the war.[42] The production of numerous weapon models and ammunition types along with the industrial disruption caused by the Allied bombing campaigns prevented the Germans from manufacturing enough weapons to equip all of their soldiers during the later years of the war. As a result, the Germans put many captured rifles and SMGs that were chambered for non-German calibers into service, which further strained their problematic logistics system.[43]

In addition to having various weapons and ammunition types in German service, weapons and ammunition types were not standardized for the other Axis armies. Nazi Germany's inability to produce sufficient weapons to arm its own forces meant that they often supplied their Axis allies with captured weapons. For example, the Romanian Army was equipped with four models of rifle of Romanian, Soviet, Austrian and Czech origins, which were chambered for calibers 6.5x53mm, 7.62x54R, 8x50mm and 7.92x57mm.[44] Due to the logistical problems of supporting so many rifle calibers, active Romanian infantry units were armed with Czech rifles when possible while rifles of other calibers were given to the reserves because German and Czech rifles had ammunition interchangeability.[45] In terms of machine guns, the Romanians used both Czech and Russian models, which were chambered for 7.92x57mm and 7.62x54R respectively.[46] In spite of Romania's attempts to better organize their supply system, the various

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[42] David M. Glantz, "Introduction," in *Slaughterhouse: Handbook of the Eastern Front*, ed. Keith E. Bonn (Bedford: The Aberjona Press, 2005), 9.
Paul Graves-Brown, "Avtomat Kalashnikova," *Journal of Material Culture* 12 (2007): 299.

[43] Dunn, *The Soviet Economy and the Red Army*, 105.
Edward Clinton Ezell, *Small Arms of the World*, 11th ed. (Harrisburg: Stackpole Books, 1977), 17.

[44] DiNardo, "The Dysfunctional Coalition," 718.

[45] Richard L. DiNardo, *Germany and the Axis Powers: From Coalition to Collapse* (Lawrence: University of Kansas Press, 2005), 113.

[46] Hixon and Cooling, *Combined Operations in Peace and War*, 214.

non-standard weapons and calibers in service meant that logistical problems persisted.[47] Therefore, weapons and ammunition standardization would have streamlined logistics and allowed the Axis Powers to better utilize their constrained supply system.[48]

The experiences of the Allies at Anzio and the Axis Powers on the Eastern Front showed that the lack of weapons and ammunition standardization caused some logistical problems, and poor logistics were one of the factors that contributed to the failure of those operations and campaigns. While Allied Lend-Lease was significant for the Soviet war effort, the USSR's efficient use of resources, standardization of factory tooling and proper application of modern production methods provided most of the weapons required to defeat the bulk of the German Army.[49] In terms of small arms and machine guns, the Soviet production was significantly greater than that of the Germans starting in 1943, and not having to use large numbers of captured weapons reduced the strain on logistics.[50] While the Soviet Union's experience highlighted the advantages of long production runs, the standardization of the British Commonwealth's weapons and ammunition enabled the alliance to avoid at least some of the logistical problems of the Axis Powers. Within the Commonwealth, the British provided the majority of the funds for weapons development and production and, as a result, Commonwealth forces were armed with British weapons. Commonwealth forces functioned as attachments to the British Army and the British had the responsibility of providing logistical support to

[47] DiNardo, *Germany and the Axis Powers*, 113.
[48] Hixon and Cooling, *Combined Operations in Peace and War*, 212.
[49] The large amount of transport provided by the Allies through Lend-Lease was crucial for the Soviet war effort because they provided means to support the Red Army logistically. Also, the amount of metals and sustenance the USSR received through Lend-Lease reduced the pressure on an already stressed Soviet economy. The Germans suffered around 13,488,000 killed, wounded or captured during the Second World War and around 10,758,000 of those were killed or captured on the Eastern Front. See Glantz and House, *When Titans Clashed*, 284, 285.
[50] Dunn, *The Soviet Economy and the Red Army*, 104, 241, 243.

Commonwealth units, which simplified training and supply for the British alliance.[51] In the post-war era, NATO would follow the example of the British Commonwealth and standardize a rifle cartridge. The Second World War would see the German development of general purpose machine guns (GPMGs) and assault rifles due to technological advances and the weakness of then-existing small arms on the modern battlefield. The assault rifle and GPMG concepts would lead to efforts by numerous NATO states to adopt new types of weapons that could replace numerous niche weapons in their armies.

1.2 Weapons Development Up To the End of the Second World War

Up to the late nineteenth century, most armies were equipped with rifles that fired large caliber soft lead rounds at fairly low velocities. These bullets were effective in terms of physiological incapacitation because they expanded shortly after striking tissue.[52] The wound track created from the bullet's crushing of tissue is known as the permanent cavity. Expanded bullets generally "increased their cross-sectional areas by four to six times" and created a larger permanent cavity than an unexpanded bullet.[53] If a bullet yawed rather than expanded, then the amount of tissue crushed was limited to "the bullet's lateral cross-section."[54] Also, when a bullet expanded or yawed, tissue adjacent to the "permanent cavity was briefly pushed laterally aside."[55] "The empty space normally occupied by the momentarily displaced tissue surrounding the wound track is known as the temporary cavity" and "the effect of temporary cavity stretch on

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[51] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 19, 2015.

[52] Gary K. Roberts, "Wounding Effects of Military Small Arms during the Past Century" (Unpublished material), 2.

[53] Jeremy J. Hollerman et al, "Gunshot Wounds: 1. Bullets, Ballistics, and Mechanisms of Injury," *American Journal of Roentgenology* 155 (1990): 686.
Martin L. Fackler, Ronald F. Bellamy and John A. Malinowski, "The Wound Profile: Illustration of the Missile-tissue interaction," *The Journal of Trauma* 28 (1988): S24.

[54] Ibid, S23.

[55] Gary K. Roberts, "Wound Ballistics Research and Consulting," accessed November 18, 2015, http://www.dlgunsmithing.com/uploads/4/5/8/2/45825609/wound_ballistics_2013_gary_roberts.pdf.

tissue is similar to that seen in blunt trauma."[56] A large temporary cavity can "severely damage less elastic tissues and fluid filled organs while elastic tissue and lower density elastic tissue are highly resistant to the blunt trauma and contusion caused by temporary cavity stretch."[57] If a rifle bullet fragmented after it yawed or deformed, then "the permanent cavity would be severely enlarged because elastic tissue perforated by bullet fragments would be severely disrupted by a large temporary cavity and pieces of tissue become detached."[58]

The late nineteenth and early twentieth centuries saw the introduction of bolt action repeating rifles chambered for FMJ rounds of a smaller caliber and higher velocity compared to their predecessors. The FMJ rifle bullets were first of a round nose configuration but spitzer shaped bullets such as the US .30-06, British .303 Mk VII and German 7.92x57mm M98 were adopted within a decade. While these FMJ rounds were much faster than their predecessors, they were also less effective at incapacitating enemy combatants.[59] Uncomplicated tissue wounds

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[56] Ibid.
Martin L. Fackler, "Ballistic Injury," *Annals of Emergency Medicine* 15 (1986): 1454/113.

[57] Roberts, "Wound Ballistics Research and Consulting."
Hollerman et al, "Gunshot Wounds," 687.

[58] Martin L. Fackler, "Ballistic Injury," 1454/113.
When a modern rifle bullet breaks apart, the individual bullet fragments travel laterally away from the main wound track and "crush their own path through tissue." See Fackler, "Ballistic Injury," 1454/113.
Large caliber, low velocity rifle bullets from the nineteenth century, such as the.45-70 Government and 10.4mm Vetterli, expand but do not fragment in soft tissue. See Martin L. Fackler, "Gunshot Wound Review," Annals of Emergency Medicine 28 (1996): 196.

[59] Roberts, "Wounding Effects of Military Small Arms during the Past Century," 3, 4.
The Chitral campaign of 1895 demonstrated the poor incapacitation potential of the .303 caliber Mk II round nosed FMJ bullet. Dum-Dum Arsenal designed a Jacketed Soft Point (JSP) bullet by eliminating 1mm of jacket from the Mk II projectile's tip to improve the bullet's terminal performance and this .303 JSP was employed during the Tirah campaign of 1897-98. The British at Woolwich Arsenal developed the .303 caliber Mk III, IV and V Jacketed Hollow Point (JHP) bullets and these .303 JHPs succeeded the Mk II in British service. The .303 Mk III, IV and V JHPs demonstrated moderate deformation and better terminal performance than the Mk II FMJ. Dr. Gary Roberts explained that: "anti-British sentiment led to the Hague Declaration, where signatories agreed 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.'" See Roberts, "Wounding Effects of Military Small Arms during the Past Century," 4, 5.
But the rear end of most modern military FMJ projectiles are not covered by the bullet's jacket, which is contrary to the Hague Declaration's wording that the entire bullet core needs to be enclosed by the jacket. Also, many of the FMJ rounds that are used by armed forces will "fragment and/or flatten" when striking tissue at shorter distances. The Hague Convention did not ban "bullets that yaw and fragment but all bullets which fragment must first deform, flatten and expand prior to fragmenting and bullet fragmentation is hyper-expansion." This showed that most FMJ

caused by round nosed FMJ bullets were minimal because they penetrated around 61 cm through tissue without yawing or expanding (See Figure 3).[60]

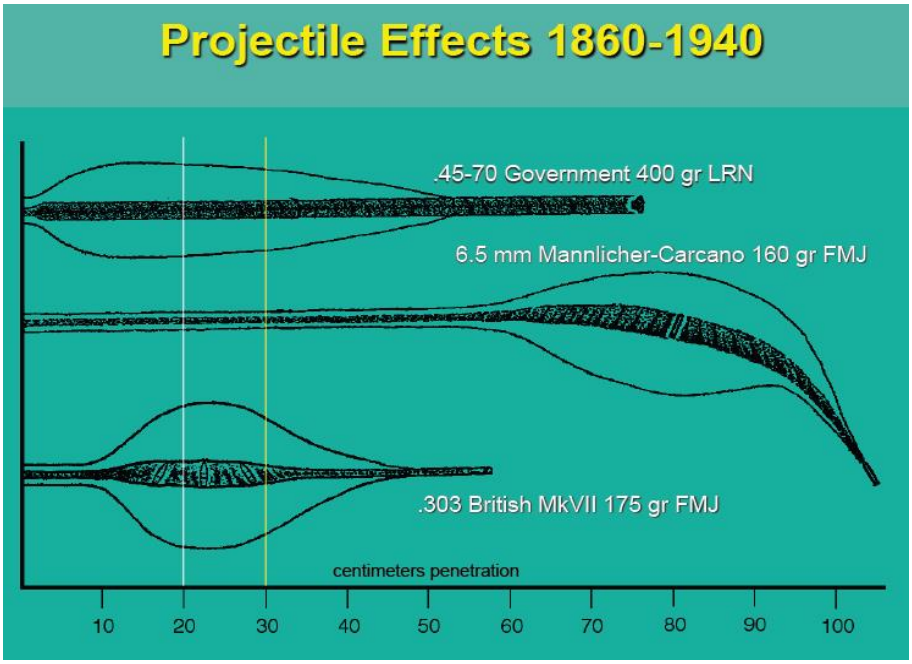

Figure 3: Wound Profiles for 19th Century and early twentieth century rifle bullets.

These wound profiles show the permanent and temporary cavities produced by the US .45-70 (19th century large caliber low velocity rifle bullet), Italian 6.5mm (round nosed FMJ rifle bullet) and UK .303 Mk VII (spitzer shaped FMJ full power rifle bullet). The .303 Mk VII FMJ replaced the .303 JHPs, had earlier yaw than several other spitzer shaped FMJ rifle bullets of its period and actually disrupted more tissue than the Mk III, IV and V JHP bullets.
Source: Gary K. Roberts, "Wounding Effects of Military Small Arms during the Past Century" (Unpublished material)."

The above mentioned spitzer shaped FMJ rifle bullets increased the range of rifles to around 1000 yards under ideal circumstances and also yawed earlier in tissue than their round nosed

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bullets designs actually violated the Hague Convention's wording on the restriction of deforming bullets. Dr. Roberts believed that it is dishonest to assume conformity to the Hague Convention because the above evidence clearly demonstrated that states do not actually abide by the Hague Convention's wording on rifle bullets. See Roberts, "Wounding Effects of Military Small Arms during the Past Century,"5, 10, 11.

[60] Ibid," 4.

Martin L. Fackler, "Gunshot Wound Review," *Annals of Emergency Medicine* 28 (1996): 195.
Uncomplicated wounds refer to those where the bullet does not strike bone or large vessels. See Martin L. Fackler, "Wounding patterns of military rifle bullets," *International Defense Review,* January 1989, 60.
For all wound profiles, the 20cm line denotes the approximate thickness of an average human chest while the 30cm line denotes the minimum distance that a bullet needs to penetrate through tissue in order to reliably reach the vital organs and blood vessels. See MAJ Thomas P. Ehrhart, "Increasing Small Arms Lethality in Afghanistan: Taking back the Infantry Half-Kilometer" (Monograph, Fort Leavenworth: Command and General Staff College, 2009), 30 and Roberts, "Wound Ballistics Research and Consulting."

predecessors. (See Figures 3 and 5).[61] Rifle cartridges, such as the .30-06, .303, 7.92x57mm and Russian 7.62x54R, produced fairly high muzzle energies and were known as full power rifle cartridges.[62] The bolt action rifle allowed soldiers to fire faster compared to older breach loading or single shot rifles because they had a magazine capacity of three to ten rounds; by manually operating the bolt, a soldier could load a round into the chamber every few seconds.[63]

Whereas rifles were originally used to engage large troop formations at long ranges, advances in artillery and communications along with the invention of the machine gun led to the eventual abandonment of such a practice in battle.[64] Due to their experiences during the First World War, the Germans invented the Blitzkrieg, which used motorized infantry and tank forces supported by artillery and airpower to fight "a battle of encirclement and annihilation."[65] Armoured vehicles carried soldiers into proximity with the enemy in order to minimize losses inflicted by machine guns and prevent the enemy from using their artillery due to friendly fire concerns. As a result, the Blitzkrieg changed the range and types of engagements for infantryman, who often had to engage fleeting targets at shorter distances.[66] Due to such changes in warfare, a higher rate of fire was needed for all types of small arms and engagement ranges for individual weapons often did not exceed 350m.[67]

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[61] Roberts, "Wounding Effects of Military Small Arms during the Past Century, 4.
Larry H. Addington, *The Patterns of War since the Eighteenth Century* (Bloomington: University of Indiana Press, 1984), 103.

[62] Maxim Popenker and Anthony G. Williams, *Assault Rifle: The Development of the Modern Military Rifle and its Ammunition* (Ramsbury: The Crowood Press Ltd, 2005), 52.

[63] Addington, *The Patterns of War since the Eighteenth Century*, 103.

[64] Mark Westrom, "Technical Note 108: Rapid Semiautomatic Fire and the Assault Rifle" (Technical Note, Armalite, Inc, 2013), 7.

[65] Addington, *The Patterns of War since the Eighteenth*, 179.

[66] Ezell, *Small Arms of the World*, 11th ed., 17.

[67] Westrom, "Technical Note 108," 7.

During the beginning of the Second World War, all other militaries except for the US were still equipped mostly with bolt action rifles, which did not have a sufficient rate of fire for the type of fighting encountered in that conflict. The standard US service rifle of the period was the semi-automatic M1, which had a significant advantage over bolt action rifles (See Figure 4).[68]

Figure 4: M1 semi-automatic rifle.

Source: "M1 Garand (USA)," accessed October 20, 2015, http://world.guns.ru/rifle/autoloading-rifles/usa/m1-garand-e.html.

Lieutenant Colonel John George, who fought in the Pacific Theatre, explained that the M1 allowed soldiers to "fire several shots in rapid succession, trebling the effectiveness of his fire against briefly exposed or fleeting targets, which are the most common types encountered in combat."[69] But the M1 rifle had a limited clip capacity of eight rounds and even the M1 rifle's rate of fire was insufficient in some circumstances and more rapid fire was required.[70] Accordingly, SMGs, which were capable of automatic fire, complemented rifles in some infantry squads for close-in fighting such as trench clearing. The SMG was chambered for a pistol cartridge and was ineffective beyond 50-100m.[71] The limitations of SMGs became evident when Red Army units armed solely with SMGs were unsuccessful against German units armed with a combination of rifles and SMGs in some types of terrain.[72] Also, pistol cartridges had poorer

[68] The M1 rifle fired full power .30-06 rifle ammunition.
[69] MAJ Bruce F. Kay, "An Analysis of the Infantry's Need for an Assault Submachine Gun" (Masters Thesis, Fort Leavenworth: Command and General Staff College, 1977), 20.
[70] Ibid, 21.
[71] Ezell, *Small Arms of the World*, 11th ed., 16.
[72] MAJ Thomas P. Ehrhart, "Increasing Small Arms Lethality in Afghanistan: Taking back the Infantry Half-Kilometer" (Monograph, Fort Leavenworth: Command and General Staff College, 2009), 11.

terminal performance compared to rifle rounds that yawed in tissue or struck bone (See Figure 5). If a rifle round hits bone, "comminuted fractures may be created and bone fragments will act as secondary missiles," leading to a more serious wound but pistol bullets cannot "fragment bone significantly."[73] Unlike rifle bullets that yawed in tissue, "the temporary cavities created by pistol rounds were too small to be a significant wounding factor."[74] Thus, with small arms available at the time, a combinations of niche weapons in different calibers were needed for a squad to be tactically effective in all circumstances.[75]

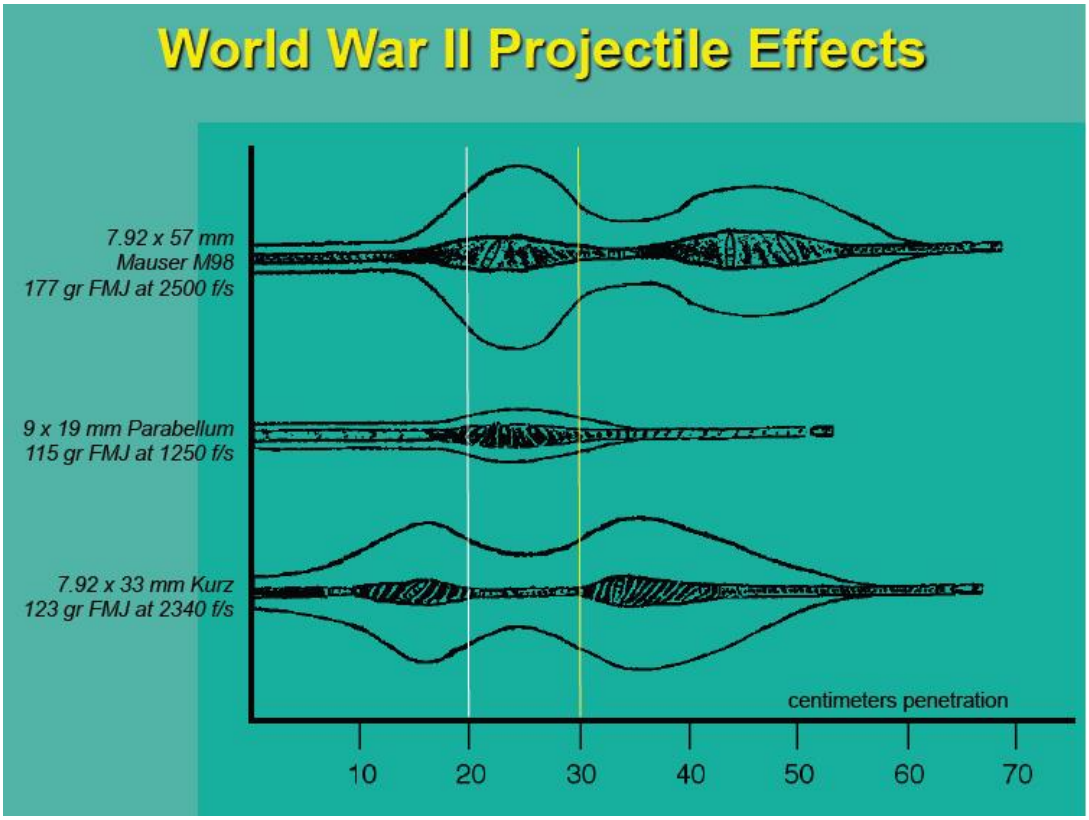

Figure 5: Wound Profiles for the Second World War small arms bullets.

The German 7.92x57mm FMJ is a full power rifle cartridge, the 9mm FMJ is a pistol and SMG cartridge and the 7.92x33mm FMJ is an intermediate rifle cartridge.
Source: Roberts, "Wounding Effects of Military Small Arms during the Past Century."

[73] Hollerman et al, "Gunshot Wounds,"686.
[74] Ibid, 687.
[75] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 11.

Aside from the previously mentioned problems from having the various calibers in the squad that included ammunition supply issues, the use of niche weapons also increased the training and wider logistics burden. The niche weapons that Allied armies were equipped with included rifles, SMGs, automatic rifles, LMGs and MMGs. As parts commonality was absent among those niche weapons, a wide variety of spare parts had to be stocked and transported.[76] Also, various niche weapons often required different weapons manipulation techniques and additional skills for effective employment. Lieutenant Colonel Roy Rayle of the US Ordnance Department explained that during the Second World War, troops needed to be familiar with the different operating mechanisms of four types of small arms, which were the Browning Automatic Rifle (BAR), M1 rifle, M1 carbine and SMGs.[77] For example, although all infantry soldiers had previous training on the BAR, if the automatic rifleman was killed in combat, a day or two was needed for another squad member to relearn the skills need to operate the BAR.[78] Rayle explained that the BAR's gas system "required adjusting the power level for proper function and a soldier's life may be lost if his weapon failed to fire due to improper adjustment."[79] In addition, a post-war study by the Belgian small arms firm FN Herstal (FNH) explained that an infantry solider should be proficient with multiple niche weapons but "the short

[76] Ezell, *Small Arms of the World*, 11th ed., 17.

[77] The M1 carbine was not chambered for the.30-06 full power rifle cartridge, used a different gas system than the M1 rifle and was not a variant of the M1 rifle. The M1 carbine was a semi-automatic personal defense weapon that was chambered for the .30 carbine cartridge and had a fifteen round magazine. The .30 carbine cartridge used a round nosed 110 grain FMJ bullet, had a muzzle velocity of 1950 feet per second and a longer effective range than pistol caliber SMGs. The US military adopted the M1 carbine as a replacement for some M1911 handguns but M1 carbines have been employed by soldiers during assaults and in environments where engagements occurred at shorter ranges. See Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 10, 14.

[78] Roy E. Rayle, *Random Shots: Episodes in the Life of a Weapons Developer* (Bennington: Merriam Press, 1996), 73, 74.

[79] Ibid.

time available before soldiers are sent into battle precludes anything but superficial knowledge being acquired."[80]

Due to the disadvantages of having multiple types of weapons, the GPMG and the assault rifle were developed in an attempt to reduce the number of niche weapons and calibers in infantry units. The Germans first started manufacturing the MG34 GPMG, which could function as a LMG when equipped with a bipod and as a MMG when mounted on a tripod.[81] But the MG34 was expensive and time consuming to manufacture because of its extensive use of machined parts and the MG42 GPMG, which used sheet steel stampings, was introduced as an intended replacement for the MG34 (See Figure 6). Production of the MG42 significantly increased output by 1943 and exceeded US machine gun production in 1944.[82]

Figure 6: MG42 configured as a LMG (left) and MMG (right) respectively.

Source: "MG 42 and MG 3 machine gun (Germany)," accessed October 20, 2015, http://world.guns.ru/machine/de/mg-42-and-mg-3-e.html.

However, the MG34 was manufactured alongside the MG42 until the war's end because Germany "lacked the time and resources" to modify their tank mounts for the MG42.[83] The

[80] Stevens, *UK and Commonwealth FALs*, 25.
[81] Maxim Popenker and Anthony G. Williams, *Machine Gun: The Development of the Machine Gun from the Nineteenth Century to the Present Day* (Ramsbury: The Crowood Press Ltd, 2008), 187.
[82] Dunn, *The Soviet Economy and the Red Army*, 105, 106.
In 1942 and 1943, the Germans manufactured 92,400 and 169,200 machine guns respectively. US machine gun production reached its height in 1943 and had an output of 297,600 machine guns. In 1944, the US slowed down production and manufactured 254,400 machine guns while the Germans manufactured 290,400 machine guns. See Dunn, *The Soviet Economy and the Red Army*, 105.
[83] Popenker and Williams, *Machine Gun*, 188.

GPMG offered logistical and training advantages over using separate LMG and MMG models but the introduction of the MG42 in wartime prevented the use of a single type of GPMG.[84]

Likewise, the disadvantages of the SMG and rifle led the Germans to develop the StG 44 assault rifle, which was a select-fire weapon chambered for an intermediate rifle cartridge and fed from a thirty round magazine, during the later stages of the war.[85] Although the StG 44's 7.92x33mm ammunition had a shorter effective range than full power rifle cartridges, it was sufficient at common combat distances around 300m and "produced similar wounds compared to full power rifle cartridges" (See Figure 5).[86] Also, the lighter recoil and weight of the 7.92x33mm allowed a higher rate of semi-automatic fire compared to the M1 rifle, controllable automatic fire and an increased combat load over full power rifle ammunition. As a result, the StG44 could replace both the rifle and SMG, had better terminal performance and range compared to SMGs and could deliver a higher volume of fire for short periods compared to rifles.[87] Also, the StG44 used a stamped metal receiver with a large trunnion made from machined steel and was more efficient to produce compared to the Mauser K98K bolt action rifle, which used a machined steel receiver.[88] If an assault rifle completely replaced SMGs and rifles that would have resulted in logistical advantages by reducing numbers of calibers and spare parts. However, Germany's inability to properly utilize their resources and production potential, the disruption caused by Allied strategic bombings and ground offensives along with many

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[84] Erenfeicht, "Sturmgewehr," 3.

[85] Select fire means being capable of both semi-automatic and automatic fire. An intermediate cartridge has less energy than a full power rifle cartridge but more than that of a pistol cartridge. See Ezell, *Small Arms of the World*, 11th ed., 333).

[86] Roberts, "Wounding Effects of Military Small Arms during the Past Century," 6.
Ezell, *Small Arms of the World*, 11th ed., 17, 333.

[87] Ibid.
Westrom, "Technical Note 108," 7, 18.

[88] Dugelby, *EM-2 Concept & Design*, 4, 5.
Erenfeicht, "Sturmgewehr," 2.

German firms' lack of sophisticated tooling for StG44 production meant that stocks of assault rifles were inadequate to replace all SMGs and rifles in German service.[89] The advantages of the StG 44 led to the development of new assault rifles and intermediate rifle ammunition by the British, Belgians and Spanish in the early post-war era. But American insistence on full power rifle cartridges would lead NATO to standardize a new full power rifle cartridge rather than take advantage of intermediate cartridges.

[89] Ibid.
Dunn, *The Soviet Economy and the Red Army*, 105, 241.
Ezell, *Small Arms of the World*, 11th ed., 17.

Chapter 2: NATO Ammunition and Weapons Standardization in the Post-War Era

2.1 NATO Weapons Standardization Trends

During the early 1950s, NATO had achieved standardization with several types of weapons because most of Europe's indigenous defence manufacturing capabilities were weakened as a result of the Second World War. As a result, US weapons were prevalent in NATO militaries during this period because NATO members received excess American military equipment through the Mutual Defense Assistance Act of 1949 and the Mutual Security Acts at the beginning of the 1950s.[90] The lack of standardization in other types of weapons became a problem for NATO starting in the late 1950s as European industry recovered and introduced its own weapons designs.[91] Kapstein argued that states with sufficient economic capability and the means to produce their own weapons would always choose to do so if other factors were the same.[92] States that choose to enter into co-production or licensing agreements want to retain their own weapons manufacturing industries but "want to share financial and technical risks of weapons development with alliance partners."[93] Kapstein believed that dependence on imports for defense related products was the least attractive option for states even though it had financial advantages.[94] Most Western European countries chose to maintain indigenous weapons industries because of nationalism, profits from sales to foreign states and preference for weapons that best met their own doctrine and needs. [95]

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[90] Taylor, "Weapons Standardization in NATO," 99.
[91] Jan Feldman, "Collaborative production of defense equipment within NATO," *Journal of Strategic Studies* 7(1984):285.
[92] Ethan Barnaby Kapstein, "International Collaboration in Armaments Production: A Second-Best Solution," *Political Science Quarterly* 106 (1991-92): 659, 660.
[93] Ibid.
[94] Ibid.
[95] Swadesh Rana, "Problems of U.S. European Co-Production in Arms," *Strategic Analysis* 3 (1979): 272. Hurley, "Arms for the alliance,"379.

In contrast to other weapons in the early 1950s, NATO was unsuccessful in the standardization of a single rifle for the alliance during that period. Since the 1950s, NATO has desired the standardization of a common rifle for all of the alliance's military forces. The advantages of having a common NATO rifle are that it allows the same manual of arms, training, spare parts and tooling for all NATO militaries.[96] Also, NATO militaries equipped with the same rifles could potentially have access to all NATO depots for high echelon weapon repairs.[97] If all alliance members had used the same weapons, then all NATO forces would likely have common supply lines for ammunition and spare parts.[98] Rifle development in NATO "was funded and executed at the national level" and unlike other weapons, several European states had existing small arms industries during the early post-war era.[99] Similar to other fields of weaponry, nationalism, differing military requirements and the desire to maintain domestic industries led to the failure to standardize on a common rifle for all of NATO.

2.2 US and British Post-War Rifle Cartridge Developments

Lessons learned during the Second World War regarding logistical problems caused by the various calibers of ammunition used by the Allies led to incentives for ammunition standardization within NATO. But different requirements between the US and UK in ammunition design almost prevented ammunition standardization from occurring. After the Second World War, the Americans attempted to design a new rifle and cartridge that could replace several of their Second World War infantry weapons. Colonel Rene Studler, who headed

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[96] Stevens, *UK and Commonwealth FALs*, 35.
Jim Schatz, "Strategic Tripartite. Historic Opportunities for US and NATO Ground Combatants" (presented at the National Defense Industrial Association Conference, Dallas, Texas, May 17-20, 2010, http://www.dtic.mil/ndia/2010armament/WednesdayLandmarkBJimSchatz.pdf), 20.

[97] Ibid.

[98] Eliot Cohen, "NATO Standardization: The Perils of Common Sense," *Foreign Policy* 31 (1978): 75.

[99] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 20, 2015.

the US Ordnance Department's small arms division until 1953, believed that intermediate rifle cartridges were advantageous from a production standpoint because they required less material to manufacture compared to existing full power rifle cartridges. But Studler and many US Army personnel were against the adoption of an intermediate cartridge because they believed a cartridge with a decrease in caliber and external ballistics would be less effective than the .30-06 full power rifle cartridge.[100] Also, the Americans believed that only a full power rifle cartridge could be used in both rifles and GPMGs. While rifle ammunition and belted ammunition of the same caliber were considered different types of ammunition during manufacture and transport, one could delink belted ammunition to use in rifles and vice versa in an emergency.[101]

Accordingly, in the 1950s, the US developed the T65 7.62mm cartridge, which had a shorter case than the US .30-06 cartridge and was a shortened full power rifle cartridge, rather than an intermediate cartridge. The use of ball powder in the T65 cartridge allowed it to match the same external ballistics of the .30-06 with less case volume, which made it more efficient to produce compared to its predecessor.[102] The US wanted a select fire rifle designed around the T65 that could replace the M1 rifle, M1 carbine, the BAR, submachine guns and sniper rifles. While the T65 cartridge was effective for GPMG use, the full power cartridge had excessive recoil during automatic fire from a relatively lightweight multi-purpose rifle.[103] This showed that many US military members preferred a shorter full power rifle cartridge that was more efficient to manufacture than the .30-06 while ignoring the advantages of reduced recoil and weight of intermediate cartridges.

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[100] Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967", 15, 16. Stevens, *North American FALs*, 4, 35.
[101] McNaugher, *The M16 Controversies*, 23, 30.
[102] Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967", 10. Ezell, "The Search for A Lightweight Rifle," 99, 100.
[103] Ibid, 121.

In contrast to the Americans, the British applied the lessons they learned during the Second World War to design an intermediate cartridge. In 1945, the UK Ministry of Supply established the Small Arms Ideal Calibre Panel, whose mission was to design the ideal rifle cartridge. The British wanted a lightweight rifle cartridge with less recoil than a full power rifle round, controllable automatic fire and a maximum range of 600 yards because they believed that most engagements with small arms did not exceed 300 yards.[104] Also, the British did not require GPMGs and rifles to have a common caliber. Dr. Richard Beeching conducted research for the Ideal Caliber Panel and came to the conclusion that the optimal rifle caliber was .270 inches.[105] After meeting with the US Ordnance Department, the British "increased the projectile diameter to .284 inches" to improve performance at extended ranges. This new British intermediate cartridge became known as the .280.[106]

After coming to the conclusion that the .280 was the ideal intermediate cartridge, the Royal Small Arms Factory (RSAF) Enfield and FNH were tasked with designing rifles in that caliber. RSAF Enfield designed the EM-1 and EM-2 bullpup rifles but the development of the former was cancelled (See Figure 7). Enfield encountered problems with the EM-1's stamped steel receiver because post-war British stamping technology was less advanced than that of Nazi Germany.[107]

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[104] McNaugher, *The M16 Controversies*, 37.
Stevens, *North American FALs*, 5.
Ezell, *The Great Rifle Controversy*, 89.
[105] Ibid.
[106] Ibid.
Popenker and Williams, *Assault Rifle*, 54.
[107] Steve Raw, *The Last Enfield*: *SA80-The Reluctant Rifle* (Cobourg: Collector Grade Publications, 2003), 7.
Author Telephone Interview with R. Blake Stevens, March 3, 2015.

Figure 7: EM-2 assault rifle in .280 caliber.

Source: "Enfield EM-2/ Rifle, Automatic, caliber .280, Number 9 Mark 1 (Great Britain)," accessed October 20, 2015, http://world.guns.ru/assault/brit/enfield-em-2-e.html.

The British Armament Design Establishment (ADE) favoured FN's Type 1 carbine and awarded FN a contract to manufacture the Type 1 carbine in .280 caliber, which became known as the FAL rifle, for further evaluation (See Figure 8). Both the EM-2 and FAL were assault rifles and had the design goal of replacing both existing service rifles and SMGs.[108]

Figure 8: FN FAL chambered for .280 British Cartridge.

Source: "FN FAL automatic rifle (Belgium)," accessed October 20, 2015, http://world.guns.ru/assault/be/fn-fal-e.html.

2.3 Rifle and Ammunition Standardization Efforts

After NATO's creation in 1949, the anticipated problems of eleven NATO armies using eleven different rifles and ammunition of various calibers made weapons and ammunition standardization a priority. In 1950, the British wanted the US to conduct tests in order to select a rifle and ammunition candidate for NATO standardization.[109] Although the Korean War was still ongoing, in 1951, the defense ministers of Canada, UK, France and the US concluded "that any

[108] Stevens, *UK and Commonwealth FALs*, 28, 41.
Dugelby, *EM-2 Concept & Design*, 27.
[109] Stevens, *North American FALs*, 7, 35.

decision on a round of small arms ammunition would not affect the immediate situation."[110] While it was beneficial to retain existing calibers during a large scale war, the conclusions of NATO's defense ministers suggested that NATO's eventual transition to a new caliber was feasible even while small wars took place.[111] Therefore, many major NATO states wanted the alliance to pursue the standardization of a common rifle and caliber in an attempt to avoid previous logistical problems caused by the lack of standardization.[112]

But conflicting requirements between the US and Enfield meant that weapons and ammunition standardization would require certain nations to compromise. In 1950, trials were conducted at Aberdeen Proving Ground (APG), which involved the US T25 rifle chambered for the T65 cartridge, the FN FAL and EM-2 and concluded that none of the candidates were mature.[113] Testers at APG were critical of the .280 cartridge because the "T65 had a flatter trajectory at extreme ranges and the .280's velocity was reduced significantly in extreme cold."[114] But the T65 cartridge was also seen as problematic due to excessive muzzle flash and smoke and "erratic pressures."[115] Also, many British officials hoped that the EM-2 rifle would become the common rifle of the British, American and Canadian militaries.[116] But the Americans disliked the EM-2 because its bullpup configuration prevented firing from the left shoulder, it had a "heavy irregular trigger pull" and malfunction clearance was more time consuming compared to a conventional design.[117] The Infantry Board at Fort Benning believed that the .280 caliber FAL was the overall best candidate and that the roles the T65 cartridge was expected to

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[110] Ezell, "Cracks in the Post-War Anglo-American Alliance," 140.
[111] Ibid.
[112] Arvidsson, "Weapons and Sensors," 3.
[113] Stevens, *North American FALs*, 7, 34.
[114] Ezell, *The Great Rifle Controversy*, 112, 113.
[115] Ibid.
[116] Stevens, *North American FALs*, 6.
[117] Ibid, 29, 30.
Rayle, *Random Shots*, 35.

perform were unrealistic.[118] The Infantry Board wanted to improve the trajectory of the .280 and the velocity of the .280 round was increased to 2550 feet per second (fps) in order to have a flatter trajectory and remedy the velocity loss problem in extreme cold.[119]

Although the Infantry Board favoured the .280 cartridge, Colonel Studler of the Ordnance Department, was staunchly opposed to anything less than a full power rifle cartridge and made a significant blunder in not accepting the .280 for US service.[120] Although the T65 cartridge had slightly superior penetration compared to the .280, the British intermediate cartridge still had acceptable penetration capability and the T65 was only needed to fulfill the Americans' penetration requirements for GPMG use.[121] However, Britain's experience in both World Wars highlighted that their .303 full power rifle cartridge was already sufficient for combat use in rifles, LMGs and MMGs.[122] Although the .280 intermediate cartridge had less muzzle energy than the .303, it actually outperformed its predecessor in terms of penetration because the .280's higher ballistic coefficient (BC) allowed it to retain more energy at distance compared to the .303.[123] More importantly, lower recoiling cartridges allowed soldiers to "fire faster and achieve more hits" compared to those using full power rifle rounds.[124] In modern warfare, soldiers often

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[118] Kern, "The Influence of organizational culture on the acquisition of the M16 Rifle," 36.

[119] Popenker and Williams, *Assault Rifle*, 54.
R. Blake Stevens and Jean E. Van Rutten, *The Metric FAL-The Free World's Right Arm* (Cobourg: Collector Grade Publications, 1981), 66

[120] R. Blake Stevens and Edward C. Ezell, *The Black Rifle: M16 Retrospective* (Cobourg: Collector Grade Publications, 2004), 4.
Gary K. Roberts, "Time for a Change: U.S. Military Small Arms Ammunition Failures and Solutions (presented at the National Defense Association Conference, Dallas, Texas, May 19-22, 2008, http://www.dtic.mil/ndia/2008Intl/Roberts.pdf), 5.

[121] McNaugher, *The M16 Controversies*, 38.

[122] W.H.B. Smith, *The Book of Rifles* (Harrisburg: Stackpole Co., 1963), 579.

[123] Ibid.
Ballistic Coefficient is "a factor that measures the aerodynamic drag of a projectile and therefore the rate at which it loses its velocity; the higher the number, the lower the drag." See Popenker and Williams, *Machine Gun*, 371.

[124] Westrom, "Technical Note 108," 8.
Rapid semi-automatic fire allows for more hits at common combat ranges because "as rapidity increases, a point is soon reached beyond which the percentage of hits decrease…but up to that point at which carelessness or hurry in aiming causes an excessive decrease in the percentages, the whole number of hits may increase." See Westrom, "Technical Note 108," 13.

needed to engage "unseen or briefly exposed targets and suspected enemy locations."[125] The milder recoil of the .280 allowed a higher rate of semi-automatic fire than the T65, and rapid semi-automatic fire was most effective against the above mentioned targets because "accuracy of fire and volume of fire were equally important."[126] Also, the .280 allowed controllable automatic fire from assault rifles at shorter distances and could effectively replace the SMG's capabilities.[127] In hindsight, the Americans should have adopted the .280 for rifle use and considered employing the T65 solely in GPMGs in the case that the .280 was unable to meet their requirements for machine gun use.

Despite the fact that Studler's preference for the T65 meant that NATO would not standardize the .280 cartridge, British Defence Minister Emanuel Shinwell declared the UK would adopt the EM-2 in April of 1951.[128] The British had conducted their own evaluations of the EM-2 and .280 caliber FAL, known as the Check-Technical Test. This evaluation showed that the EM-2 had a marginal advantage during a 6000 round endurance test but the FAL was superior in adverse conditions testing.[129] Also, the FAL had better accuracy when fired semi-automatically while the EM-2 had "unacceptable vertical spread."[130] The Check-Technical Test concluded that while neither the FAL nor the EM-2 was mature enough to be adopted and required further changes, the FAL was the overall better rifle.[131] During a War Office meeting in 1951, those in favour of adopting the EM-2 over the FAL outnumbered those against 9:1. The official justification on selecting the EM-2 over the FAL was that the EM-2's weight was lower,

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[125] Kenneth L. Evans and Joel D. Schendel, "Development of an Advanced Rifle Marksmanship Program of Instruction" (Alexandria: US Army Research Institute for the Behavioral and Social Sciences, 1984), 2.
[126] Ibid, 2, 24.
Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967", 13.
[127] W.H.B. Smith, *The Book of Rifles*, 580.
[128] Stevens, *North American FALs*, 35.
[129] Stevens, *UK and Commonwealth FALs*, 49, 52, 54.
[130] Ibid.
[131] Ibid, 55.

had a shorter overall length while retaining a longer barrel and was equipped with an optical sight. Also, a statement was made that the EM-2's problems highlighted in the Check-Technical Test would be remedied quickly.[132] The War Office's official reasoning for adopting the EM-2 prioritized the bullpup configuration's advantages while other factors were given less consideration. National pride influenced the decision to adopt a British designed rifle. For example, certain British officials favoured rifles designed by RSAF Enfield, which was closely associated with the British Army's small arms and an important part of the British military's "esprit de corps lay in the national origin of the weapon."[133] By August of 1951, the US "successfully maneuvered other nations such as France to support" the T65 cartridge but Shinwell refused to reverse his decision because he believed that the .280 caliber EM-2 was "the best rifle and ammunition" combination.[134] So the UK's adoption of the EM-2 is arguably a case of a nation with the capability to manufacture indigenously designed weapons selecting their domestic designs due to national pride.[135]

Shinwell's approval of the .280 caliber EM-2's adoption led to several concerns by other NATO allies and Conservative Party members in the UK. Canada was opposed to the UK's adoption of the EM-2 because they hoped that all NATO members would use standard calibers and also wanted to co-manufacture the 7.62mm FAL with Britain. Also, Canada rejected the EM-2 because the EM-2 was an expensive design which they had trouble manufacturing for previous evaluations.[136] When Churchill was re-elected as Britain's prime minister, he reversed

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[132] Ibid, 55, 57.
[133] Ezell, "Cracks in the Post-War Anglo-American Alliance," 138.
Raw, *The Last Enfield*, 1.
[134] Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967," 24, 25, 99.
Stevens, *UK and Commonwealth FALs*, 60.
[135] Kapstein, "International Collaboration in Armaments Production," 659.
[136] Stevens, *UK and Commonwealth FALs*, 77, 78.

Shinwell's decision to adopt the EM-2 due to his commitment to ammunition standardization and belief that collaboration with the US was needed to further unite the alliance.[137] As a result, the FAL and EM-2 rifles were converted to fire the T65 cartridge and entered in the 1952 trials at Fort Benning along with the American T25 and T44 rifles. The 1952 trials recommended further development of the FAL and T44 based on reliability and rejected the other candidates for adoption by the US.[138]

The lack of modern rifles in the British Army and Churchill's hope for weapons standardization led to the UK's decision to adopt the FAL as the L1A1 rifle in 1956.[139] The conversion of the EM-2 from the .280 to the T65 cartridge resulted in reliability problems because the rifle "was not designed to handle so powerful a cartridge."[140] Rayle explained that the British chose to abandon addressing the teething pains of the 7.62mm EM-2 because the process was costly. In the beginning of the 1950s, the British Army was still equipped with the obsolete bolt action Lee-Enfield rifle and the UK needed a modern semi-automatic rifle more urgently than the US; the available options were the FAL and T44 rifles.[141]Compared to costly efforts to rectify the 7.62mm EM-2's issues, the 7.62mm FALs could be manufactured in a shorter timeframe for evaluation by soldiers, were more easily made in volume and were twenty five percent less expensive to manufacture. [142] Due to British cooperation with FN during the FAL's development, FN allowed the British Crown to have unlimited domestic production of the

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[137] Ezell, "Cracks in the Post-War Anglo-American Alliance," 139, 140.
[138] Ezell, *The Great Rifle Controversy*, 114, 116, 117.
The T44 was chambered for the T65 cartridge and had a locking system based on that of the M1 rifle and had a magazine capacity of 20 rounds. See Ezell, *The Great Rifle Controversy*, 114.
[139] Stevens and Van Rutten, *The Metric FAL*, 217.
[140] Dugelby, *EM-2 Concept & Design*, 2.
[141] Rayle, *Random Shots*, 35, 36.
[142] Stevens, *UK and Commonwealth FALs*, 78.
Stevens and Van Rutten, *The Metric FAL*, 92.

FAL without a fee.[143] Thus, the developmental issues of the 7.62mm EM-2 led to British adoption of the FAL, a case in which a state that was unable to develop their own weapons in the required timeframe had to make co-production agreements with a foreign firm.[144]

Churchill's acceptance of the T65 cartridge in favour of the .280 showed that he wanted to avoid interoperability problems between British and NATO forces stemming from the use of non-standard ammunition. If the .280 caliber had remained in British service, other NATO militaries would have been unable to resupply British forces if needed and ammunition shortages in the UK would have led to significant problems.[145] Also, before France's withdrawal from NATO in 1966, the Canadian Brigade Group was "assigned as a unit within I British Corps" and relied on the British logistics system for ammunition.[146] If the British used .280 ammunition while their Canadian allies used NATO standard ammunition, the supply systems would have been strained. As a result, in 1953, the NATO member states "issued a joint announcement standardizing the US T65 cartridge as the 7.62x51mm NATO."[147]

2.4 7.62mm NATO Ammunition Standards

Standardization Agreement (STANAG) 2310 set the standards for 7.62mm NATO ammunition and the concomitant "Manual of Proof and Inspection (MOPI) detailed the testing to be conducted to ensure that ammunition met the requirements of STANAG 2310."[148] Several NATO states supplied the alliance with rifles and GPMGs to serve as NATO Nominated Weapons (NNWs), which "were used as reference when new ammunition designs were

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[143] Ibid, 217.
[144] Kapstein, "International Collaboration in Armaments Production," 659.
[145] Raw, *The Last Enfield*, 9.
[146] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015.
[147] Ezell, "Cracks in the Post-War Anglo-American Alliance," 141.
[148] Dominic Pellegrino and Charles "Tim" Kirkman, "NATO Small Arms Ammunition Interchangeability via Direct Evidence Testing (presented at the National Defense Industrial Association Conference, Indianapolis, Indiana, May 23-26, http://www.dtic.mil/ndia/2011smallarms/WednesdayInter12315Pellegrino.pdf), 11.

standardized."[149] Ammunition designs which had "passed standardized tests in NNWs as outlined in the STANAGs and MOPI were deemed NATO Qualified."[150] For example, the NATO Qualification Approval confirmed whether an ammunition design complied with the STANAG and MOPI.[151] Ammunition that had not been NATO Qualified could not be "guaranteed to properly chamber and fire in weapons or assumed to produce the expected performance or necessary level of safety required by the STANAG or MOPI."[152] However, STANAG 2310's technical performance specifications allowed different muzzle energies and projectile weights and there were only limits that the average chamber pressure could not exceed.[153] Variations in some of these specifications may have been necessary for designing different 7.62x51mm bullet configurations such as FMJ, Tracer and AP rounds.[154] But STANAG 2310's technical performance specifications did not require ammunition of the same bullet configuration to have the same technical characteristics and different NATO members were not required to manufacture the same FMJ, tracer and AP ammunition designs.[155] This showed that the STANAG "was an agreement of all parties and its standards were a compromise that represented the minimum needed."[156]

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[149] Stevens, *North American FALs*, 115.
Arvidsson, "Weapons and Sensors," 8.

[150] NATO Military Agency for Standardization, *AOP-6 (V) Vol. I: Catalogue of Ammunition* AOP-6 Volume 1 (March 2007).

[151] Pellegrino and Kirkman, "NATO Small Arms Ammunition Interchangeability via Direct Evidence Testing," 12.

[152] Ibid, 7.

[153] For example, STANAG 2310 stated "that the mean chamber pressure of any type of ammunition shall not exceed 50,000 PSI, the weights of all bullets shall be within the limits of 130 to 155 grains and the minimum muzzle energy from the standard proof barrel shall be 2150 foot-pounds." See NATO Military Agency for Standardization, *STANAG 2310*, 3d ed. (November 1976), C-2.

[154] NATO Military Agency for Standardization, *STANAG 2310-Small Arms Ammunition (7.62mm)*, 3d ed. (Brussels, November 1976), C-2.

[155] Stevens, *North American FALs*, 114, 115.
For example, American and Canadian manufactured 7.62mm NATO FMJ ammunition had more muzzle energy than that of British manufactured 7.62mm NATO FMJ rounds. See Stevens, *North American FALs*, 114).

[156] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015.

2.5 Churchill's Desire for a Common Anglo-American Rifle

Churchill had hoped that his concessions to the Americans on the issue of ammunition standardization would convince the US to adopt the FAL and allow the Anglo-American militaries to field a common rifle. There was a tacit arrangement that if NATO accepted the US T65 cartridge as NATO standard, the Americans would adopt the FAL rifle.[157] The Canadians accepted the FAL for service as the C1 rifle in 1956, which had parts interchangeability with the L1A1 and it was hoped that the US would follow their lead.[158] During the Second World War, the British needed more weapons than their industry could provide and often contracted American companies to "build weapons to British specifications."[159] If all three states would manufacture FAL rifles with a large degree of parts interchangeability, then the UK could make use of the US and Canada's industrial capability during wartime.[160] While the British adopted a common rifle with Canada, the US Ordnance Department's preference for its indigenous designs resulted in the adoption of the T44 as the US M14 rifle in 1957 (See Figure 9).[161]

Figure 9: M14 rifle.

Source: "M14 rifle/Mk. 14 Mod. 0 Enhanced Battle rifle (USA)," accessed October 20, 2015, http://world.guns.ru/assault/usa/m14-e.html.

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[157] Ezell, "Cracks in the Post-War Anglo-American Alliance," 141.

[158] Stevens, *North American FALs*, 111, 81.
Rayle, *Random Shots*, 42.

[159] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 19, 2015.

[160] Rayle, *Random Shots*, 42.
Stevens, *UK and Commonwealth FALs*, 78.
Production of the FAL in the UK and North America required "the conversion of Belgium first-angle projection drawings in the metric scale to inch standards and third-angle projections and selecting the tolerances to be used in terms of manufacturing on English system machine tools." See Stevens, *UK and Commonwealth FALs*, 65 and Rayle, *Random Shots*, 56.
As a consequence, some parts were not interchangeable between metric FALs adopted by the Belgians in 1954 and inch pattern C1 and L1A1. See Stevens, *North American FALs*, 1.

[161] Ezell, "Cracks in the Post-War Anglo-American Alliance," 141.

2.6 US Adoption of the M14

One of the reasons that the US chose to not adopt the FAL was because they wanted to maintain their own domestic industry. In the early 1950s, FN had agreed to only charge the Americans an assembly fee for the test guns and allowed US production of FALs free of licensing fees. But Leo Carten, from the Office of the Chief of Ordnance, was opposed to FN's proposal on the grounds that the offer was based on the condition that the US-made FALs were to be used by the American military only.[162] If a significant number of US-made FAL were to be provided to its allies, then the US "would become liable to payment of royalties and Carten believed that judging by America's past involvements, this could amount to a rather sizable bill."[163] In this case, the US would maintain its own domestic industries rather than rely on foreign designs due to financial considerations.

After the trials in 1953, the Infantry Board suggested the "adoption of the FAL as a limited procurement item and the suspension of further development on the T44."[164] Despite the Infantry Board's report, Army Headquarters decided to proceed with further modification of the T44 for trial in the Arctic, where the FAL had not been thoroughly evaluated. This suggested that Army leadership hoped that such modifications to T44 would make it a more obviously viable alternative to the FAL.[165] During this period, certain American organizations invoked nationalistic sentiments to oppose the idea of the US adopting the FAL and supported the indigenous T44. This was evident in the US Ordnance Association's writings in 1955, which stated that: "American genius in the gun-design field has not had a chance to be heard, nor have the production abilities of the American manufacturers been allowed to bring their forces into

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[162] Rayle, *Random Shots*, 36.
[163] Ibid.
[164] Ezell, "The Search for A Lightweight Rifle," 209.
[165] Ezell, *The Great Rifle Controversy*, 120, 124.

play… Our Army would do well to avoid a 'shoo-in' at all costs."[166] When further refinement of the FAL and T44 made both rifles suitable for adoption, the US chose to adopt the T44 as the M14 because the American design was "politically the best weapon."[167]

Aside from politics, the US Ordnance Department's preference for rifles based on previous models led to the rejection of significantly different designs and the adoption of the M14. For example, the US Ordnance Department terminated the development of the T28 rifle around 1950-1 due to technical issues with the T28's "sheet metal stock" and conflicting design philosophies.[168] The US favoured rifles with machined receivers designed to be used for long periods of training and then rebuilt for combat use while the T28 had a shorter service life but was less expensive to manufacture.[169] Indeed, Studler and Carten favoured a new rifle based on the M1 due to the belief that "such a weapon could be produced on existing M1 tooling or a modified version of that equipment."[170] Such requirements were the reason for development of the T44 and its adoption as the M14 because the Americans thought the M14 could be made on "existing M1 production tooling while the FAL required costly outlays for entirely new production equipment."[171] However, the M14 could not be efficiently manufactured on "M1 tooling because the design of the M14 was just different enough that the use of the older equipment guaranteed production headaches" and it was more cost efficient to produce M14s on new machinery.[172] Thus, the M14 was selected over the FAL in practice primarily due to

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[166] Ezell, "Cracks in the Post-War Anglo-American Alliance," 141.
[167] Ibid.
[168] Ezell, Search For Lightweight Rifles, 123, 433.
Rayle, *Random Shots,* 18.
The T28 was based on the German StG 45(M) prototype assault rifle of the Second World War and made extensive use of sheet steel stampings. See Rayle, *Random Shots,* 18.
[169] Ezell, "The Search for A Lightweight Rifle," 431.
[170] Ibid, 135.
[171] Ezell, *The Great Rifle Controversy*, 135.
[172] Ibid, 157, 158.

financial considerations, nationalistic sentiments and the belief that US Ordnance's design criteria best suited the US Army's requirements.

The M14 had several disadvantages compared to competing Western designs, some of which were carried over from the M1 rifle. The M14 had similar ergonomics compared to the M1 rifle, which were poorer than those of the FAL.[173] The M14 was expensive to manufacture because the receivers of the M1 and M14 were fabricated from machined steel and their "geometries were more complex than that of other US small arms."[174] M14s made by Harrington and Richardson in 1960 experienced problems with the receiver because the 1959 steel strike led to availability and cost issues with the required steel and "the substitute steel became overly hard and brittle when heat treated."[175] Factors that negatively affected the accuracy of both the M1 and M14 included "loose gas cylinder and lack of tension between the stock ferrule and lower band."[176] Also, the standard M14's "accuracy standard was a 5.6 inch group at 100 yards," which was similar to those of the Soviet AK-47 and AKM assault rifles and unmodified M14s did not have superior accuracy compared to many of its competitors.[177] As well, APG discovered that in

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[173] Stevens and Van Rutten, *The Metric FAL*, 143.
During FN's demonstrations that compared the FAL and T44, troops were able to operate the FAL more quickly because the FAL's charging handle placement "on the left side of the gun allowed the shooter to keep his finger on the trigger at all times." See Stevens and Van Rutten, *The Metric FAL*, 143.
Also, the safety switch of the M14 is located close to the trigger and operating the safety puts the finger in close proximity to the trigger and increases the risk of a negligent discharge. See Mike Jones, "Slaying the Sacred Cow: Myth of the M14," *S.W.A.T.*, April 2010, 86.

[174] "Fulton Armory," accessed March 25, 2015, http://www.fulton-armory.com/m14-receiver-semi-automatic-fulton-armory.aspx.

[175] Ibid, 70.

[176] Email communication from Angus N. Norcross to author, July 6, 2015.
The M14's "gas cylinder and front band were frequently loose, there was a tendency for the cylinder plug to loosen during firing, there was a lack of positive relationship between barrel and stock and the M14's flash hider had a tendency to become misaligned." These factors led to accuracy issues with the M14. See R. Blake Stevens, *US Rifle: From John Garand to the M21* (Toronto: Collector Grade Publications, 1993), 232 and Jones, "Slaying the Sacred Cow," 86.

[177] Mike Jones, "Slaying the Sacred Cow: Myth of the M14," *S.W.A.T.*, April 2010, 84.
The M14s tested by the Infantry Board in 1958 produced a maximum spread of 18.60 inches with three ten-round groups at 300 yards using 7.62mm NATO M59 FMJ ammunition. This maximum spread is around 6 inches at 100 yards and showed that many unmodified M14s did not shoot accurate groups. See United States Army Infantry

terms of accuracy, the "M14 was more sensitive to variations in ammunition" than the Canadian C1 and West German G3 service rifles.[178] L.F. Moore of APG explained that "the C1 and G3 rifles followed very well a predicable formula when firing lots of ammunition with varying dispersion characteristics. The M14 rifle appear to have the characteristic of magnifying the dispersion due to the ammunition…the increase in dispersion with an increase in ammunition error is not consistent, but it increases as the quality of the rifle decreases."[179] Therefore, the desire for a rifle design based on the M1 resulted in a weapon with many less than ideal characteristics and the M14 had disadvantages compared to competing designs.

2.7 Spanish and German Post-War Rifle Developments

Unlike the Americans, the Spanish and Germans were not constrained by the same rifle design philosophies and their efforts resulted in West Germany's adoption of the G3 rifle. In 1949, the Spanish government assigned the task of designing an indigenous assault rifle to former Mauser engineers and German experts residing in their country. This led to the development of the CETME assault rifle chambered for a new 7.92x41mm intermediate cartridge and was based on the StG 45(M) assault rifle prototype of the Second World War (See Figure 10).[180] The StG 45(M) was developed due to German wartime conditions, which prioritized the fabrication of rifle receivers from steel stampings because stampings were less expensive and more common than steel billets.[181] Due to Allied strategic bombing, the Germans also wanted "fully interchangeable parts and subassemblies that could be assembled in

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Board, *Report of Project Nr 2787: Evaluation of Small Caliber High Velocity Rifles- Winchester* (Georgia: Fort Benning, 1958), 10.
Sweden obtained a license from Heckler and Koch of West Germany to manufacture the G3 rifle and Swedish made G3s generally shot 3 to 4 inch groups at 100m with Swedish military issue 7.62mm NATO FMJ ammunition. See Email communication from Per G. Arvidsson to author, May 26, 2015.

[178] R. Blake Stevens, *US Rifle: From John Garand to the M21* (Toronto: Collector Grade Publications, 1993), 232.

[179] Ibid.

[180] R. Blake Stevens, *Full Circle: A Treatise on Roller Locking* (Cobourg: Collector Grade Publications, 2006), 137.

[181] Jim Schatz, email message to author, April 21, 2015.

decentralized production facilities by relatively unskilled workers."[182] Compared to the StG 44, the StG 45(M) used less machined steel and reduced the amount of "materials used and assembly time" by half.[183] The Germans believed that the shorter life of stamped rifle receivers was sufficient for high intensity warfare because the high attrition rates for materiel prioritized the need for inexpensive weapons.[184] Likewise, the major philosophy behind the CETME's design was to minimize the use of "special machinery and talented specialists" and utilize common materials.[185]

Figure 10: StG 45(M) on the left and CETME on the right.

Source: "CETME A, B, Modelo 58, C Assault Rifles (Spain)," accessed October 20, 2015, http://world.guns.ru/assault/sp/cetme-mod-a-b-195-c-e.html.

Initial West German interest in the CETME was shown by the Border Guard (BGS) and after West Germany was allowed to rearm, the German Defense Department examined the possibility the CETME's adoption by the Bundeswehr. In 1954, the Spanish wanted the West Germans to license produce the CETME, and Heckler and Koch (HK) was chosen.[186] Although West Germany favoured an intermediate cartridge, the US required the CETME to be converted to 7.62mm NATO.[187] But the BGS decided to procure the FAL because the CETME's conversion to 7.62mm NATO required significant changes while the FAL was already

[182] Ibid.
[183] Stevens, *Full Circle*, 57.
[184] Ezell, "The Search for A Lightweight Rifle," 432.
[185] Stevens, *Full Circle*, 145, 189.
[186] Ibid, 163, 164.
[187] W.H.B. Smith, *The Book of Rifles*, 578.

manufactured, which led to shorter wait times.[188] Likewise, the Bundeswehr procured FALs from FN starting in 1956, which were designated as the G1 in German service because the developmental issues with the FAL's conversion to 7.62mm NATO had been addressed. However, HK's modified 7.62mm CETME was adopted as the G3 in 1959 after the rifle passed the Bundeswehr's testing (See Figure 11).[189]

Figure 11: G3 Rifle.

Source: "The G3," accessed October 20, 2015, http://www.hkpro.com/index.php?option=com_content&view=article&id=87:the-grandfather-g3&catid=8:the-automatic-rifles&Itemid=5.

2.8 German and Norwegian Adoption of the G3

While the desire for an indigenously modified design was one reason behind the Bundeswehr's selection of the G3, advantageous production arrangements and economic advantages were important factors for the G3's adoption by Germany and Norway. The Germans favoured the G3 over the FAL despite the fact that the G3 had performance issues during the early trials because they preferred rifles modified and produced by their own domestic industry.[190] West Germany and FN were unable to work out an agreement for German licensed production of the FAL.[191] Instead, the "German government was able to acquire worldwide

[188] Stevens, *Full Circle*, 178, 183..
[189] Stevens, *Full Circle*, 178, 183, 244.
Other NATO states that adopted the G3 were Norway, Greece, Portugal and Turkey. See Stevens, *Full Circle*, 364, 384, 398.
[190] Author Telephone Interview with R. Blake Stevens, March 3, 2015.
[191] CAPT Robert Bopp, email message to author, March 2, 2015.

manufacturing rights to the G3," which allowed West Germany to re-establish its firearms industry and allowed foreign sales.[192]As well, the FAL had disadvantages from a manufacturing perspective because the Belgian rifle used a forged and milled steel receiver and took twenty-five hours to produce compared to the StG44's ten hours.[193] The G3's receiver was fabricated from alloy steel stampings, which made the G3 less expensive and easier to manufacture compared to competitors such as the FAL and M14.[194] For example, during the period when the G3 was in high demand around the world, HK was able to manufacture up to 2000 G3 rifles each day.[195] The advantages of domestic production and lower unit cost were major reasons that the Bundeswehr chose the G3 instead of the FAL.[196]Also, the finalists in the Norwegian military trials were the FAL and G3 rifles and both rifle candidates eventually met the level of reliability demanded by the Norwegian forces. But Norway selected the G3 over the FAL due to its lower unit cost, ease of manufacturing and the uncertainty that FN would grant a license and they were able to obtain a license from HK to manufacture the rifle as the AG3.[197] Therefore, the G3's adoption by West Germany and Norway showed that states would enter into advantageous production agreements rather than rely on foreign deliveries and cost effective rifles which met a military's requirements were advantageous from a procurement perspective.

2.9 Basic Comparison of the FAL and G3

Aside from the manufacturing advantages of the G3, the G3 and FAL had different strengths and weaknesses. In the Bundeswehr's experience, the G3 was less "dirt sensitive" than

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[192] Stevens, *Full Circle*, 234.
[193] Ibid, 209.
[194] Ibid, 221.
Email communication from Per G. Arvidsson to author, December 9, 2014.
[195] Jim Schatz, email message to author, April 21, 2015.
[196] CAPT Robert Bopp, email message to author, March 2, 2015.
[197] Ola Bøe-Hansen, email message to author, March 10, 2015.
Stevens, *Full Circle*, 375.

the G1 FAL variant and the "G1 had insufficient dirt tolerance."[198] In 1969, testers at APG believed the G3 would function in "adverse conditions because stoppages in automatic weapons were most likely to occur during a cycle that was slower or faster than average."[199] But "compared to other automatic weapons of the time, the variations that could be tolerated in the cycling of the G3 was extremely large."[200] Unlike previous guns with stamped receivers, the G3 could be rebuilt up to eight times, which meant the G3 could meet the US requirement for guns used extensively for training and then rebuilt for combat.[201] But the FAL had better ergonomics compared to the G3.[202] Another weakness of the G3 was that its "extractor had no limit on its movement within the bolt head which allowed the extractor spring to be bent well beyond its tolerances if an obstruction forced the extractor away from the center of the bolt face, which bent the spring beyond repair."[203] Once the extractor spring was bent, the G3 would experience continual failures to extract and eject until a new extractor spring was installed.[204] While both the FAL and G3 were NNWs,[205] the G3's roller delayed blowback operating system "needed a predetermined degree of recoil impulse to make the mechanism run reliably but that impulse

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[198] CAPT Robert Bopp, email message to author, March 2, 2015.

[199] Thomas E. Carlson and David A. Golm, *A Comparative Evaluation of the 7.62mm and 5.56mm, G-3 Assault Rifles* (Maryland: Aberdeen Proving Ground, 1969), 42, 43.

[200] Ibid.

[201] Email communication from Jim Schatz to author, February 25, 2015.
A rebuild of "the G3 could be done for about half the cost of a new weapon including new barrel. If the barrel holder was damaged this refurbish was not possible but that was a very rare thing." For more information, see Jim Schatz, email message to author, April 21, 2015.
The G3's barrel had to be changed at the factory because the procedure requires a press, which would not be available to battalion level armourers. See MAJ James Williamson (USMC), email message to author, April 23, 2015.

[202] Jones, "Slaying the Sacred Cow," 86.

[203] Jim Schatz, email message to author, April 21, 2015.
Jim Schatz explained that: [examples of an] "obstruction in the chamber and receiver area include a misfed round or an empty case that does not eject and then get crunched back in against the barrel face. If this case/round lines up just right, that obstruction forces the extractor away from the bolt face and the extractor spring is bent beyond repair/use. [The newer HK roller delayed blowback guns such as] the HK21E, G41 and MSG90 have extractors that have limits on extractor travel and coil springs to address this issue." See Jim Schatz, email message to author, April 21, 2015.

[204] Ibid.

[205] Email communication from Per G. Arvidsson to author, December 9, 2014.

changes with different ammunition types."[206] The "angles on the forward 'wedge' of the G3's locking piece" determined the time the rollers stay locked and different angled locking pieces were available for different ammunition pressures and barrel lengths.[207] As a result, the G3 needed to change locking pieces for optimal reliability with some types of NATO Qualified 7.62mm ammunition designs.[208] In contrast, the FAL's adjustable gas system allowed the rifle to function with a variety of ammunition designs when used on the proper gas setting.[209] In hindsight, if stricter standards had enabled the G3 to function optimally with all NATO Qualified ammunition designs without changing locking pieces, the G3 would likely have been the overall

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[206] Jim Schatz, email message to author, April 21, 2015.
In the G3, the "chamber pressure during firing overcomes the resistance of the bolt locking mechanism in the bolt and drives the bolt assembly out of battery and enough momentum is imparted to the bolt assembly during the blowback to drive the system through a complete cycle." For more information, see Carlson and Golm, *A Comparative Evaluation of the 7.62mm and 5.56mm, G-3 Assault Rifles*, 20.
The G3's bolt has two rollers that are locked to the trunnion recess. The rollers are supposed to remain locked when pressures are the highest, then slowly get squeezed into the bolt and enable the rearward travel of the bolt carrier. See "Identification of HK Locking Pieces," accessed March 20, 2015, http://www.hkpro.com/index.php?option=com_content&view=article&id=135:guide-to-hk-locking-pieces&catid=4:special-topics&Itemid=5.
[207] "Identification of HK Locking Pieces," accessed March 20, 2015, http://www.hkpro.com/index.php?option=com_content&view=article&id=135:guide-to-hk-locking-pieces&catid=4:special-topics&Itemid=5.
HK had around 80 different locking pieces for the G3 in order to optimize the rifle's performance for different barrel lengths and ammunition types. See Jim Schatz, email message to author, April 21, 2015.
Not all G3 users were NATO members and non-NATO states were not required to get their ammunition designs NATO Qualified.
[208] Email communication from Jim Schatz to author, February 25, 2015.
NATO Qualified 7.62x51mm ammunition designs from the Cold War to the 1990s included FMJ rounds from Belgium, Canada, France, West Germany, Italy, Norway, Spain, Portugal, the Netherlands, the UK and the US, tracer rounds from Canada, Belgium, the US, West Germany, France, Norway, Portugal and the Netherlands and an AP round from the Netherlands. See NATO Army Armaments Group, *NATO Design List* (July 2011), 1-2.
[209] Stevens, *North American FALs*, 116.
According to Canadian Lieutenant Colonel Townsend: "STANAG 2310 requires the mean chamber pressure to not exceed 50,000 PSI but omit saying anything about the spread of pressures. But nothing can be made without tolerances and some rounds may have an extreme spread up to 7000 PSI and therefore produce 57,000 PSI maximum chamber pressure. It was estimated that primers would probably stand about 50,000-55,000 PSI. The restrictive action of the barrel on the movement of the bullet influences pressure and if a bullet is allowed to go forward a short distance without being restrained and the engraving force kept to a minimum, the pressure will be kept down." See Stevens, *North American FALs*, 114, 115,
As a result, the C1A1 rifle was introduced and had slightly more generous barrel dimensions and a reduced firing pin tip diameter. These changes solved the original C1's problems with blown primers and also allowed the C1A1 to operate reliably with the ammunition designs of other NATO member states. See Stevens, *North American FALs*, 116.

best NATO rifle for high intensity warfare due to its low cost and having sufficient reliability for a design of its period.

While NATO was unsuccessful at standardizing on a common rifle for all of the alliance's military forces, several NATO states attempted to replace purpose-built niche weapons. In addition to the introduction of new rifles, many alliance members introduced new 7.62mm NATO caliber GPMGs into service. In 1957, the US adopted the domestically designed M60 GPMG, which replaced the .30-06 caliber Browning MMGs at the company level.[210] FNH's MAG-58 GPMG was adopted by the militaries of Belgium, Britain and Canada.[211] West Germany still had large stockpiles of MG42s from the Second World War and chose to adopt an improved 7.62mm NATO caliber version as the MG3.[212] The 7.62mm NATO caliber was adequate for the GPMG use but generated excessive recoil in rifles weighing around ten pounds, which meant that the FAL, M14 and G3 rifles were useless during automatic fire and could not replace SMGs.[213] Both the Canadians and Americans adopted automatic rifle variants of their respective service rifles, which were known as the C2 and M14E2 respectively (See Figure 12).[214] The C2 and M14E2 shared several common components with their respective service

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[210] Rayle, *Random Shots*, 111, 121.

[211] Popenker and Williams, *Machine Gun*, 125.

[212] Folke Myrvang, *German Universal Machine Guns, Volume II: From the MG08 to the MG3* (Cobourg: Collector Grade Publications, 2012), 805, 819.
One weakness of the MG42 was that it "was operating so fast that the bolt head/carrier would bounce back and cause 'out of battery detonations,' basically the gun was unlocked when it fired." However, "the Germans solved this problem with a spring loaded shock absorber installed in the carrier to dampen the bolt head/carrier's tendency to bounce out of battery" and this shock absorber was used in the MG3. See Cris E. Murray, email message to author, July 26, 2011.
In addition to the Bundeswehr, other NATO users of the MG3 included Denmark, Greece, Italy, Norway, Portugal, Spain and Turkey. See Popenker and Williams, *Machine Gun*, 125.

[213] McNaugher, *The M16* Controversies, 38.
Due to being uncontrollable during automatic fire, the standard M14 was equipped with a selector lock, which prevented automatic fire. For the same reason, the British and Canadians eliminated automatic fire capability from the L1A1 and C1/C1A1. See Ezell, "The Search for A Lightweight Rifle," 240.

[214] Notable differences between the C1 and C2 was that the latter had a heavy barrel and bipod. The M14E2 was equipped with a straight line buttstock, bipod, two pistol grips and a muzzle brake to improve controllability over the standard M14. Due to the lack of a heavier barrel, the M14E2 was not adequate for higher volumes of automatic fire. See Ezell, "The Search for A Lightweight Rifle," 244, 462.

rifles, which simplified the training required for weapons operation and logistics compared to previous niche weapons such as the BAR.[215] But both the C2 and M14E2 were still difficult to control during automatic fire due to their relatively light weight and were less effective compared to their predecessors.[216]

Figure 12: C2 automatic rifle (left) and M14E2 automatic rifle (right).

Sources: "FN FAL automatic rifle (Belgium)."
"M14 rifle/Mk. 14 Mod. 0 Enhanced Battle rifle (USA)."

During the early Cold War era, the US and its NATO allies understood the benefits of standardization within their alliance and the development of weapons that could replace several niche weapons. The goal of a common NATO rifle for all of the alliance's militaries was not fulfilled due to national preferences for domestically designed rifles, the benefits of preserving national industries and different requirements. Also, the most cost-effective design was available too late compared to the FAL and M14 as some NATO states such as the UK had an urgent need for a new rifle. NATO lost the opportunity to standardize on an effective intermediate cartridge due to the US preference for a full power rifle cartridge. The excessive recoil of such a cartridge prevented the replacement of several niche weapons by a single rifle family. America's importance in the NATO alliance ensured that the US candidate rather than the best cartridge

[215] Rayle, *Random Shots*, 74.
MAJ V. Sattler and CAPT Michael O'Leary, "Analysis of Modern Section Fighting Power," *Canadian Army Journal* 13 (2010): 36.
[216] Email communication from Corporal (retired) Jonathan Zyto to author, February 3, 2015.
MAJ James Williamson (USMC), email message to author, April 23, 2015.

was selected for standardization. Although ammunition standardization was mostly successful, the STANAGs were insufficient to ensure optimal reliability with all NATO Qualified ammunition designs for all rifles models in NATO service.

Chapter 3: US Development of the M16 and NATO Standardization of the SS109 Round

3.1 Alternatives to the 7.62mm NATO Cartridge

Despite the US Ordnance Department's preference for a full power rifle cartridge, studies done by the Operations Research Office (ORO) would explore the advantages of new intermediate cartridge designs and lead to the development of the M16 assault rifle.[217] The ORO was set up by the US Army "to formulate broad concepts that would increase the effectiveness of military operations" and they had completed an analysis of small arms in 1952.[218] ORO's studies argued that the distance where point targets were visible and that the range of engagements with rifles had commonly occurred at no more than 300 yards. [219] Also, ORO's study discovered that soldiers' hit probability (pH) with rifles "reached a low order at 300 yards and argued that a small arm design that produced "desirable dispersion patterns" would improve pH out to 300 yards.[220] In 1952, Donald Hall of the US Army's Ballistics Research Laboratory (BRL) had done a primarily abstract study which supported the use of .21 Small Caliber High Velocity (SCHV) intermediate cartridges for military rifle use.[221] SCHV rounds had significantly less recoil than

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[217] Ezell, *The Great Rifle Controversy*, 163.
[218] Ibid.
[219] Stevens and Ezell, *The Black Rifle*, 9.
[220] Ibid.
[221] Donald Hall argued that at identical impact velocities, the .220 round was almost as effective as the .30-06 M2 FMJ round because "the caliber .220 appeared to tumble in clay." Hall hypothesized that .220 caliber bullets with a higher impact velocity than .30 caliber bullets would create more "severe wounds" than the .30 caliber rounds. See Stevens and Ezell, *The Black Rifle*, 8.
But clay is not an appropriate "tissue simulant because it is inelastic, the cavities produced in clay remain in the position to which they were stretched by temporary cavitation and do not show the permanent cavity." See Martin L. Fackler and John A. Malinowski, "The Wound Profile: A Visual Method for Quantifying Gunshot Wounds Components," *The Journal of Trauma* 25 (1985): 524.
Also, military FMJ rifle projectiles rarely tumble and the phenomenon that Hall was referring to was likely bullet yaw. See W. Hays Parks, "SOST: A Way Forward in Contemporary Understanding of the 1899 Hague Declaration on Expanding Bullets," *Small Arms Defense Journal* 5 (2013):2, accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=2109.
More importantly, Hall's hypothesis was incorrect because "high velocity bullets did not invariably cause extensive damage" and SCHV bullets produced minimal tissue damage when they did not yaw, expand or fragment. If a larger bullet like a 7.62mm NATO and a SCHV bullet "both yawed and fragmented at the same depth of penetration," then the 7.62mm bullet would cause far more tissue damage than the SCHV projectile. See Martin L. Fackler, *Wound*

full power rifle cartridges, which would reduce dispersion during automatic fire.[222] ORO theorized that during automatic burst fire, SCHV rounds "might produce the necessary dispersion patterns" to "compensate for aiming errors" up to 300 yards and improve pH.[223]

Although the dispersion produced by SCHV intermediate cartridges during automatic fire was still too large to increase pH, their reduced recoil over 7.62mm NATO allowed more rapid semi-automatic and controllable automatic fire within 25 yards from the unsupported position.[224] Unlike the Ordnance Department, the Infantry Board preferred intermediate cartridges for the above mentioned advantages and they endorsed the SCHV concept because those low recoiling cartridges allowed the development of a lightweight assault rifle. [225] By 1957, the Continental Army Command (CONARC) supported the Infantry Board's stance on the SCHV concept because they believed that the SCHV rounds' reduction in weight and recoil over full power cartridges allowed an increase in the soldier's combat load and firepower. [226] CONARC consulted with two American commercial firearms firms, Armalite and Winchester, to develop SCHV assault rifles.[227] Armalite engineer Eugene Stoner had developed the lightweight aluminum alloy based AR-10 rifle in 7.62mm NATO caliber, which was preferred by the Infantry Board after the rifle was first exhibited at Fort Benning in 1955. But the Ordnance Department rejected the AR-10 because they were heavily invested in the M14 and the AR-10

Ballistics Research of the Past Twenty Years: A Giant Step Backwards (San Francisco: Letterman Army Institute of Research, 1990), 1, 4.

[222] Stevens and Ezell, *The Black Rifle*, 8, 9.

[223] Ezell, *The Great Rifle Controversy*, 168.
Norman Hitchman, *Operational Requirements for an Infantry Handheld Weapon* (Baltimore: Operations Research Office, 1952), 24, 25.

[224] Ibid.
Westrom, "Technical Note 108," 26.

[225] McNaugher, *The M16 Controversies*, 58, 59.

[226] Ibid.
Rayle, *Random Shots*, 96.

[227] Ezell, *The Great Rifle Controversy*, 172.

design was less mature than either the M14 or FAL.[228] In order to meet CONARC's criteria, Stoner's design team at Armalite developed the AR-15 assault rifle by scaling down the AR-10 to fire a 55 grain 5.56mm SCHV cartridge and this SCHV round would later become the M193 FMJ cartridge (See Figure 13).[229]

Figure 13: 5.56mm caliber AR-15 rifle.

Source: "Armalite/Colt AR-15/ M16 M16A1 M16A2 M16A3 M16A3 M16A4 assault rifle (USA)," accessed October 20, 2015, http://world.guns.ru/assault/usa/m16-m16a1-m16a2-m16a3-e.html.

Winchester designed a SCHV rifle based on the Second World War era M1 carbine but it was a poor competitor compared to the AR-15 and was discontinued.[230] In 1957, CONARC's commander General Willard Wyman wanted to postpone the US military's decision to manufacture the M14 so that the merits of SCHV rifles could be further analyzed. Unfortunately, the Ordnance Department and other US Army leaders opposed Wyman's recommendation because the 7.62x51mm cartridge was already standardized by NATO and the AR-15 could not be produced on the same tooling as the M1 rifle.[231]

3.2 US Procurement of AR-15 Rifles

Although the M14 was adopted as the standard US service rifle, American involvement in Vietnam led to renewed American interest in the AR-15. In 1961, the Advanced Research Projects Agency (ARPA) of the US Department of Defense chose to equip the South Vietnamese

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[228] Stevens and Ezell, *The Black Rifle*, 28, 30, 31.
[229] McNaugher, *The M16 Controversies*, 59.
Due to financial troubles, Armalite sold the AR-15 to the US firearms company Colt. See Stevens and Ezell, *The Black Rifle*, 81.
[230] Ezell, *The Great Rifle Controversy*, 172.
[231] McNaugher, *The M16 Controversies*, 60.

and their US advisors with AR-15s. ARPA believed that rifles with lower recoil were better suited for smaller Vietnamese soldiers compared to existing US weapons.[232] The AR-15 received positive feedback from its users in Vietnam and the new rifle's capabilities had impressed the Office of the Secretary of Defense (OSD). The OSD decided to conduct a study that analyzed factors such as rifle capabilities, costs and logistical factors. [233] This study was signed by Comptroller Charles Hitch and stated that:

> The AR-15 is decidedly superior in many of the factors considered. In none of them is the M14 superior… The report, therefore, concludes that in combat the AR-15 is the superior weapon. Furthermore, the available cost data indicate that it is also a cheaper weapon. Although analyzed less thoroughly, the M14 also appears to be somewhat inferior to the M1 rifle and decidedly inferior to the Soviet AK-47.[234]

In 1962, Secretary of Defense Robert McNamara "requested the opinion of his Secretary of the Army Cyrus Vance" regarding the M14, AR-15 and AK-47 and the measures that would be taken if the Army believed that the Hitch report's analysis was correct.[235] As a result, the US Army conducted an evaluation of the three rifles, which concluded that the AR-15 had several advantages over the M14 but the design needed to be further refined before it could be adopted.[236] During this period, the Ordnance Department had initiated work on the flechette firing Special Purpose Individual Weapon (SPIW) and they believed that the new weapon would provide a significant increase in pH, become operational in a few years and "render current weapons obsolete."[237] Vance stated that the Army would retain the M14 as their standard rifle,

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[232] Stevens and Ezell, *The Black Rifle*, 100.
[233] McNaugher, *The M16 Controversies*, 85.
[234] Stevens and Ezell, *The Black Rifle*, 109.
When manufactured in volume, gas operated rifles with forged aluminum receivers like the AR-15 "reduced the ease of production and unit cost even further" compared to roller delayed blowback rifles with stamped alloy steel receivers such as the G3. See Jim Schatz, email message to author, November 25, 2015.
[235] Stevens and Ezell, *The Black Rifle*, 110.
[236] Ibid, 116.
[237] Ibid, 117.

purchase AR-15s for their Air Assault, Airborne and Special Forces and invest in the SPIW as a successor to the M14. Accordingly, McNamara made the decision to terminate M14 production in 1963 because he believed that the Army had sufficient quantities of M14s for the intervening period and funding for additional M14s could be better used to procure AR-15s for the above mentioned units.[238]

3.3 The Vietnam War and US Adoption of the M16

Although the OSD's support for the AR-15 led to its adoption by select US units, the Vietnam War led to its widespread use by the US military and the AR-15 "was type classified as the M16."[239] The M14 was not well suited for jungle warfare encountered in Vietnam because combat occurred at short ranges in such environments and the Soviet AK-47's ability to deliver a high volume of fire for short periods "gave it a sizeable firepower advantage over the M14."[240] The M16s in use by the US Army's Air Assault, Airborne and Special Forces were a better alternative so theatre commander General Westmoreland chose to equip all US maneuver battalions in Vietnam with the assault rifle by the end of 1965.[241] But the initial large scale usage of the M16 in Vietnam resulted in reliability problems and the majority "of the malfunctions encountered were failures to extract (FTE) the cartridge case."[242] The major culprit behind the

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The theory that flechette firing rifles would provide a significant increase in combat capability has been proven to be incorrect. The US Advanced Combat Rifle (ACR) trials conducted from the 1980s to 1990s, had evaluated flechette firing small arms designed by the AAI Corporation and Steyr of Austria. The ACR trials discovered that "the dispersion of flechettes was still greater than that of bullets and the flechette rifles did not exhibit the hit performance of the bulleted rifles." See Christopher R. Bartocci, *The Black Rifle II: The M16 into the 21st Century* (Cobourg: Collector Grade Publications, 2004), 65.
Worse off, flechettes have extremely poor terminal performance for rifle use because they "are made out of steel and are unlikely to deform and fin stabilization prevents them from yawing." See Martin L. Fackler, "ACR Candidates: Assessing Their Wounding Potential," *International Defense Review,* August 1, 1989, 1091.

[238] Stevens and Ezell, *The Black Rifle*, 110, 116,

[239] Rayle, *Random Shots*, 97.

[240] McNaugher, *The M16 Controversies*, 123.

[241] Ibid.
Kern, "The Influence of organizational culture on the acquisition of the M16 Rifle," 81.

[242] Stevens and Ezell, *The Black Rifle*, 148, 217.

FTE malfunctions that occurred in Vietnam was the lack of chrome lining in the M16's chamber to prevent corrosion because "a cartridge would stick in a pitted chamber and cause the extractor to tear the rim off the case."[243] Moreover, Stoner had designed the M16 to function with 5.56mm cartridges that utilized IMR extruded propellant but starting in 1964, the Ordnance Department switched to ball propellant for the military's standard 5.56mm M193 cartridge.[244] But ball powder produced a higher gas port pressure compared to IMR powder, which increased the M16's cyclic rate and led to earlier parts breakage, failure to feed malfunctions and extraction issues.[245] In order to remedy these reliability issues, the updated M16A1 variant was introduced and the improved rifle was favoured by US soldiers in Vietnam for "its ability to deliver a high volume of fire at the critical juncture of a combat engagement."[246] Therefore, the combat

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[243] Christopher R. Bartocci, "The M16 in Vietnam," *Small Arms Review*, accessed October 20, 2015, http://www.smallarmsreview.com/display.article.cfm?idarticles=1735.
Although Springfield Armory had suggested chrome lining the M16's chamber and bore, the OSD refused the Armory's proposition because they believed that feature was not needed. See Stevens and Ezell, *The Black Rifle*, 218.

[244] McNaugher, *The M16 Controversies*, 136.

[245] Ibid, 158.
Bartocci, "The M16 in Vietnam."
The decision was made to switch from IMR propellant to ball propellant for the 5.56mm M193 cartridge because certain lots of 5.56mm rounds loaded with IMR powder had "excessive chamber pressure." See Rayle, *Random Shots*, 99.
The higher port pressures produced ball powder increased the cyclic rate of the M16, which caused the "bolt to open up at higher speeds while the cartridge case was still sticking in the chamber under high residual pressure." The earlier unlocking of the bolt made extraction of the cartridge case more difficult and caused failure to extract malfunctions. Some of the components that experienced earlier breakage as a result of the increased cyclic rate included the bolt and disconnector. Also, the M16 suffered from bolt carrier bounce, which causes light primer strikes during automatic fire. See Stevens and Ezell, *The Black Rifle*, 200, 217, 225, 226.

[246] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 20.
MAJ Bruce F. Kay, "An Analysis of the Infantry's Need for an Assault Submachine Gun," 34.
The M16A1 had a chrome plated chamber and bore and a new buffer and disconnector. Also, amendments were made to the M16A1's bolt hardness requirements and the bolt was shot peened for increased durability. The M16A1's buffer had five cascading steel weights, which served to eliminate bolt carrier bounce. See Stevens and Ezell, *The Black Rifle*, 201 225, 226.
Furthermore, the M16A1's buffer "slowed initial carrier movement and unlocking, lowering component recoil velocity, and reducing the rebound velocity of the bolt, which brought under control the feeding issues" caused by the excessive cyclic rate. See Cris E. Murray, email message to author, January 11, 2016 and Rayle, *Random Shots*, 99.
By the 1970s, the US military further enhanced the M16A1's extraction reliability by incorporating a rubber extractor spring insert that "greatly increased the extractor force." See Bartocci, "The M16 in Vietnam."

conditions of the Vietnam War showed that conventional US military units had an urgent requirement for assault rifles.

Although the US forced NATO to standardize on the full power 7.62mm cartridge, the efforts of ORO, the Infantry Board and CONARC led to the development of America's own assault rifle. Although the SPIW was supposed to become the future American individual weapon, it continued to experience significant technical problems and was not feasible as an infantry weapon. Due to the lack of revolutionary alternative weapons, the M16A1 was selected as the new standard US service rifle since it was better suited for the needs of American forces than its predecessor.[247] Compared to the standard M14, the M16A1 had greater accuracy, achieved more hits on targets at closer combat distances by utilizing rapid semi-automatic fire and could deliver controllable automatic fire for short periods to fulfill the SMG's capabilities.[248] At the fire team level, American infantry forces also employed a bipod equipped M16A1 in the automatic rifle role, which was "primarily fired in the automatic mode" and "was intended to be a base of fire around which the fire team maneuvers."[249] But the M16A1 was not ideal for the automatic rifle role because it had a limited sustained rate of fire of twelve to fifteen rounds per minute (RPM).[250] By 1969, the M16A1 became the standard rifle for US troops stationed in

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During the aftermath of the M16 problems in Vietnam, the US Army issued an improved "semi-fluid synthetic lubricant, known as MIL-L-4600A" and instructed soldiers to generously lubricate the M16A1 with MIL-L-4600A "in place of the sparing application recommended for the previous military lubricant." See Rayle, *Random Shots*, 99.

[247] McNaugher, *The M16 Controversies, 127*.

[248] Ezell, *The Great Rifle Controversy*, 189.
Westrom, "Technical Note 108," 18, 20.

[249] CWO3 Jeffrey L. Eby, "Automatic Rifle Concept: Part I—History and Empirical Testing," *Marine Corps Gazette* (2004), accessed March 14, 2013, http://council.smallwarsjournal.com/attachment.php?attachmentid=1351&d=1291962635.
Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 22.

[250] Ibid.
Rayle, *Random Shots*, 181.
The sustained rate of fire "is defined as the rate at which a weapon can fire indefinitely without experiencing a major malfunction such as (but not limited to) a cook-off or a significant degradation in accuracy." See Robert Bruce, "M27 From BAR to IAR: How the Marines Finally Got Their Infantry Automatic Rifle," *Small Arms Defense Journal* 4 (2012): 59.

Europe, which meant that NATO forces in the area no longer had a standard rifle caliber.[251] As a result, NATO determined that a new intermediate cartridge along with a single assault rifle model should be standardized and the alliance held new ammunition and weapons trials during the 1976-1979 period.[252]

3.4 NATO Ammunition and Weapons Trials of 1976-79

Compared to previous ammunition standardization efforts in the 1950s, the NATO trials of 1976-79 exhibited a greater degree of cooperation among participants because the alliance had introduced measures to better enable participation in joint programs.[253] In 1966, NATO formed the Conference of National Armaments Directors (CNAD), which was in charge of managing joint NATO programs and "as a means for exchanging information" among member states.[254] At CNAD, NATO states had acknowledged that the alliance's infantry weapons for the 1980s would "consist of Individual Weapons (IW), Light Support Weapons (LSW) and Medium Support Weapons (MSW)."[255] IWs were "assault rifles with an effective range of 300 to 400m" and the main objective of the NATO trials was to standardize a new cartridge that would be suitable for IW use and should also be capable of filling the LSW role.[256] LSWs were LMG designs that would be employed at the squad level but there were differing opinions among NATO members on whether LSWs should be chambered in the same caliber as IWs or in

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In addition to being uncontrollable during automatic fire, the M14 rifle had a sustained rate of fire of eight to ten RPM and was also inadequate for the automatic rifle role. See Rayle, *Random Shots,* 173.
Since the M16A1 fired from the closed bolt position and lacked a heavy barrel, it had a low cook off point. Firing 140 rounds quickly and constantly through the M16A1 will result in a cook off. See *TM 9-1005-249-100 Operator's Manual for Rifle, 5.56-mm, M16A1* (Department of the Army, 1985), C.

[251] Ezell, *Small Arms of the World*, 12th ed., 57.

[252] Per G. Arvidsson, "NATO Infantry Weapons Standardization" (presented at the National Defense Industrial Association, Dallas, Texas, May 19-22, 2008, http://www.dtic.mil/ndia/2008Intl/Arvidsson.pdf), 4.

[253] Ezell, *Small Arms of the World*, 12th ed., 57.

[254] Hurley, "Arms for the alliance," 380.

[255] Angelo N. Mancini Jr., "NATO Field Trials," *Army R,D&A,* May-June 1979, 15.

[256] Ibid.
Ezell, *Small Arms of the World*, 12th ed., 58.

7.62mm NATO.[257] MSWs were machine guns capable of engaging targets out to 1000m and most alliance members chose to retain their existing 7.62mm NATO caliber GPMGs as MSWs at the platoon or company level.[258]

Furthermore, the 1976-79 NATO trials were conducted under the arrangements of rationalization, standardization and interoperability (RSI).[259] During the 1970s, NATO articulated "a new formal doctrine of RSI" in response to improvements in Warsaw Pact conventional forces.[260] RSI sought to improve the degree of standardization in order to "increase both military effectiveness and cost efficiency" throughout NATO.[261] Memoranda of Understanding (MOU) were one of the major arrangements advocated by RSI and they allowed one state to eliminate barriers that would keep other signatory states' products out of one's own market.[262] This meant that each state would "obtain exemptions from the other's customs, duties, tariffs and protectionist legislation and give equal consideration to all qualified bidders regardless of nationality."[263] In 1976, the US, Belgium, Canada, Denmark, France, West Germany, Greece, Luxembourg, Netherlands, Norway and the UK "signed a MOU for the testing, evaluation and selection of a second NATO standard caliber for small arms ammunition."[264] In order to avoid national prejudice in the testing, the signatories of the MOU decided that the trials would be carried out by the NATO Army Armaments Group (NAAG). This led to the formation of a Coordination Panel for the Testing and Evaluation of Small Arms,

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[257] Mancini, "NATO Field Trials," 15.
[258] Ezell, *Small Arms of the World*, 12th ed., 115.
[259] Mancini, "NATO Field Trials," 15.
[260] Feldman, "Collaborative production of defense equipment within NATO," 285.
[261] Ibid, 282.
Keith A. Hirschman, "The Costs and Benefits of Maintaining the Buy American Act" (Masters thesis, Naval Postgraduate School, 1998), 18.
[262] Feldman, "Collaborative production of defense equipment within NATO," 286.
[263] Ibid.
[264] Ezell, *Small Arms of the World*, 12th ed., 56.

Ammunition and Weapons to oversee the administration of the testing and the NATO Small Arms Test Control Commission (NSMATCC) was created to conduct the evaluations.[265] NSMATCC's goal was to ensure that the evaluations were based on scientific tests so that "the data would be objective even though the data evaluation would be subjective in nature."[266] Accordingly, the NATO Infantry Weapons Panel established Subpanel 4, which was composed of specialists from NATO states and their responsibility was to set the requirements and update the testing criteria for the candidate ammunition and weapons.[267] As various NATO states had different testing criteria, Subpanel 4 ensured that "acceptable testing procedures and common agreements regarding the meaning of technical words and phrases were established."[268]

3.5 Weapons and Ammunition Candidates of the 1976-79 NATO Trials

Several signatories of the 1976 MOU chose to enter their new IW, LSW and ammunition developments as candidates in the 1976-79 trials (See Figure 14).

Figure 14: IW candidates of the NATO 1976-79 NATO trials.

Starting from the top left clockwise: West German G11, British XL64, Belgian FNC, Dutch MN-1, US M16A1 and French FAMAS F1.
Source: Per G. Arvidsson, "NATO Infantry Weapons Standardization" (presented at the National Defense Industrial Association, Dallas, Texas, May 19-22, 2008, http://www.dtic.mil/ndia/2008Intl/Arvidsson.pdf).

[265] Ibid, 57.
[266] Ibid.
[267] Ibid, 58.
[268] Ibid.

During the late 1960s, the French firm Manufacture d'Armes de St-Etienne (MAS) began developing the FAMAS F1 rifle and the French Ministry of Defense decided to "force the adoption of the FAMAS because it was a politically correct solution."[269] Although France had not been part of NATO's military command since 1966, they entered their FAMAS rifle and its accompanying steel cased 5.56mm ammunition in the NATO trials.[270] The US chose to submit the M16A1 along with the 54 grain 5.56mm XM777 and XM778 FMJ and tracer cartridges that were developed for the Squad Automatic Weapon (SAW) program as NATO trial candidates. The SAW program was initiated by the US Army in the 1970s with the intention of fielding a LMG model at the squad level and the XM777 was designed to meet the penetration requirements for LMG use while remaining compatible with the M16A1.[271] NATO states which submitted their own IW, LSW and SCHV ammunition designs as trial candidates included Belgium, the UK and Germany while the Dutch only nominated their 5.56mm MN-1 rifle as an IW candidate for the NATO trials. FNH's Minimi LMG was Belgium's LSW candidate and its accompanying 62 grain 5.56mm SS109 FMJ and tracer rounds were "designed as machine gun ammunition for engaging enemy troops wearing light body armor at distances of several hundred meters" (See Figure 15).[272]

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[269] Email communication from French Defense Professional to author, April 29, 2015.

[270] Mancini, "NATO Field Trials," 15.
Edward Cody, "After 43 Years, France to Rejoin NATO as Full Member," *Washington Post,* March 12, 2009, accessed October 20, 2015, http://www.washingtonpost.com/wp-_dyn/content/article/2009/03/11/AR2009031100547.html.
In 1974, the FAMAS was not a mature design but was sufficient "to validate the possibility of a French rifle for the French Army and the French Ministry of Defense forced the adoption of the FAMAS". See Email communication from French Defense Professional to author, April 29, 2015.

[271] Ibid, 91, 97.
Although studies showed that a 6x45mm cartridge was ideal for the SAW, the US Army chose to develop the 54 grain 5.56mm XM777 FMJ and XM778 tracer ammunition in order to avoid the logistical issues of introducing another new caliber. See Ezell, *Small Arms of the World*, 12th ed, 96, 115.

[272] Roberts, "Time for a Change," 6.

Figure 15: FN Minimi LMG.

Source: "FN Minimi (Belgium)/ M249 and Mk.46 model 0 (USA), accessed October 20, 2015, http://world.guns.ru/machine/usa/m249-saw-e.html.

While SS109 ammunition was "not originally intended for use in rifles," FN chose to design an assault rifle that fired SS109, which was known as the FNC, for the NATO trials.[273] Although the SS109 was a 5.56mm round, it could not be stabilized by the 1/12 inch twist barrels of the M16A1, MN-1 and FAMAS F1 because the Belgian bullet was heavier and longer than the M193 round.[274] The British XL64 IW and LSW variants were chambered for a new 4.85mm cartridge and both variants shared a high degree of parts commonality. HK's G11 rifle and its 4.7mm caliber caseless ammunition were the most advanced IW and ammunition candidates (See Figure 16). But the G11 and its ammunition experienced premature cook-off issues and were removed from the NATO trials so the West Germans could further refine the system.[275] Also, West Germany entered the MG3E as an LSW candidate for the NATO trials but this weapon was a lighter variant of their standard GPMG and fired the 7.62mm NATO cartridge.[276]

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[273] Ibid.
John Walter, *Rifles of the World*, 3rd ed. (Iola: Krause Publications, 2006), 123.
[274] Ezell, *Small Arms of the World*, 12th ed, 60.
Both the XM777/778 and SS109 use a steel penetrator and lead slug. See Ezell, *Small Arms of the World*, 12th ed., 60.
[275] Ibid, 58.
Mancini, "NATO Field Trials," 15.
[276] Ezell, *Small Arms of the World*, 12th ed., 60.

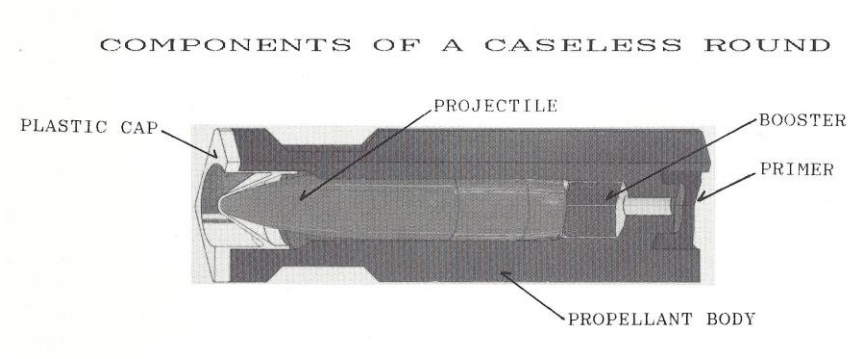

Figure 16: Components of the G11's 4.7mm caseless ammunition.

Source: Jim Schatz, "Caseless Ammunition Small Arms. The Good, The Bad and The Ugly" (presented at the National Defense Industrial Association Conference, Seattle, Washington, May 14-17, 2012, http://www.dtic.mil/ndia/2012armaments/Wednesday13614JimSchatz.pdf).

Overall, the 1976-1979 trials were successful at selecting the ammunition candidate that the evaluators believed had best met NATO's requirements for standardization. After reviewing the test results, NATO's Coordination Panel for the Testing and Evaluation of Small Arms, Ammunition and Weapons explained that "all ammunition candidates had a considerable advantage in terms of weight, size and cost over 7.62mm NATO rounds."[277] The Panel determined that "there were no significant discriminators in the various candidate rounds" for assault rifle use but the SS109 had superior penetration over the other SCHV rounds at distances greater than 500m and was the best candidate for LSW use.[278] As a result, in 1980, NSMATCC published their report on the trials, which suggested standardization of the SS109 for use in assault rifles and LSWs and NAAG approved of NSMATCC's recommendations.[279] Thus,

[277] Ibid, 62.
[278] Ibid.
The 5.56mm SS109 will penetrate the 3.5mm mild steel NATO plate and US helmet at longer distances compared to the 5.56mm XM777 round. Although 7.62mm NATO lead core FMJ rounds had inferior penetration against the above mentioned targets compared to 5.56mm SS109, a 7.62mm NATO version of the SS109 would have superior penetration compared to the 5.56mm SS109. See Ezell, *Small Arms of the World*, 12th ed., 60, 62, 63.
[279] "Impact of NATO Small Arms Test Recommendations for Second NATO Round, NATO Standardization Agreement and NATO Country Decisions" (NATO Draft Point Paper, 1980), 1.

NATO selected the SS109 for standardization because the evaluators believed it was the best SCHV candidate for use in LMGs and still met NATO's requirements for assault rifles use.

STANAG 4172 was produced to set the standards for 5.56mm SS109 ammunition and its goal was to "ensure interchangeability of ammunition on the battlefield."[280] SS109 bullets produced by all NATO states were to weigh 62 grains, "contain a steel penetrator in the tip" and meet the penetration requirements specified in the STANAG. [281] But STANAG 4172 allowed each NATO state's iteration of the SS109 bullet to have "varying jacket thickness and steel penetrator sizes, cannelure types and positions and overall bullet lengths." [282] This meant that different versions of the SS109 could have different terminal performance. For example, the US version of the SS109 FMJ bullet was designated M855 and the wound profile for M855 was similar to that of the M16A1's Vietnam era M193 projectile (See Figure 17).[283] Both the M193 and M855 bullets would yaw and fragment at a minimum impact velocity of 2700 fps and produced a larger permanent cavity than certain FMJ rifle bullets that only yawed but did not fragment in soft tissue.[284] In contrast, the British version of the SS109 FMJ projectile was designated L2A2 and had poorer terminal performance than the M855 because the British bullet

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[280] NATO Military Agency for Standardization, *STANAG 4172 MMS-5.56mm Ammunition (Linked or Otherwise)*, 2nd ed. (May 1993), 1.

[281] Lucien C. Haag, "5.56x45mm SS109/M855 Bullets: Design, Exterior and Terminal Ballistic Performance," *AFTE Journal* 33 (2001): 21.

[282] Ibid.

[283] Figure 17 showed the wound profile of the copper jacked 7.62mm M80 FMJ cartridge, which does not fragment in soft tissue. But the US also produced a steel jacketed version of the M80 FMJ that may fragment in soft tissue at a terminal velocity of 2800 fps or higher. The wound profile for the steel jacketed M80 FMJ round showed that on average, it fragmented after 20 cm of penetration. See Roberts, "Time For a Change," 21.

[284] Lucien C. Haag, "5.56x45mm SS109/M855 Bullets: Design, Exterior and Terminal Ballistic Performance," 23. Mark D. Minisi, "Soft Target Terminal Ballistic Testing Standardization for the U.S. Military" (presented at the National Defense Industrial Association Conference, Las Vegas, Nevada, May 10-13, 2004, http://www.dtic.mil/ndia/2004arms/session9/minisi.ppt), 15.
On average, the West German 7.62mm NATO FMJ round would start to yaw and fragment after going through approximately 8cm of soft tissue. As a result, the West German 7.62mm NATO bullet produced a much larger permanent cavity compared to the 5.56mm M193 and M855 cartridges. See Fackler, "Wounding patterns of military rifle bullets," 62.

often flattens a bit but does not fragment in soft tissue due to its thicker jacket.[285] Also, STANAG 4172's technical requirements allowed SS109 designs manufactured by various states to have different specifications for technical metrics such as average gas port pressure and bullet trajectory.[286]

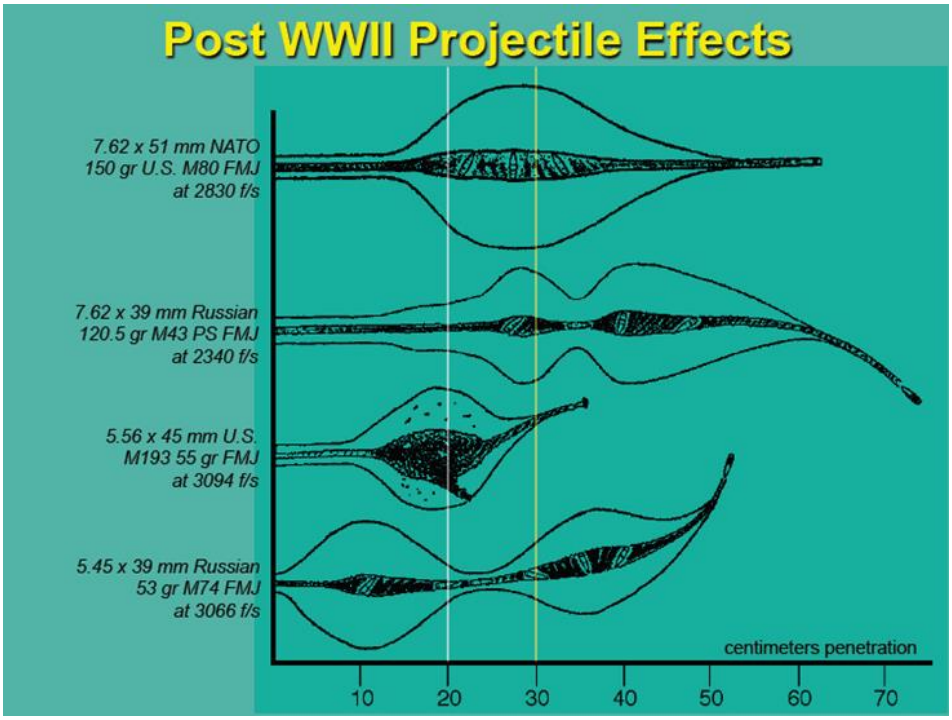

Figure 17: Wound profiles for Cold War era small arms ammunition.

Source: Roberts, "Wounding Effects of Military Small Arms during the Past Century."

[285] Lucien C. Haag, "Base Deformation as an Index of Impact Velocity for Full Metal Jacketed Rifle Bullets," *AFTE Journal* 33 (2001): 17.

[286] NATO, *STANAG 4172*, C-2.
A US report on 5.56mm L2A2 ammunition stated that: "undocumented claims from qualified and knowledgeable non-commissioned officers concluded that there was a minimum of point of impact variance of two Minute of Angle between US 5.56mm M855 and UK L2A2 ammunition designs and resulted in a six inch handicap for soldiers qualifying with mismatched ammunition (zeroed with M855 and qualifying with L2A2 or vice versa) when engaging 300 meter targets (excluding the effects of environmental influences and operator error)." See Jason R. Gillis, "Failure Report in Relation to U.K. 5.56mm Ammunition" (Report to NATO, SG-1, 2010).

Since STANAG compliant SS109 rounds of different national origins were not required to be identical ammunition designs, several SS109 type cartridges were treated as separate ammunition designs by NATO.[287]

3.6 Challenges to NSMATCC's Recommendations

Moreover, some NATO states chose to not adopt the SS109 during the initial period after the NATO trials because they wanted revolutionary technology for successor weapons rather than an incremental improvement over 7.62mm NATO rifles. After the NATO trials, West Germany rejected the SS109 round because they believed that caseless ammunition rather than improved 5.56mm rounds were major advancements over their predecessors.[288] The Germans believed the G11 would be mature by the late 1980s and its 4.7mm caliber caseless ammunition had one third less volume compared to the 5.56mm cartridge and was fifty percent lighter as well.[289]Also, the Germans stated that "4.7mm caseless ammunition, during side-by-side testing with the SS109, shows equal test results as that recommended for the SS109."[290] More importantly, the use of caseless ammunition allowed the extraction and ejection phases to be eliminated from the G11's cycle of operations and allowed the rifle to fire a three round burst at

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[287] NATO, *NATO Design List*, 1-1.

[288] "National Comment by the Federal Republic of Germany relative to the outcome of the NATO Small Arms Test and Evaluation Programme" (NATO Small Arms Test, 1980), 2.

[289] "Impact of NATO Small Arms Test Recommendations for Second NATO Round, NATO Standardization Agreement and NATO Country Decisions," 3.
Also, Germany wanted to develop a LMG which fires caseless 7.62mm ammunition instead of adopting the SS109 for LMG use. See "Impact of NATO Small Arms Test Recommendations for Second NATO Round, NATO Standardization Agreement and NATO Country Decisions," 3.
But caseless ammunition's "maximum cook off rate was still 210 rounds from a single chamber mechanism" and was not sufficient for neither the automatic rifle role nor LMG use. See Jim Schatz, "Caseless Ammunition Small Arms. The Good, The Bad and The Ugly" (presented at the National Defense Industrial Association Conference, Seattle, Washington, May 14-17, 2012, http://www.dtic.mil/ndia/2012armaments/Wednesday13614JimSchatz.pdf), 32.

[290] Ibid.

a cyclic rate of 2200 RPM, which was known as a salvo burst.[291] The G11 designers explained that "under stressful combat conditions, single aimed shots by a typical infantryman may miss a target due to aiming errors."[292] The G11's salvo burst had tighter dispersion compared to conventional 5.56mm assault rifles firing short bursts of automatic fire and the designers believed that reduced dispersion would compensate for aiming errors and improve pH (See Figure 18).[293] Likewise, Norway and the Netherlands wanted to adopt caseless ammunition weapons but were unable to develop such systems so they entered into "cooperative agreements with West Germany for the G11."[294] Therefore, a major problem during the trial's aftermath was that some NATO states chose not to pursue ammunition standardization with the rest of NATO because they believed caseless ammunition would soon mature and render the new NATO standard SS109 obsolete.

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[291] "G11 (Caseless Military Rifle)," accessed April 15, 2015," http://www.hkpro.com/index.php?option=com_content&view=article&id=23:the-g11-caseless-military rifle

Ezell, *Small Arms of the World*, 12th ed., 66.

[292] Ibid, 67.

[293] Jim Schatz, "Caseless Ammunition Small Arms. The Good, The Bad and The Ugly" (presented at the National Defense Industrial Association Conference, Seattle, Washington, May 14-17, 2012, http://www.dtic.mil/ndia/2012armaments/Wednesday13614JimSchatz.pdf), 24.

The G11 has "an interior operating floating system (IOFS) which compromises most of parts in the internal operating system such as the barrel, magazine, breech system, gas system and counter recoil system and recoils within the outer polymer housing." See Jim Schatz, email message to author, November 25, 2015.

When firing a salvo burst, the G11's IOFS "strikes the buffer in the receiver after the third shot cycle has been completed and only then is the total momentum transferred to the shooter's shoulder." See T. Moller, "G11 Rifle for Caseless Ammunition" (presented at NATO Small Arms Test Control Commission, Brussels, Belgium, November 4, 1976), 12.

The G11's IOFS along with the low recoil of the 4.7mm round "helped to greatly reduce the effect of recoil on the shooter's hold" compared to conventional assault rifles during burst fire. See Jim Schatz, email message to author, November 25, 2015.

[294] "Summary-Status NATO Second Round Ammunition" (1980), 3.

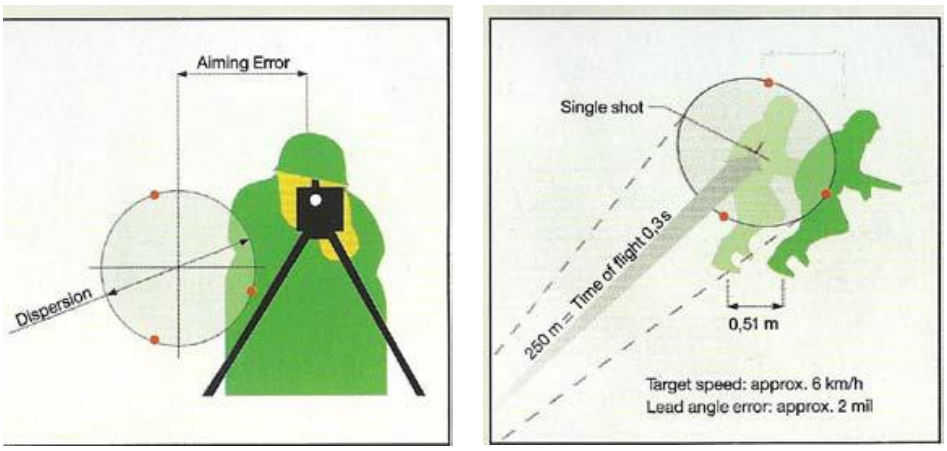

Figure 18: Theory that a Salvo Burst Compensated for Aiming Errors.

Source: Schatz, "Caseless Ammunition Small Arms."

However, the SS109 would remain NATO standard due to technical issues with the G11 and its caseless ammunition. After the SS109 was standardized by NATO, the Americans fielded the improved M16A2 rifle, which had a 1/7" twist rifling barrel to stabilize SS109 rounds, as their standard rifle. But in 1981, the US Department of Defense signed a MOU with West Germany's Ministry of Defense to test caseless ammunition technologies to ensure that they would not be behind in small arms technology if the G11 was successfully fielded.[295] As a result, the US Army initiated the Advanced Combat Rifle (ACR) Program in the late 1980s and the G11 was HK's candidate for the ACR Program.[296] It was during the ACR program's testing that some of the G11's perceived advantages were invalidated. The evaluators discovered that the aiming errors of soldiers participating in the ACR trials were smaller than previously thought. Consequently, the dispersion of the G11's salvo burst was still too large to compensate for the

[295] Ezell, *Small Arms of the World*, 12th ed., 73.
[296] Jim Schatz, "Time for a Change" (presented at the National Defense Industrial Association, Dallas, Texas, May 19-22, 2008, http://www.dtic.mil/ndia/2008Intl/Schatz.pdf), 87.
The goal of the ACR Program shifted from "a caseless ammunition experiment to a 100% increase in pH over the M16A2 during the early 1990s." See Schatz, "Time for a Change," 87.

actual aiming errors and did not offer an increase in hit probability compared to the M16A2.[297] Accordingly, HK's ACR Program Manager Jim Schatz explained that "well aimed rapid semi-automatic fire remained the most efficient means to bring effective fire on target for assault rifles."[298]

Also problematic was that the G11 and its caseless ammunition had serious technical problems that could not be overcome.[299] In the G11, a special firing pin design was intended to seal the firing pin opening and "a two part expanding chamber that sealed the chamber front and rear."[300] But "things like debris, fouling, lack of lube, heat build-up or swapping chamber parts can cause the chamber to not fully seal."[301] In such a scenario, "the user would either end up with countless broken pieces of the caseless round to try and clear or a gas jet that cuts a grove in the chamber, which would destroy the most important part of the weapon" and present a safety hazard for the operator (See Figure 19).[302]

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[297] Christopher R. Bartocci, *The Black Rifle II: The M16 into the 21st Century* (Cobourg: Collector Grade Publications, 2004), 65.

Email communication from Jim Schatz to author, February 25, 2015

"As soon as the first round of the G11's salvo burst is fired and the recoil spring is compressed, some of the recoil energy is transmitted into the point in the firearm where it is attached opposite the working parts. That energy then gets transferred into the weapon housing and on to the buttstock and ultimately into the shoulder of the shooter. As the shoulder is pushed rearward, the natural rotation of the body drives the weapon away from the point of aim causing dispersion." See Jim Schatz, email message to author, November 25, 2015.

[298] Jim Schatz, email message to author, May 13, 2011.

[299] Schatz, "Caseless Ammunition Small Arms," 29.

[300] Ibid.

In conventional rifles, the cartridge case sealed the chamber, bore and firing pin opening in order to prevent "the propellant gas jet from cutting through the chamber and receiver." See Schatz, "Caseless Ammunition Small Arms," 30.

[301] Email communication from Jim Schatz to author, February 25, 2015.

[302] Ibid.

Figure 19: G11 malfunction.

The malfunction shown in Figure 19 is due "to the chamber not being sealed completely at ignition point" and takes less than ten minutes to clear.
Source: Schatz, "Caseless Ammunition Small Arms."

Also, caseless ammunition has a "fragile propellant body and rough handling must be avoided," and misfired caseless ammunition generally resulted in more serious malfunctions compared to those with cased cartridges.[303] Due to those significant issues, the G11 was terminated at the beginning of the 1990s and Germany, Norway and the Netherlands would adopt rifles chambered for 5.56mm SS109 ammunition during the post-Cold War period. Thus, caseless ammunition's insurmountable technical obstacles outweighed its benefits and the investment in caseless ammunition delayed the adoption of the SS109 for several NATO member states.

[303] Schatz, "Caseless Ammunition Small Arms," 31.
For example, "significant feeding issues would occur if the caseless ammunition's lacquer coating was scrapped or the top part of ammunition was cracked" due to improper loading procedures. See Schatz, "Caseless Ammunition Small Arms," 39.
Also, since caseless ammunition requires "the propellant block to be fragmented for complete ignition, a misfired round will require the operator to clear propellant fragments from the gun's mechanism," which is a more difficult task than ejecting a misfired cased cartridge. Jim Schatz, email message to author, November 25, 2015.

3.7 Failure to Standardize a Common NATO Rifle

While NATO was able to standardize an intermediate cartridge, the alliance's goal of standardizing a single assault rifle model for all NATO forces was not successful. Although RSI reduced the obstacles towards standardizing a non-American ammunition candidate, such arrangements did not involve co-development efforts for small arms. Similar to rifle developments in the 1950s, rifle developments for the signatories of the 1976 MOU were still separate efforts "funded and executed at the national level."[304] In the NATO trials, the M16A1 was the most reliable IW candidate while most of the other rifle designs were still prototypes when they were evaluated by NATO.[305] The alliance believed "that a weapon's reliability appeared to be directly related to its maturity" but some of the candidates were further modified and converted to different calibers after the trials. [306] As a result, "the actual suitability of the weapons to meet operational characteristics could not be validly established" and a common rifle could not be standardized.[307] Likewise, NATO chose to not make suggestions regarding the standardization of LSWs because the candidates evaluated included both prototype and production weapons.[308]

Moreover, factors such as national pride and the desire of some European states to maintain their domestic industries remained as obstacles towards the adoption of a common NATO rifle in spite of the doctrine of RSI.[309] These factors can be seen in the decisions of NATO states such as Belgium and the UK to adopt indigenously designed weapons. The Belgian

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[304] Email communication from Defense Industry Professional and former Canadian Army officer to author, March 20, 2015.
[305] Email communication from Per G. Arvidsson to author, December 9, 2014.
R.L. Wilson, *Colt: An American Legend (*New York: Artabras Publishers, 1985), 358.
[306] Ezell, Small Arms of the World, 12th ed, 62.
[307] Ibid.
[308] Ibid.
[309] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015.

FNC did not perform well during the NATO trials because their candidate was not yet mature at the time. In 1980, FN chose to address several of the FNC's issues and marketed the rifle as a competitor to the M16 rather than abandon their design.[310] The "Belgian Army has always" adopted guns manufactured by FNH instead of other competing designs and "their entire small arms arsenal is FN based."[311] So after the FNC had passed the Swedish military's evaluations in 1981-82, the Belgian military was persuaded that the FNC was a viable design and adopted it as their service rifle in 1989.[312] Thus, Belgium's adoption of the FNC is arguably a case showing that states would choose to procure a viable indigenous design instead of foreign rifles in order to support their domestic industries.[313]

Moreover, national pride and the desire to maintain their domestic industries led the UK to adopt indigenously designed rifles and LSWs rather than superior foreign weapons. Churchill's decision to scrap the EM-2 in favour of the FAL rifle was seen by "the British officer class" and Labour members of Parliament as "Conservative politicians betraying an excellent rifle design by bowing to pressure from the US Ordnance Department."[314] By the 1960s, the British Army requested that an indigenous design succeed the L1A1 once their service rifles become worn out in the coming decades, which led to RSAF Enfield's development of the 4.85mm XL64 IW and LSW variants in the 1970s.[315] Before the commencement of the 1976-79 NATO trials, the XL64 series was highly publicized by the British Ministry of Defence as their

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[310] Ezell, *Small Arms of the World*, 12th ed., 73.
[311] Email communication from Salvatore A. Fanelli to author, December 3, 2015.
Although Salvatore A. Fanelli is currently the APdM-Engineering Supervisor at USMC IWS SYSCOM, the information that he provided the author regarding the Belgian Army's procurement of FN firearms are based on his own opinions and experiences as a former FNH USA employee and are not those officially from the USMC.
[312] Walter, *Rifles of the World*, 123.
[313] Currently, "the FN FNC rifle is at least as reliable as the M16."See Email communication from Per G. Arvidsson to author, December 4, 2015.
[314] Hinrichs, "Rifle development, standardization, and Procurement in the United States military 1950-1967," 26. Raw, *The Last Enfield*, xxv.
[315] Ibid, 15.

military's standard infantry weapons for the 1980s and "the XL64's official unveiling was to be a day of national pride and an endorsement of British manufacturing expertise."[316] Although the British believed that the XL64 IW and LSW could be quickly fielded after the NATO trials, their weapons candidates were not mature and did not fare well in NSMATCC's evaluations. Due to NATO's rejection of the 4.85mm round, the XL64 IW and LSW had to be modified to fire 5.56mm ammunition and the converted weapons became known as the SA80 series (See Figure 20).[317]

Figure 20: SA80 rifle (left) and LSW (right) variants.

Sources: "Enfield SA-80: L85A1 and L85A2 assault rifle, L22 carbine (Great Britain)," accessed October 20, 2015, http://world.guns.ru/assault/brit/sa0--l5-e.html.
"L86A1 – SA-80 Light Support Weapon (Britain)," accessed October 20, 2015, http://world.guns.ru/machine/brit/l6a1-sa-0-lsw-e.html.

But the British SA80s "were notoriously unreliable mainly due to their flawed design and production" methods.[318] In addition to poor reliability, the LSW variant "could not stay on target during automatic fire due to split groups, with the second group being off to the left of the point of aim."[319] Although many of the SA80's reliability issues and the LSW variant's problem with

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[316] Ibid, 35.
[317] Ibid, 35, 55, 59.
[318] Email communication from Jim Schatz to author, December 3, 2014.
[319] Raw, *The Last Enfield*, 95.
While the SA80 LSW variant was technically an automatic rifle due to the lack of a quick change barrel, it was adopted as Machine Gun 5.56mm Light Support Weapon L86A1 and was intended to supersede both the L4 LMG and MAG 58 GPMG in the LMG role. See Raw, *The Last Enfield*, 32, 101.
Most machine guns fired from the open bolt position, which meant that a live round is only fed into the chamber when it is about to be fired and this feature reduces the risk of ammunition cook-offs. See Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 22.
Due to the lack of a quick change barrel and firing from the closed bolt position, the L86A1 LSW had a lower sustained rate of fire than other machine gun models. The British had evaluated foreign designs as alternatives to the

split groups were unresolved, the British military adopted the SA80 series in 1985 and RSAF Enfield received the contract to manufacture the initial order of weapons. There was a lot of enthusiasm from the official press releases, government and military officials and the media that the British military would finally field indigenously designed weapons.[320] The above mentioned sources portrayed the SA80 as a world class weapons system and "anyone who offered even minor criticisms were condemned as nitpickers who would find fault with anything."[321] The British hoped that there would be significant foreign demand for the SA80 because large purchases abroad would have compensated for their weapons system's developmental cost of 500 million pounds.[322] After the Conservatives chose to privatize state owned industries, RSAF Enfield was sold to British Aerospace (BAe) in 1988 and BAe received the contract to produce the second order of SA80s at Royal Ordnance Factory Nottingham. This suggested that the British government believed that even after the closure of RSAF Enfield, it was still politically unacceptable to adopt a new foreign weapon or select foreign manufacturers over domestic firms.[323] Due to national pride and the desire to maintain their domestic industries, the British chose to field their problematic SA80 series rather than more mature foreign weapons.

L86A1 and the Steyr AUG HBAR variant was favoured by the evaluators because "it produced tight, evenly-distributed bursts." Even though accurate automatic fire was the major requirement for the LSW, the British rejected the Steyr because it did not meet the UK's semi-automatic accuracy requirements for the LSW due to firing from the open bolt position and the Steyr also used a different magazine than the SA80 series. See Raw, *The Last Enfield*, 93, 301.

[320] Ibid, 96, 101.

[321] Ibid, 102.
James Meek, "Off Target," *The Guardian*, October 10, 2002, accessed October 20, 2015, http://www.theguardian.com/uk/2002/oct/10/military.jamesmeek.

[322] Matthew Hickley, "Is the Army about to scrap the rifle it cannot rely on?," *Daily Mail*, accessed December 7, 2015, http://www.dailymail.co.uk/news/article-133241/Is-Army-scrap-rifle-rely-on.html.
Raw, *The Last Enfield*, 101, 102.
The SA80 was a complete failure on the export market and only Mozambique and Jamaica purchased a limited quantity of weapons. See Raw, *The Last Enfield*, 178.

[323] Ibid, xxvii, 164.

3.8 Impact of the 1976-79 NATO Trials and RSI on US Procurement

Likewise, the US chose to retain the M16 design rather than pursue a common rifle with their European allies. By the late 1970s, many M16A1s in USMC military service were past their service life due to extensive use and new rifles needed to be procured. But an examination of foreign alternatives showed that other Western rifle designs were unsatisfactory for the USMC's needs. The USMC concluded that the M16A1 was an overall sound assault rifle design and decided to pursue an upgraded M16 variant that was designed to their specifications.[324] In 1979, the US Army believed that replacing their entire stock of M16A1s would have cost around $360 million and adopting an alternative rifle design would have required completely different training and spare parts.[325] Compared to procuring a completely different 5.56mm rifle model, a M16 that fired NATO standard 5.56mm M855 ammunition was a better option for the US Army. Afterwards, the Joint Services Small Arms Program office "approved a joint service rifle program" that led to the adoption of the M16A2 as the US military's new service rifle in the 1980s (See Figure 21).[326] Therefore, the Americans did not pursue a common NATO rifle because other Western rifles of the period were not superior to the M16 and transitioning to a completely new design would be costly.

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[324] Stevens and Ezell, *The Black Rifle*, 343.
Ezell, *Small Arms of the World*, 12th ed., 63, 64.
[325] Ibid, 58.
[326] Stevens and Ezell, *The Black Rifle*, 347, 350.
"JSSAP tasked the USMC Firepower Division to oversee the Marine portion of the trials of the new rifle and the singular impetus provided to the M16 Product Improvement Program was from the Marines." See Stevens and Ezell, *The Black Rifle*, 347, 350.

Figure 21: M16A2 rifle.

Source: "Armalite/Colt AR-15/ M16 M16A1 M16A2 M16A3 M16A3 M16A4 assault rifle (USA)."

Despite the lack of a common rifle, the Americans did make commitments to RSI by procuring some European weapons and this could be seen in the US military's adoption of the Belgian Minimi.[327] The Minimi was one of the candidates evaluated by the US Army's SAW Program along with the HK21A1, Ford Aerospace's XM248 and the BRL's XM106, and all candidates were tested with the XM777 and XM778 cartridges. But the US wanted a NATO compliant LMG design so they did not select any SAW candidates for adoption before the conclusion of the 1976-79 NATO trials, where both the Minimi and SS109 combination and XM777/778 cartridges were evaluated.[328] By 1980, the Americans agreed with NATO's decision to standardize the SS109 and the US Army endorsed the Minimi "as the best SAW candidate based on technical performance and production cost grounds."[329] This showed that the "US positon for RSI was to rely on market principles of cost and quality to determine what is produced and procured."[330] After further refinements to the design, the Minimi entered US Army service as the M249 SAW and succeeded the M16A1 as the automatic rifleman's weapon.[331] Although the USMC preferred a true automatic rifle, they also adopted the M249 SAW in the automatic rifle role due to the "existing US Army contract in place and the lack of suitable

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[327] Feldman, "Collaborative production of defense equipment within NATO," 287
[328] Thomas Cosgrove, "Squad Automatic Weapon," *Army R,D&A*, May-June 1979, 6, 7.
[329] Ezell, *Small Arms of the World*, 12th ed., 62, 103, 104.
"Impact of NATO Small Arms Test Recommendations for Second NATO Round, NATO Standardization Agreement and NATO Country Decisions," 2.
[330] Feldman, "Collaborative production of defense equipment within NATO," 283.
[331] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 23.

alternatives."[332] Traditionally, states with existing industries do not want to procure large quantities of weapons "from abroad due to the fear of generating domestic unemployment."[333] But dual production arrangements advocated under RSI allowed a state to co-produce components or complete weapons fielded by other allies and "co-production is a form of economic compensation" for states procuring foreign designs.[334] The M249 SAW was manufactured by FNH's American subsidiary, FNH USA, which showed that dual production arrangements enabled the Americans to procure a superior European LMG candidate.[335]

3.9 Canadian Weapons Procurement after the NATO Trials

While the 1976-79 NATO trials failed to select a common rifle for all NATO forces, Canadian participation in NATO standardization efforts led them to adopt similar weapons models with the US. In addition to conducting the NATO trial's cold temperature testing, the Canadians independently tested the NATO weapon candidates so they could field weapons that were compliant with the NATO standards of the 1980s. The M16A1 and FNC were the most suitable rifle candidates but the Canadians favoured the M16A1 due to its superior reliability. As a result, the Canadian government initiated the Small Arms Replacement Program (SARP) to replace the C1A1 and C2 rifles. The Canadian firm Diemaco license produced a modified version of the US M16A2 as the C7 rifle and a shorter barrel variant was adopted as the C8 carbine (See Figure 22).[336]

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[332] Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.
[333] Feldman, "Collaborative production of defense equipment within NATO," 285.
[334] Ibid.
Charles W. Harper, "NATO Weapon Systems: The Impact of Interdependence" (paper presented at a regional meeting of the International Studies Association, Raleigh, North Carolina, November 15, 1984), 96.
[335] Ibid.
[336] Stevens and Ezell, *The Black Rifle*, 367, 368.
Unlike the M16A1, the M16A2 has a 3 round burst fire mode instead of full automatic fire because USMC Headquarters opposed the idea of automatic fire from an assault rifle while Weapons Training Battalion wanted automatic fire capability. See Patrick A. Rogers, "Strong Men Armed: The Marine Corps 1st Force Reconnaissance Company, accessed October 20, 2015, http://www.forcerecon.com/strongmenarmed3.htm.

Figure 22: Current Canadian Forces standard C7A2 rifle (left) and C8A3 carbine (right).

Source: "Existing Fleet Upgrades," accessed October 20, 2015," http://www.coltcanada.com/upgrades.html.

The cold hammer forged (CHF) barrels of the C7 and C8s had a longer barrel life than their US counterparts.[337] Also, "SARP determined that the Minimi was the LMG of choice and Diemaco was given the contract to produce components of the Minimi under license to FNH."[338] This is a case where a nation without domestic alternatives would adopt superior foreign weapons when dual production agreements were successfully negotiated. Thus, a state that wanted to comply with RSI through competitive bidding and those who lacked their own designs may adopt variants of a common weapon.

A major disadvantage of the "3 round burst control was that it does not recycle, meaning that if one or two rounds are fired because the trigger is not held long enough, a magazine change is required, or in the event of a stoppage for any other reason, the next pull of the trigger will not result in a three-round burst, but will result in one or two shots being fired." See Arthur D. Osborne and Seward Smith, *Analysis of the M16A2 Rifle Characteristics and Recommended Improvements* (Fort Benning: US Army Research Institute for the Behavioral and Social Science, 1986), 26.

Both the C7 and C8 series have full automatic capability. The C7 also had different iron sights compared to the M16A2 and a shorter buttstock option. See Stevens and Ezell, *The Black Rifle*, 370.

[337] "Original C8 Carbines," accessed October 20, 2015, http://www.coltcanada.com/c8-carbines.html.

C7 and C8 barrel life figures are proprietary information and cannot be listed in this thesis. All C7 variants have 20 inch barrels. The original C7 and C7A1 rifles had fixed buttstocks and the former was equipped with a fixed carrying handle while the latter had a flattop accessory rail for mounting optics. The current Canadian standard C7A2 differs from the C7A1 due to the addition of a collapsible buttstock. Both the C8 and C8A1 carbines have 14.5 inch barrels but they have now been replaced by the C8A3 variant in Canadian service and the C8A3 has a 15.7 inch barrel. See "Canadian American Strategic Review," accessed October 20, 2015, http://www.casr.ca/101-army-smallarm-1.htm.

Unlike the US M4 carbine, the C8 series of carbines have a different chamber design with looser dimensions, which improves extraction reliability. The Canadian Forces' C8A3 carbines do not have "an O-ring or D-ring to add tension to the extractor because if the gas port diameter is correct for the barrel length and the chamber is enlarged, the D-ring is of questionable utility." See Email communication from CWO (Mr Gnr) John Yoshida to author, November 4, 2015.

[338] Canadian Firearms Industry Professional, email message to author, May 27, 2015.

Colt later purchased Diemaco and the Canadian firearms manufacturer was renamed Colt Canada. "In subsequent years, Colt Canada has modified the Minimi by adding a short barrel option, as well as improved hand rails and other minor alterations." See Canadian Firearms Industry Professional, email message to author, May 27, 2015.

Due to the US introduction of the non-NATO standard 5.56mm round, the alliance needed to standardize a new intermediate cartridge. The SS109 was chosen for standardization because it best met NATO's established criteria for a SCHV round that could meet the requirements of both assault rifles and LSWs. The demise of the G11 Program insured that most NATO member states were able to successfully standardize the 5.56mm SS109. France was a participant in the NATO trials but did not have an urgent need for ammunition interchangeability with other NATO military forces during the 1980s and 1990s because the French were not part of NATO's military command. As a result, the French Army retained many FAMAS F1 rifles with their original 1/12 inch twist barrels that could not stabilize the NATO standard SS109.[339] Factors such as the different maturity level of the candidate rifles, national pride and the desire to maintain the indigenous industries of Western Europe prevented NATO from standardizing a single rifle model. Dual production arrangements enabled the US to adopt the M249 and field a common LMG model with many of their allies as numerous NATO states have procured variants of the Belgian Minimi by the early twenty first century.[340] However, NATO standardization of the SS109 was not ideal and some of its limitations were evident by the twenty first century. Some of STANAG 4172's technical performance specifications, such as its average gas port pressure requirement, were not sufficient enough to ensure that all SS109 bullet designs would function reliably in all 5.56mm weapons used by NATO forces. Also, the wound profiles for all

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[339] Email communication from French Defense Professional to author, May 4, 2015.
Also, the French Army wanted the FAMAS as an interim weapon and initiated their own caseless ammunition program known as FAMAS MSD (FAMAS with Caseless Ammunition) in 1985 and the MSD was intended to enter full production by the twenty first century. But the MSD program was a failure and was cancelled during the 1990s. See Email communication from French Defense Professional to author, May 4, 2015.

[340] Per G. Arvidsson, "NATO Weapons & Sensors Working Group" (presented at Soldier Technology Conference, London, UK, June 13, 2013), 10.
In 2003, the UK military procured Minimi LMGs to replace the SA80A2 LSW because British soldiers believed that the LSW variant was not suited for the LMG role. See Raw, *The Last Enfield*, 302. As of 2013, other European NATO users of the Minimi include Belgium, the Czech Republic, Denmark, France, Hungary, the Netherlands and Norway. See, Arvidsson, "NATO Weapons & Sensors Working Group", 10.

FMJ rounds showed an average penetration depth until yaw but the distance until yaw can vary "twenty five percent from the average for a group of shots."[341] Consequently, FMJ rifle rounds that exited the target without yawing produced minimal wounds and those SS109 style bullets which yawed later than on average did not demonstrate adequate terminal performance for rifle use.[342]

[341] Martin L. Fackler, *Wound Ballistics Research of the Past Twenty Years: A Giant Step Backwards* (San Francisco: Letterman Army Institute of Research, 1990), 3.

[342] Ibid.
Roberts, "Time for a Change," 7.

Chapter 4: NATO Standardization Limitations and Post-Cold War Efforts

4.1 NATO Ammunition Interchangeability Procedures

NATO has devised several documents which highlight the procedures used to determine whether specific NATO members could share each other's ammunition. The NATO Catalogue known as Allied Ordnance Publication-6 (AOP-6), was first published around thirty years ago, "identified ammunition that is suitable for land forces ammunition interchangeability" and consisted of two volumes.[343] AOP-6 Vol. I consisted of data on the form, fit and function of ammunition in use by NATO states.[344] Function is defined as "the correct fulfillment of the purpose for which the ammunition is designed, including actions in the weapon from ignition to launch, and the qualitative nature of its effect at the target."[345]AOP-6 Vol. I was intended to assist NATO states in deciding which ammunition types could likely be interchanged in scenarios where ammunition shortages would hinder the success of missions.[346] AOP-6 Vol. I included NATO Qualified ammunition designs and non- NATO Qualified ammunition that met NATO's criteria for form, fit and function.[347] However, AOP-6 Vol. I does not include information on "safety, ballistics and effectiveness on target so commanders will have to balance the potential risk to personnel and materiel against the importance of achieving the mission" when interchanging ammunition listed in Vol. I.[348] Only ammunition designs included in AOP-6 Vol. II could be "interchanged during training, operations, or both, without further

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[343] Patterson, Markov and Richter, *Western-Style Armaments for New NATO Countries*, 4-10. Email communication from Per G. Arvidsson to author, December 15, 2015.
[344] NATO, *AOP-6 (V) Vol. I.*
[345] NATO Military Committee Land Standardization Board, *STANAG 2459 I-Ammo-The Procedures for Ammunition Interchangeability*, 3rd ed. (Brussels, April 2010), 2.
[346] Ibid, A-1.
[347] NATO, *AOP-6 (V) Vol. I.*
[348] Ibid.

authorization."[349] In order for an ammunition design to be included in AOP-6 Vol. II, it first had to be subjected to "an interchangeability study regarding weapon system related safety and performance."[350] Further testing could be conducted to "determine the degree of interchangeability" if the initial interchangeability study was insufficient.[351] The purpose of the above mentioned tests was to determine whether an ammunition design had safety issues when fired in specific weapons and if the ammunition had "limitations or restrictions."[352] An ammunition design could only be included in AOP-6 Vol. II if there were no safety issues, a National Interchangeability Document was completed and "interchangeability data and supporting documents were submitted to the custodian of AOP-6 Vol. II."[353]

STANAG 2459- The Procedures for Ammunition Interchangeability included information regarding the actions to be taken in situations which required the use of another NATO state's ammunition.[354] When a NATO military needs to utilize the ammunition of another NATO state during an emergency, they should select an ammunition design from AOP-6 Vol. II and can only choose ammunition designs from AOP-6 Vol. I when alternatives were not available from Vol. II. Factors commanders should consider when using another NATO member's ammunition include whether both states use identical ammunition designs and common weapon models, whether the ammunition has been NATO Qualified and "if the risk of using such ammunition was acceptable."[355] Ammunition designs from Vol. I which did not

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[349] NATO Military Agency for Standardization, *AOP-6 (V) Vol. II: Catalogue of Ammunition with National Approval for Specified Interchangeability*, 3rd ed. (August 2008), II.
[350] NATO, *STANAG 2459*, B-1.
[351] Ibid.
[352] NATO, *STANAG 2459*, B-1.
[353] Ibid.
[354] NATO Military Committee Land Standardization Board, *STANAG 2034 CSS-NATO Standard Procedures for Mutual Logistic Assistance*, 7th ed. (Brussels, March 2011), 4.
[355] NATO, *STANAG 2459*, D-1.

satisfy the above mentioned criteria should not be used in emergencies.[356] However, if a NATO state wanted to use another member state's ammunition "for planning purposes or effective logistics," a suitable alternative must be selected from AOP-6 Vol. II rather than Vol. I.[357]

4.2 Why NATO Standardization is still needed in the Post-Cold War Era

After the collapse of the Soviet Union in 1991, ammunition standardization was still necessary for NATO members due to their involvement in the Global War on Terror (GWOT) in areas such as post-9-11 Afghanistan and Iraq. During the War in Afghanistan, NATO directed the International Security Assistance Force (ISAF), which was "a multinational force consisting primarily of European states committed to provision of security in and around Kabul for the Afghans."[358] Due to the commitment of US forces to the War in Iraq, the Americans required assistance from ISAF during the later stages of the War in Afghanistan.[359] Although several NATO states did not participate in the War in Iraq, the US-led coalition consisted of NATO members such as Britain and Denmark and former Warsaw Pact states who joined NATO during the late 1990s and early twenty first century.[360] According to the NAAG, "NATO ammunition standardization supported coalition warfare because NATO forces operate side by side more than ever before" and there were situations where alliance members had to share ammunition in Afghanistan and Iraq.[361] For example, US soldiers needed to share ammunition with other NATO forces when "the supply chain was sometimes unable to keep up with highly mobile combat units."[362] Therefore, the option of using another NATO member's ammunition in

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[356] Ibid.
[357] Ibid.
[358] Paige Irwin, "NATO in Afghanistan," in *Redefining Security: NATO's Role in the 21st Century*, ed. Ryan Braun (Seattle: University of Washington, 2011), 43.
[359] Ibid, 45.
[360] "Operation Iraqi Freedom," accessed May 20, 2015, http://georgewbush-whitehouse.archives.gov/news/releases/2003/03/20030327-10.html.
[361] Pellegrino and Kirkman, "NATO Small Arms Ammunition Interchangeability via Direct Evidence Testing,"26.
[362] Jim Schatz, email message to author, November 25, 2015.

scenarios such as logistical emergencies was still required for joint operations in the twenty first century.

Furthermore, the nature of asymmetric warfare makes logistical support more challenging than conventional operations. In order to offset NATO's conventional superiority during the GWOT, Third World adversaries had "sought sanctuary in complex and urban terrain in an attempt to deny access to US and allied forces."[363] As a result, "US infantry forces had to operate in a distributed manner" in theatres such as Afghanistan and Iraq.[364] This meant that the Americans had to "break their forces down into smaller units, such as company, platoon, squad or even smaller sized patrol bases in order to saturate areas with patrols and provide sustained operations."[365] But the "increased number of smaller units dispersed throughout the battle space makes resupply more challenging" compared to previous operations.[366] Rather than "a wheeled convoy, helicopter or air drop bringing supplies such as ammunition, food, water and medication to one location such as a company base, that unit now needs to push those supplies out to many more locations, which requires much more time, manpower and vehicle assets."[367] Thus, during distributed operations, it would be beneficial for US and NATO soldiers operating in the same battle space to be supplied with a common ammunition design or be able to reliably use each other's ammunition.[368]

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[363] MAJ William Wando, "Future War Paper Infantry Small Arms of the Future: Practical and Tactical Considerations" (Masters Thesis, Marine Corps University, 2007), 4.
[364] Ibid.
[365] MAJ James Williamson (USMC), email message to author, November 18, 2015.
[366] Wando, "Future War Paper Infantry Small Arms of the Future," 5.
[367] MAJ James Williamson (USMC), email message to author, November 18, 2015.
[368] Ibid.

4.3 Limitations of NATO Ammunition Standardization

Although some NATO members were able to "successfully use each other's ammunition,"[369] certain rifle designs in service with the alliance's national armies did not operate reliably with all 5.56mm SS109 type NATO Qualified ammunition designs. Since a common rifle was not standardized for all NATO forces during the aftermath of the 1976-79 trials, some NATO member states fielded improved versions of their service rifles to meet evolving user requirements. During the GWOT, US forces used the upgraded M16A4 along with shorter barrel variants of the M16 known as the M4 and M4A1 carbines and all three assault rifles are equipped with Picatinny rails for mounting optics and accessories (See Figure 23).[370]

Figure 23: M16A4 assault rifle (left) and M4 carbine (right).

Sources: "M16A2/A4 Rifle," accessed October 20, 2015, http://www.peosoldier.army.mil/portfolio/#201.
"PEO Soldier Live," accessed October 20, 2015, http://peosoldier.armylive.dodlive.mil/files/2012/08/M4_standard_accessories_delivered.jpg.

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[369] Pellegrino and Kirkman, "NATO Small Arms Ammunition Interchangeability via Direct Evidence Testing," 26.

[370] The M4 and M4A1 carbine have 14.5 inch barrels while the M16A2 and M16A4 have 20 inch barrels. The M16A4 differs from the M16A2 by having a flattop Picatinny rail in place of the fixed carrying handle. Both the M4 and M16A4 are capable of semi-automatic and three round burst fire and do not have full automatic fire capability. Starting in 1999, many US Army light infantry forces were armed with the M4 carbine. No later than 2006, every Brigade Combat Team that went overseas was equipped with M4s. See Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 24.
In 2010, the US Army decided to convert their M4 carbines to M4A1s, which are the full automatic capable versions of the M4 and are equipped with a heavier barrel. See Scott R. Gourley, "Soldier Armed: M14/M4A1 Carbine," *Army*, September 2014.
The USMC's infantry forces were initially equipped with M16A4s while M4s were employed by officers and Marines with occupations that required a more compact weapon. See George E. Kontis, "Sal Fanelli: The Interview," *Small Arms Defense Journal* 6 (2015), accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=2879.
But the USMC is "currently transitioning to all M4s within the infantry, light armored reconnaissance and reconnaissance battalions." See Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.

Britain's SA80 series encountered significant reliability issues during the first Persian Gulf War and the British government tasked HK with upgrading the SA80 series to the SA80A2 standard to address those reliability issues (See Figure 24).[371]

Figure 24: SA80A2 assault rifle.

Source: "Enfield SA-80: L85A1 and L85A2 assault rifle, L22 carbine (Great Britain)."

The UK's NATO Qualified 5.56mm SS109 round was designed for the SA80 series and designated as L2A2.[372] The M16A4 and M4 are reliable weapons when firing US military standard ammunition such as NATO Qualified M855 cartridges but had issues when using L2A2 ammunition.[373] The UK's "SA80 rifles had a higher spring rate and internal parts friction than

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[371] Raw, *The Last Enfield,* 172, 277.

[372] Email communication from Jim Schatz to author, December 3, 2014.
NATO, *NATO Design List*, 1-1.
The British military's current 5.56mm FMJ ammunition for the SA80A2 is manufactured by Radway Green and known as L17A2. Also, Radway Green currently manufactures another 5.56mm FMJ cartridge known as the L15A2 for use in the M16 series and export. See Email communication from Anthony G. Williams to author, February 4, 2015.
The last lot of L2A2 ammunition became NATO Qualified in 2004 and both L17A2 and L15A2 are now NATO Qualified. See NATO, *NATO Design List*, 1-1.
But 5.56mm L17A2 is not in the third edition of AOP-6 Vol. II and the author was unable to get information on the performance of the L17A2 ammunition in the M16A4 and M4 from the British Ministry of Defence and Radway Green.

[373] Email communication from Salvatore A. Fanelli to author, January 8, 2015.
The M16 series' direct gas impingement system works the following way: "after the bullet passes the gas port, gas is routed through the gas tube and bolt carrier key into the cylinder formed between the bolt and bolt carrier. Gas pressure in the cylinder drives the bolt carrier to the rear. As this happens, the bolt cam pin rotates the bolt and disengages the bolt lugs from the lugs in the barrel extension. As the bolt and carrier move rearward, the extractor withdraws the spent cartridge case from the chamber, and the ejector throws it out the ejection port." See Stevens and Ezell, *The Black Rifle,* 88, 89.
Former US Ordnance Corps officer Mark Westrom explained that: "the distance from the chamber to the gas port, the length of barrel beyond the port, and the pressure of the propellant gasses determine the amount of energy provided to the action of the M-16 series. The M16's bolt carrier group and the location of the gas port were carefully balanced to provide outstanding reliability with the ammunition designed for the M16. A change in the cartridge (bullet weight and propellant), barrel length and the location of the gas port along the barrel can substantially change the pulse of gas that enters the carrier group and drives the rifle action. [When transitioning

the M4 and M16 and a different port pressure" than that produced by M855 ammunition "was required to operate the SA80 reliably."[374] Consequently, "the L2A2's higher port pressures overdrove the direct gas impingement system components of the M16A4 and M4, which caused earlier than expected component damage and the USMC restricted the use of the British ammunition."[375] Furthermore, L2A2 ammunition produced higher port pressures in the M4 than in the M16A4 because the carbine's gas port is closer to the chamber than that of the rifle.[376] In addition to "overdriving the M4's operating components," L2A2 caused failure to cycle malfunctions in the M4 because the carbine's "operating components were moving too fast for the ejector to have enough time to eject the spent cartridge."[377] Likewise, the SA80A2 rifle requires sufficient gas port pressure to operate reliably but "M855 lacks enough pressure at the

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from the 5.56mm M193 to the heavier NATO standard M855,] the US Army changed propellants to assure that the pressure that powered the firearm did not change and the chamber and port pressures of M855 are nearly identical to those of M193." See Mark Westrom, "Technical Note 104: Some Thoughts on Design and Reliability of AR-Style Firearms" (Technical Note, Armalite, Inc, 2012), 2.

When comparing the M4's carbine length gas system with the M16's rifle length gas system, Westrom explained that: "the M4 carbine's gas port is located closer to the chamber than the gas port of the M16 so "the gas pulse reaches the bolt carrier group earlier than it does in the rifle length barrel and the carbine's port pressure is also double that of the rifle (around 26,000 PSI vs 13,000 PSI for M855 ammunition). The carbine's gas port must be smaller in diameter than the rifle's gas port to compensate for the higher pressure. The earlier pressurization of the bolt carrier group causes the M4 to extract earlier than the M16 does and the cartridge case has less time to shrink away from the chamber wall before extraction begins." See Mark Westrom, "Technical Note 104," 2.

Although extraction in the M4 is less efficient than that of the M16, stronger extractor springs and an extractor O-Ring, which "adds four times more extractor tension," has improved extraction reliability in the M4 and the M4 is still a reliable weapon. See Bartocci, "The M16 in Vietnam," and Mike Pannone and Erik Lawrence, *HK416 Handbook* (Philippi: Blackheart International, 2008), 43.

[374] Email communication from Salvatore A. Fanelli to author, January 8, 2015.

5.56mm L2A2 has a higher port pressure because it uses "tubular powder and has a slightly smaller case volume." See Email communication from COL Miroslaw Zahor to author, March 1, 2015.

[375] Email communication from Salvatore A. Fanelli to author, January 8, 2015.

Compared to a M16A4 firing M855 ammunition, a M16A4 firing L2A2 ammunition will have a lower Mean Rounds Between Stoppages (MRBS) than the former. See Email communication from Salvatore A. Fanelli to author, January 8, 2015.

MRBS "is determined by dividing the total number of rounds fired by the total number of stoppages and a stoppage is defined as any unplanned cessation in firing or the inability to commence or cease firing attributable to the gun." See Dan Shea, "Torture Test: US Ordnance MAG-58/M240," *Small Arms Defense Journal* (2013):3, accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=1692.

[376] Email communication from Salvatore A. Fanelli to author, January 8, 2015.

[377] Ibid.

gas port of the SA80A2 due to the upgraded action springs."[378] Although the M4 is not a NATO reference weapon, both the M16A4 and SA80A2 rifles are NNWs and "have to work with all NATO Qualified ammunition designs."[379] But the above mentioned issues showed that some NATO Qualified ammunition designs were not reliable enough for combat use in certain NNWs. In hindsight, there would have been greater logistical benefits if ammunition standardization had allowed all 5.56mm NATO Qualified designs to operate reliably in all 5.56mm weapons in NATO service. A greater degree of standardization would have allowed a common source of ammunition supply and would give national commanders more options regarding the use of another NATO state's ammunition during multinational and distributed operations.

Another supposed advantage of NATO standardization was that a member state which experienced ammunition shortages could procure ammunition from another alliance member. After the Vietnam War, the US shut down "all other government owned ammunition production facilities" aside from Lake City Army Ammunition Plant and discontinued "contracted production for small arms ammunition."[380] During the GWOT, the US Army's demand for small arms ammunition increased significantly compared to previous periods.[381] "The Lake City Ammunition Plant was the sole production facility for small arms ammunition" but was unable to manufacture sufficient quantities of ammunition for the US Army's needs.[382] Due to "the lack

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[378] Jack Leuba, email message to author, January 9, 2015.

[379] NATO Army Armaments Group, *LCG/1/SG/1 NATO Nominated Weapons List* (September 2010), 1-2. Arvidsson, "Weapons & Sensors," 8.
The SA80A2 rifle and LSW were known as the L85A2 and L86A2 respectively. The L85A2 rifle is a NNW but the L86A2 LSW is not a NNW. In addition the L85A2 and M16A4, the other 5.56mm NNWs are the G36, FNC and AR-70/90 assault rifles and Minimi LMG. See NATO, *NATO Nominated Weapons List*, 1-2.

[380] MAJ Mark W. Siekman, "Small Arms Ammunition Production and Acquisition Strategy for the US Army" (Masters Thesis, US Army Command and General Staff College, 2009), 22.

[381] Ibid.

[382] Ibid, 18, 50.
The Lake City Ammunition Plant is Government Owned and Contractor Operated. The US Army's "total annual requirements for 2005 was 1.253 billion rounds of 5.56mm and 282 million rounds of 7.62mm linked." But the "maximum annual production at Lake City was 1.2 billion rounds of 5.56mm and 230 million rounds of 7.62mm linked." See Siekman, "Small Arms Ammunition Production and Acquisition Strategy for the US Army,"20, 42).

of availability of M855 ammunition" during the GWOT, the US Army ordered British 5.56mm L2A2 ammunition for training use in the M16A2/A4, M4/M4A1 and M249.[383] The Americans believed that utilizing L2A2 ammunition in US weapons for training was advantageous because standard issue M855 could be conserved for use in combat operations.[384] The third edition of AOP-6 Vol. II authorized "5.56mm L2A2 ammunition for training use only" and L2A2 was the only 5.56mm round listed in the catalogue that "was capable of being interchanged with M855 and could be safely fired from the M16A2/A4, M4/M4A1 and M249."[385]

However, 2nd Battalion, 325th Airborne Infantry Regiment, 82nd Airborne Division (2-325 AIR) experienced significant reliability issues when using L2A2 in M4 carbines during training in 2006.[386] Soldiers encountered numerous failures to extract (FTE) in the M4, which "rendered all types of training substantially less effective due to the repetitive interruptions" caused by such malfunctions.[387] Company level armourers attempted to retain functionality of the M4s by changing extractors and springs when experiencing FTEs and increased component wear. As a result, training was disrupted and heightened parts replacement intervals were required.[388] The FTEs were likely due to the L2A2's higher port pressure causing "the bolt to open up earlier and at higher speeds while the cartridge was still sticking in the chamber."[389] Worse off, "M4 bolts

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[383] Email communication from Jim Schatz to author, February 25, 2015.
Jeffrey Dykeman, "Small Arms Ammunition Know What You Are Shooting," *Infantry*, January-February 2008, 50.

[384] Ibid.

[385] NATO, *AOP-6 (V) Vol. II*, 104-1.

[386] Jason R. Gillis, "Failure Report in Relation to U.K. 5.56mm Ammunition" (Report to NATO, SG-1, 2010).

[387] Ibid.

[388] Ibid.

[389] Email Communication from Jim Schatz to author, February 25, 2015.
Stevens and Ezell, *The Black Rifle*, 217.
Gillis' report on the L2A2 ammunition stated that: "analysis by the battalion master gunner and other experienced NCOs concluded that the symptoms were indicative to a difference in the cycle times of L2A2 compared to the M855 resulting in (or resulting from) over-pressure related failures, primarily during the extraction cycle. [L2A2 produced more fouling compared to M855 and] while this did increase maintenance time, it was not believed that increased fouling was enough to substantially hinder the M4's cycle of operation had it not been for other identified issues." See Gillis, "Failure Report in Relation to U.K. 5.56mm Ammunition."

began to break at an excessively high rate when using L2A2" and two companies from "2-325 AIR alone had experienced no less than six broken bolts in one afternoon of reflexive firing training."[390] This showed that the L2A2's higher port pressures overdrove the M4's bolt group and led to premature bolt failures. Because of the unit's allocation of weaponry and training demands, the bolt failures hindered "the rifle company's ability to provide adequate numbers of M4s for training."[391] In order to avoid the above mentioned issues with L2A2, the battalion had to use L2A2 sparingly and "request M855 when forecasting training ammunition."[392] Although 5.56mm L2A2 was safe for training use because it will chamber and fire in the M4, the reliability issues caused by the British NATO Qualified ammunition significantly hindered training tasks.

Although a STANAG required some compromises because they are an "agreement of all parties," STANAG 4172's purpose was "to ensure ammunition interchangeability on the battlefield."[393] But the above mentioned examples showed that STANAG 4172 did not allow total ammunition interchangeability because some NATO Qualified ammunition designs did not demonstrate an adequate level of reliability for combat use and had issues during training use in certain NATO weapons. There were limitations to some of STANAG 4172's technical performance specifications such as its average gas port pressure requirements, which stated that "the average pressure at the gas port minus three standard deviations shall not be less than 88 megapascals (MPa) when measured at 21 degrees Celsius."[394] This showed that NATO "only standardized the port pressure for the lowest level of pressure but there is no limit for high

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[390] Gillis, "Failure Report in Relation to U.K. 5.56mm Ammunition."
The bolt breakages experienced were primarily at the two locking lugs adjacent to the extractor and M4's with broken bolts had to be taken out of service. See Gillis, "Failure Report in Relation to U.K. 5.56mm Ammunition."
[391] Ibid.
[392] Ibid.
[393] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015.
NATO, *STANAG 4172*, 1.
[394] Ibid, C-2.

pressure."[395] The gas port pressures of both 5.56mm L2A2 and M855 were not less than 88 MPa so both ammunition designs "met the STANAG's requirements."[396] As can be seen, STANAG 4172's technical performance specifications were "too general" to guarantee that all SS109 designs manufactured to its standards would function reliably in all 5.56mm caliber weapons in NATO service.[397] In spite of the problems with some of STANAG 4172's technical requirements, NATO ammunition STANAGs do not receive significant revisions because "any major change to a STANAG will lead to a re-adoption of the STANAG by each country and this process is too complicated to do all over again."[398]

The GWOT required the US to wage war as a coalition and showed that there was a need for American and NATO troops to use each other's ammunition during emergency combat situations and for training. The inability of the STANAGs to ensure that all 5.56mm NATO Qualified ammunition designs would operate reliably in all 5.56mm caliber NATO weapons limited the number of ammunition options available for combat and training use. The US has compensated for Lake City's production shortfalls by "awarding additional sourcing contracts to their indigenous firm General Dynamics Ordnance Tactical Systems for approximately 300 million additional small arms ammunition rounds."[399] But even the combined production capabilities of General Dynamics and Lake City may be insufficient to meet the US military's ammunition demands for total conventional warfare.[400] For example, during the Second World War, the US Army needed 21.6 billion rounds of small arms ammunition in a year and the

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[395] Ondrej Podel, email message to author, February 17, 2015.
[396] Westrom, "Technical Note 104," 3.
Email communication from COL Miroslaw Zahor to author, March 1, 2015.
[397] Ibid.
[398] Email communication from French Defense Professional to author, December 7, 2015.
[399] Siekman, "Small Arms Ammunition Production and Acquisition Strategy for the US Army," 50.
[400] Ibid.

Americans were also required to provide ammunition for their allies.[401] If this kind of high intensity conventional warfare scenario occurs again, the US government would have to re-open their closed ammunition manufacturing plants, but a greater degree of ammunition standardization would be beneficial for NATO in this situation. If specific NATO Qualified ammunition designs did not have functional issues in certain NATO weapons, then the US could supply their own military and allied forces with a common ammunition design and have the option of procuring ammunition from their allies if shortages arise.

4.4 Common NATO Rifle for the Future?

Although NATO has standardized infantry weapon calibers, the alliance has been unsuccessful at standardizing a common rifle since its creation and is unlikely to adopt a common rifle in the future. In the 1990s, Western European countries with existing firearms industries chose to procure indigenously designed 5.56mm assault rifles when they needed NATO compliant weapons. After the Cold War, the "German constitution was amended" to enable participation in foreign military missions so the Bundeswehr needed a rifle firing NATO standard SS109 ammunition.[402] As a result, HK developed the 5.56mm HK50 rifle to meet the German Army's requirements of the 1990s, which was evaluated alongside the Austrian Steyr AUG rifle by the Bundeswehr.[403] The Bundeswehr choose to adopt the HK50 as the G36 in 1997 because they wanted a modern lightweight 5.56mm assault rifle and preferred weapons that were made by domestic industries (See Figure 25). [404]

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[401] Ibid, 19, 39

[402] Jim Schatz, email message to author, November 25, 2015.

[403] Both the G36 and Steyr AUG "made extensive use of plastics externally and internally" and the G36 uses a polymer receiver with steel inserts. See Stevens, *Full Circle*, 461.

[404] Stevens, *Full Circle*, 461.

Email communication from Jim Schatz to author, December 14, 2015.

In HK's testing, the G36 was more reliable compared to other 5.56mm assault rifles available at the time. See Email communication from Jim Schatz to author, December 14, 2015.

Figure 25: G36 assault rifle.

Source: "G36," accessed October 20, 2015, http://hk-usa.com/hk-models/g36/.

A positive feature of the G36 was that HK tested the rifle's self-regulating pusher rod gas system with 200 different ammunition types to ensure reliable function with most 5.56mm rounds encountered internationally.[405] In 1990, Italy procured the 5.56mm AR70/90 rifle from their indigenous firm Beretta when their military forces needed a rifle firing NATO standard ammunition.[406] Since Beretta had significant political influence in Italy, the maintenance of their

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Although the G36 met the "technical supply specifications established by the Germany Army," it has been reported that the Bundeswehr's G36 allegedly suffers from Point of Impact shift due to thermal shock but not all of the information regarding this issue are currently public. See "Additional response by Heckler & Koch to the press statement of the German Minister of Defence regarding the assault rifle G 36," accessed May 20, 2015, http://www.heckler-koch.com/en/press/detail/article/additional-response-by-heckler-koch-to-the-press-statement-of-the-german-minister-of-defence-regar.html.

The German government plans on opening a tender to European firearms industries for a new assault rifle starting in 2019. See Thomas Wiegold, "German Armed forces to scrap G36 Assault Rifle, will procure new system,"*Augen Geradeaus*, September 8, 2015, accessed September 9, 2015, http://augengeradeaus.net/2015/09/german-armed-forces-to-scrap-g36-assault-rifle-will-procure-new-system/.

Later on, it was reported that a commission interviewed over 150 German soldiers and those soldiers stated that they did not experience accuracy issues with the G36. "Mängel bei Sturmgewehr G36 Die Bundeswehr trifft doch," *taz.de*, accessed October 30, 2015, http://www.taz.de/!5243499/.

[405] Email communication from Jim Schatz to author, February 25, 2015.

The G36's gas system is comprised of a short stroke gas piston and pusher rod. The G36's gas system is self-regulating because as the gas piston is traveling rearwards, "the tip of the piston will expose the forward gas escape vent and gases not needed to operate the system will be vented out the gas block." See *G36 Armorers Instruction* (Heckler & Koch, Inc. USA, 2002).

It was HK's own requirement to test the G36 with around 200 different types of 5.56mm ammunition and the German Army did not specify for the G36 to work with around 200 different ammunition types. Although the G36 operates reliably with most 5.56mm ammunition designs, it does not function reliably with a few lightweight 5.56mm frangible rounds that are not NATO Qualified designs. See Jim Schatz, email message to author, November 25, 2015 and NATO, *NATO Design List*, 1-1.

Also, "the G36 SF, a semi-automatic version for the British Police, has been adjusted to British ammunition and has a different diameter of gas port" than the German G36s. See Email communication from COL Miroslaw Zahor to author, June 18, 2015.

[406] Popenker and Williams, *Assault Rifle*, 127.
Stevens, *Full Circle*, 334.

domestic firearms industry was a major reason that the Italians chose to adopt the indigenous AR-70/90.[407]

But compared to the Cold War, some Western European NATO states no longer have indigenous firearms industries and will have to procure foreign designs once their existing service rifles are worn out. Due to the fulfillment of the British Army's orders and the lack of foreign orders, the SA80 is no longer in production and Royal Ordnance Factory Nottingham was closed in 2001.[408] After the demise of the G11 program, HK experienced significant financial problems, was acquired by BAe in 1991 and the SA80A2 upgrades were conducted in Germany.[409] But HK was sold to German investors in 2002, which meant the British no longer owned any small arms industries and will need to procure a foreign rifle once the SA80A2 reaches the end of its service life in 2025.[410] France rejoined NATO in 2009 and plans on procuring new rifles after 2016 because the "cost to sustain their fleet of FAMAS rifles, which were manufactured between 1979- 89, is rising exponentially."[411] Also, re-entry into NATO meant that the French Army wanted a new standard rifle that was compatible with SS109 ammunition.[412] But the FAMAS' successor will be a foreign design because MAS was shut down in 2002 due to the fulfilment of the French military's orders and the lack of foreign sales of the FAMAS.[413] So the number of different rifle models in service with Western European NATO forces is expected to decrease in the future. But a common rifle for American and Western

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[407] Ibid.
[408] Raw, *The Last Enfield*, 280.
[409] "Chronicle", accessed May 20, 2015, http://www.heckler-koch.com/en/company/history/print.html.
[410] Ibid, 312.
Anthony G. Williams, "Shooting stars: divining the signs for small arms replacements," *International Defence Review*, November 27, 2013.
[411] Cody, "After 43 Years, France to Rejoin NATO as Full Member."
Email communication from French Defense Professional to author, February 4, 2015.
[412] Ibid.
[413] Ibid.
Remigiusz Wilk, "France launches FAMAS replacement tender," *IHS Jane's Defence Weekly,* May 22, 2014.

European members is still unlikely because some states still have domestic firearms industries, such as FNH in Belgium and Beretta in Italy, and those states may continue to procure indigenous weapons in the future.[414] For example, when the Italian Army needed a more modern 5.56mm rifle for their future soldier program, they chose to adopt Beretta's new ARX-160 rifle as the successor to the AR-70/90 in 2009 (See Figure 26).[415]

Figure 26: AR-70/90 assault rifle.

Source: "Beretta AR-70/223 and AR-70/90 assault rifle (Italy)," accessed October 20, 2015, http://world.guns.ru/assault/it/beretta-ar-70223-and-ar-7090-e.html

4.5 Eastern European Challenges towards NATO Standardization

Furthermore, the introduction of new alliance members were further obstacles towards a common NATO rifle and ammunition standardization. Several former Warsaw Pact states such as Poland, Hungary, the Czech Republic, Latvia, Lithuania, Bulgaria and Romania have recently acquired NATO membership through NATO programs such as the Partnership for Peace and Membership Action Plan.[416] But a mutual problem for Eastern European NATO members in terms of infantry weapons standardization was that their militaries used the Warsaw Pact's small

[414] Although HK has several firearms that are the best in their class and have some of the best material technologies, the company is currently in financial trouble due to mismanagement along with German government restrictions on weapons and parts sales abroad. As a result, it is currently not known if HK would still be around in the future. See Email communication from Jim Schatz to author, December 14, 2015.

[415] "Soldato Futuro Future Soldier System, Italy," accessed May 20, 2015, http://www.army-technology.com/projects/italiansoldiersystem/ .

[416] Leszek Erenfeicht and Lt. COL Miroslaw Zahor. "Beryl Tantalsson: The Saga of the Polish Kalashnikov Continues," *Small Arms Defense Journal* 1 (2011):1, accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=295.

Raymond A. Millen, *Tweaking NATO: The Case for Integrated Multinational Divisions* (Carlisle: Strategic Studies Institute, 2002), 10, 13.

arms calibers such as 7.62x39mm, 5.45x39mm and 7.62x54R.[417] One solution to improve compatibility with NATO was for Eastern European states to procure NATO caliber weapons which are already in service with the alliance's Western member states. This could been seen in Hungary and Czech Republic's purchase of the Minimi LMG and the adoption of the G36 rifle by the Latvian and Lithuanian militaries.[418] But several Eastern European NATO members still have domestic arms industries and may rely on their own indigenous defense companies for less sophisticated types of weapons, which would prevent the fielding of a common rifle for all NATO states.

The domestic industries of both Poland and the Czech Republic were involved in their states' small arms modernization efforts by developing indigenous 5.56mm rifles for the needs of their national militaries. The Polish government preferred to entrust their indigenous industries with the development of weapons that would be compatible with other NATO forces rather than procuring foreign weapons.[419] This could be seen in the Deputy Director of the Technical Directorate of the General Staff's statement that "the government and the Polish Armed Forces should adopt as a standard the requirement that every kind of product supplied to the military include a contribution of the Polish engineer and worker."[420] This showed that Poland wanted to maintain self-sufficiency and to promote the development of their domestic industries.[421] In 1995, the Polish General Staff set new requirements for an assault rifle in order to field a rifle that was compatible with NATO standard SS109 FMJ ammunition. This led to the development

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[417] Email communication from Per G. Arvidsson to author, December 9, 2014.
[418] Arvidsson, "NATO Weapons & Sensors Working Group," 10.
"Latvia's 'riflemen' now equipped for the 21st century," accessed May 20, 2015, http://www.rigasummit.lv/en/id/cats/nid/877/.
"Weaponry and Technology," accessed September 1, 2015, http://kariuomene.kam.lt/en/weaponry_and_technology.html.
[419] Patterson, Markov and Richter, *Western-Style Armaments for New NATO Countries*, 2-19.
[420] Ibid, 2-20.
[421] Ibid, 3-18.

of the 5.56mm caliber Beryl assault rifle, which was accepted for service in 1997 by the Polish Army (See Figure 27).[422] Since the Beryl was based on the AKM rifle of the 1950s, it had the same weaknesses as the older Soviet design including less than ideal ergonomics and the need to re-zero optical sights after fielding stripping.[423]

Figure 27: Beryl assault rifle.

Source: "Mod. 96 Beryl Assault Rifle," accessed October 20, 2015. http://en.fabrykabroni.pl/?d=111.

As the Beryl cannot be upgraded any further, "the Modular Small Arms System 5.56mm (MSBS-5.56) Program was launched in 2007 as a joint research and development program of Poland's domestic firm FB Radom and Military Technology University" (See Figure 28).[424]

Figure 28: MSBS-5.56 assault rifle in conventional configuration.

Source: "MSPO 2013, MSBS-5.56 The next generation Polish assault rifle," accessed March 16, 2016, http://loadoutroom.com/6926/mspo-2013-msbs-5-56-next-generation-polish-assault-rifle/.

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[422] Leszek Erenfeicht and Lt. COL Miroslaw Zahor. "Beryl Tantalsson: The Saga of the Polish Kalashnikov Continues," 2.

[423] Ibid.

[424] Ibid.
Leszek Erenfeicht, "Radon MSBS-5.56: Poland's New Battle Rifle," *Small Arms Defense Journal* 7 (2015), accessed June 1, 2015, http://www.sadefensejournal.com/wp/?p=2975.

The MSBS-5.56 is intended to replace the Beryl and is available in both conventional and bullpup rifle configurations that share a common upper receiver and both configurations will consist of assault rifle, carbine, designated marksman and automatic rifle variants.[425] Poland "plans on having each of its military branches choose the rifle configuration" that best suits their needs although the bullpup configuration will most likely be used by special units.[426] This is a case that suggests that states with the capability to develop their own NATO compatible designs will do so rather than procure rifles designed by Western firms.[427]

Furthermore, the Czech Republic chose to not procure rifles in service with other NATO allies when they gained NATO membership. During the Cold War, the Czech firearms firm Ceska zbrojovka (CZ) had supplied the Czechoslovakian Army with indigenous assault rifle and machine gun designs. After the separation of Czechoslovakia in 1992, CZ became a private company of the Czech Republic.[428] Before 1998, it was uncertain whether the Czech Army would support native industries or procure Western weapons, but afterwards the Czech government "has promoted an environment to strengthen the Czech defense industry."[429] The government believed that supporting domestic industries would "bolster the Czech Republic's overall economy" and native firms will be responsible for producing NATO compatible weapons.[430] Starting in 2005, CZ designed a new 5.56mm rifle known as the CZ805 with the intention of becoming the Czech Army's new service rifle (See Figure 29).[431]

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[425] Ibid.
[426] Anthony G. Williams, "Design dilemma: the challenge of future small arms and ammunition development," *Jane's International Defence Review*, August 1, 2014.
[427] Patterson, Markov and Richter, *Western-Style Armaments for New NATO Countries*, 3-18.
[428] Leszek Erenfeicht, "Old Name, New Gun: The CZ 805 Bren Modular Rifle," *Small Arms Defense Journal* 4 (2012):1, accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=1083.
[429] Patterson, Markov and Richter, *Western-Style Armaments for New NATO Countries*, 2-7.
[430] Ibid.
[431] Leszek Erenfeicht, "Old Name, New Gun: The CZ 805 Bren Modular Rifle," 2.

Figure 29: CZ805 assault rifle.

Source: "CZ 805 Bren A1," accessed October 20, 2015, https://www.czub.cz/en/catalog/86-law-enforcement-military/OS-AUT/CZ_805_BREN_A1.aspx.

In 2009, the Czech Ministry of Defense released a tender for a rifle capable of firing SS109 ammunition so that Czech and other NATO soldiers can share each other's ammunition during emergencies.[432] The CZ 805 assault rifle won the tender and the Czech Republic chose to procure the "domestic rifle design due to its technical performance."[433] After the Czech Army's trials of the CZ805, "minor changes were made" to the new rifle and the Czech Army received their first deliveries of the CZ 805 in 2011.[434] Thus, the Czech Republic's adoption of the CZ 805 is arguably a case showing that governments might in some instances prefer to procure weapons from domestic industries due to economic reasons and would adopt an indigenous rifle if such a design was believed to be the best candidate from the technical standpoint.

Some Eastern European states such as the Czech Republic and Poland have made progress towards NATO standardization by designing modern small arms in NATO calibers but the transition to NATO caliber small arms and NATO Qualified Ammunition designs will be dependent on the procurement funding provided.[435] Due to limited funding, Eastern European states will have "to acquire NATO caliber small arms over several years and those weapons will

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[432] Ibid.
Jiri Kominek, "Czechs expect CZ 805 assault weapon delivery," *International Defence Review*, November 24, 2011.
[433] Ondrej Podel, email message to author, January 18, 2016.
[434] Ibid.
[435] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015

be prioritized for units first scheduled to adjust to NATO standards or participate in NATO operations."[436] In addition, most new NATO members still need to get their ammunition designs NATO Qualified to ensure that the performance requirements of STANAGs 2310 and 4172 are met. In 2014, Lithuania was the only Eastern European alliance member to get their 5.56mm and 7.62mm NATO caliber ammunition designs NATO Qualified while Czech 5.56mm ammunition became NATO Qualified in 2015.[437] Poland has not yet submitted their 5.56mm and 7.62x51mm ammunition designs for NATO Qualification because the process is expensive but they intend on "having NATO Qualified ammunition in the future."[438] Aside from getting their own ammunition NATO Qualified, some Eastern European members will need additional funding for conducting a national interchangeability study because they want to "reduce their own logistical footprints" by having another NATO state provide some of the ammunition supply.[439]

4.6 Current NATO Weapons Standardization Efforts

Although several NATO states like the US, Canada, Germany, Spain, the Netherlands and the UK need to procure new rifles around the 2020s period,[440] NATO does not have any

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[436] Patterson, Markov and Richter, *Western-Style Armaments for New NATO Countries*, 3-22.

[437] Email communication from Per G. Arvidsson to author, December 9, 2014.
Email communication from Michal Kuklik to author, August 17, 2015.

[438] Email communication from COL Miroslaw Zahor to author, February 20, 2015.
Also, Poland's domestic ammunition producer Mesko chose to manufacture a mild steel core 5.56mm FMJ bullet rather than the NATO SS109 style projectile for the Beryl rifle before Poland gained NATO membership. For more information, see Email communication from COL Miroslaw Zahor to author, February 20, 2015.

[439] CPT Cristian V. Rus, "Transformation of the Romanian Army" (Masters Thesis, US Army Command and General Staff College, 2006), 90.
NATO, *STANAG 2459*, B-1.
NATO, *AOP-6 (V) Vol. II*, VI.
According to Col Miroslaw Zahor: "Due to the Polish military requirements, the MSBS-5.56 to be chambered for the 5.56mm NATO standard cartridge. Therefore, all shooting tests of the MSBS-5.56 rifle will be carried out with NATO Qualified 5.56mm ammunition from RUAG and additional tests will be done using Mesko cartridges due to the Polish military's wishes." See Email communication from COL Miroslaw Zahor to author, February 20, 2015.
"The MSBS-5.56 rifle works well with Polish ammunition of moderate quality" and NATO Qualified RUAG ammunition but it might not have optimal reliability with every single foreign 5.56mm ammunition design that has been NATO Qualified. See Email communication from COL Miroslaw Zahor to author, June 18, 2015.

[440] Email communication from Jim Schatz to author, December 3, 2014.

plans for a common rifle in the future because many alliance members are not currently devoted to such a goal.[441] But NATO's Infantry Master Plan of 2004 had highlighted the characteristics for new 5.56mm NATO assault rifles. Those features are a shorter barrel and accessory rails.[442] Some examples of NATO assault rifles that meet the above mentioned criteria include the M4/M4A1, C8A3, ARX-160, CZ805 and MSBS-5.56. Due to the failure to adopt a common rifle, NATO "has started to standardize the interfaces on infantry weapons for the last ten years and will continue to do so."[443] The NATO Accessory Rail is a weapon interface that became NATO standard after "the ratification of STANAG 4694 by Belgium, Bulgaria, Canada, the Czech Republic, Germany, Denmark, Spain, Estonia, France, the UK, Hungary, Italy, Lithuania, Luxemburg, Latvia, the Netherlands, Romania and the US."[444] The NATO Accessory Rail is "backwards compatible with the US Picatinny rail used on many of the alliance's rifles but provides better zero retention and repeatability for optics and accessories" compared to the former.[445]

Moreover, rifle magazines are another weapons interface that NATO is currently working to standardize. During the aftermath of the 1976-79 trials, STANAG 4179, which "proposed the standardization of the interface for the thirty round M16 magazine for all 5.56mm rifles and magazine fed LSWs in NATO service, was drafted but never finalized."[446] Since NATO did not

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[441] Email communication from Per G. Arvidsson to author, January 29, 2015.
"Testing Times – Nato's Rifle Standardisation Dilemma," accessed May 20, 2015, http://www.army-technology.com/features/feature60347/

[442] Per G. Arvidsson, "Soldier Lethality and Wound Ballistics from a Swedish Perspective" (presented at the National Defense Industrial Association, Atlantic City, New Jersey, May 16-19, 2005, http://www.dtic.mil/ndia/2005smallarms/wednesday/arvidsson.pdf), 17.

[443] Email communication from Per G. Arvidsson to author, December 9, 2014.

[444] Arvidsson, "NATO Weapons & Sensors Working Group, 18, 19.

[445] Ibid.
Felix A. Alejos Cutuli, "NATO Developments on Rail Interface Systems," *Small Arms Review*, accessed May 20, 2015, http://www.smallarmsoftheworld.com/display.article.cfm?idarticles=1047.

[446] Stevens and Ezell, *The Black Rifle*, 370.

standardize magazines, some European manufactures chose to design their rifles around proprietary magazines instead of the M16 pattern magazine. The thirty round US Government Issue (USGI) M16 magazine had a curved bottom and straight top section. As a result, "the cartridges must turn a corner where the magazine transitions from the radius's section to the upper straight section, which may cause the cartridges to readjust their position or bind" and the magazine follower to get canted.[447] In 2009, the US Army introduced an improved version of the USGI M16 magazine, which used anti-tilt followers and "heavier springs and these features had improved magazine reliability by fifty percent."[448] But in theory, well designed full radius magazines are still more reliable than the improved USGI magazines because "anytime the cartridge stack has to change from the radius dictated by the cartridges dimensions there is the possibility of sticking or binding in the magazine."[449] Both the G36 and older versions of the CZ805 use proprietary full radius magazines for ideal magazine reliability while the M16 series,

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[447] Cris E. Murray, email message to author, August 9, 2010.
"Army's Improved Magazine Increases Weapons Reliability: 'Tan is the Plan' for the New Magazine," accessed May 20, 2015, http://peosoldier.armylive.dodlive.mil/2009/12/14/armys-improved-magazine-increases-weapons-reliability-tan-is-the-plan-for-the-new-magazine/
The "original twenty round M16 magazine had a straight body because the taper of the cartridge case and the number of cartridges did not require a radius to be formed into the magazine and the angled bottom plate provided enough offset for the accumulated angles." See Cris E. Murray, email message to author, August 9, 2010.
In 1966, the US military requested the development of the thirty round M16 magazine and a thirty round magazine required a full radius magazine body for optimal reliability. Since the M16 had a straight magazine well, a fully curved magazine "would not fit in many M16s" and it was decided to design a magazine with a curved bottom portion and straight top section. See Stevens and Ezell, *The Black Rifle*, 236, 237.
[448] "Army's Improved Magazine Increases Weapons Reliability."
[449] Cris E. Murray, email message to author, August 22, 2010.
Since "many stoppages begin in the magazine or the interface of the magazine with the breech mechanism, HK designed a reliable proprietary full radius magazine and then designed the G36 and its magazine well around the full radius magazine to ensure that the rifle's feeding dynamics were uncompromised." See Jim Schatz, email message to author, November 25, 2015.
Another weakness of the M16 magazines was that they have a limited service life because they were initially designed to be disposable and have thin aluminum walls. See Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 43.
Polymer materials of the 1990s required the magazine walls of a polymer magazine to be two to three times thicker than a metal magazine to have the same strength. The G36 magazine has sufficient magazine wall thickness to allow for a durable polymer magazine, "a good quality spring and anti-tilt follower" and a longer service life than USGI M16 magazines. Also, the G36 magazine is more drop impact resistant than the USGI M16 magazine because "aluminum bends and stays bent while polymer flexes." See Jim Schatz, email message to author, February 8, 2010.

SA80, AR-70/90, ARX-160 and MSBS-5.56 all use M16 style magazines (See Figure 30).[450] This meant that on joint operations, soldiers equipped with G36s and earlier CZ805 models cannot use the M16 style magazines of other NATO forces if their ammunition load is exhausted during a tactical engagement and NATO is currently working on standardizing rifle magazines.[451]

Figure 30: M16 and G36 magazines.

The magazine on the left is the 30 round USGI M16 magazine, which has a curved bottom and straight top section. In contrast, the G36 magazine shown on the right has a full radius/constant curve magazine body.
Source: Arvidsson, "NATO Infantry Weapons Standardization."

The improved USGI M16 magazine is currently the most logical choice for standardization because those magazines have acceptable reliability and the majority of NATO rifles utilize M16 style magazines.[452] Also, both the G36 and previous CZ805 models could use M16 style

[450] Leszek Erenfeicht, "Old Name, New Gun: The CZ 805 Bren Modular Rifle," 3.
[451] Arvidsson, "NATO Infantry Weapons Standardization," 14
Vladimir Marek, "Aligning the crosshairs with the hit point," *Czech Army Review*, February 2012, accessed May 20, 2015, http://www.mocr.army.cz/assets/multimedia-a-knihovna/casopisy/czech-army/areview_2-2011.pdf, 17.
[452] Although full radius magazines such as the G36 magazines are a better design, improved USGI magazines are still reliable and most magazine related issues are due using poorly maintained or worn out magazines. See "Gunfighter Moment – Mike Pannone," accessed May 20, 2015, http://soldiersystems.net/2015/06/20/gunfighter-moment-mike-pannone-28/.

magazines by swapping out their original magazine wells[453] while "new versions of the CZ 805" are delivered with the M16 magazine well.[454]

During the aftermath of the 1976-79 trials, NATO failed to adopt a common rifle and was only able to standardize the 5.56mm SS109 round by having its member states ratify STANAG 4172. While STANAG 4172's purpose was to enable NATO states to use each other's SS109 ammunition, its technical performance specifications could not insure that all SS109 designs would achieve a sufficient degree of reliably in all 5.56mm weapons for combat use and not hinder training tasks. Improving 5.56mm ammunition interchangeability at the NATO level is currently not practical because a significant revision to STANAG 4172 would require all NATO states to a re-ratify the STANAG.[455] It is unlikely that a common rifle will be standardized for all NATO forces in the future because states with domestic industries generally prefer to adopt their own designs rather than procure foreign weapons. In particular, the governments of several Eastern European alliance members have emphasized that they would prefer to rely on their domestic industries to produce NATO compatible weapons due to economic reasons. The Czech Republic and Poland have made progress by designing modern 5.56mm rifles that meet the characteristics outlined in NATO's Infantry Master Plan. But Eastern European members can only complete their transition to NATO compatible small arms, get their ammunition designs NATO Qualified and conduct a national interchangeability study if increased funding would be available for such purposes. Since adopting a common NATO rifle and modifying STANAG

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[453] Vladimir Marek, "Aligning the crosshairs with the hit point," 17.
"Conversion magazine well for use of HK416 type magazines," accessed May 20, 2015, http://www.heckler-koch.com/en/products/accessories/accessories-military-law-enforcement/detail/articlenumber/210777.html.

[454] Ondrej Podel, email message to author, January 18, 2016.
"The Czech Army is currently using the USGI M16 magazines as a standard." See Ondrej Podel, email message to author, January 18, 2016.

[455] Email communication from French Defense Professional to author, December 7, 2015.

4172 to improve interchangeability for 5.56mm ammunition are both unfeasible, the alliance will improve standardization by adopting common interfaces for small arms and machine guns.

Chapter 5: Alternatives to NATO Standard SS109

5.1 Is NATO Standard 5.56mm SS109 Ideal for Rifle Use?

Although maintaining ammunition standardization within NATO is important, another crucial factor that the alliance should consider regarding ammunition is whether the existing standards "remain current in the face of evolving user requirements."[456] The experiences of several NATO states during the GWOT showed that SS109 ammunition designs were not optimal for rifle use. M855 bullets may significantly fragment in tissue at a minimum impact velocity of 2700 fps and "continue to break into two large fragments until the velocity was under 2500 fps."[457] When fired from the M16 and M4, M855 reached 2500 fps around 200m and 120m respectively and M855's terminal performance was significantly reduced beyond those ranges (See Figure 31).[458] Since NATO's Infantry Weapons Master Plan calls for shorter barrel assault rifles like the M4, it would be ideal to develop ammunition that would fragment at lower velocities. There have been numerous accounts from experienced US military personnel in Afghanistan and Iraq that M855 rounds had inconsistent terminal performance and may pass through a target without yawing and fragmenting. [459] A bullet's penetration "depth before initial bullet upset is known as neck length (NL)."[460] The complaints about the M855's inconsistent terminal performance showed that a FMJ rifle bullet may penetrate deeper than they do on average before yawing, which resulted in a long NL and minimal wounds.[461] These issues were a

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[456] Email communication from Defense Industry Professional and former Canadian Army officer to author, February 24, 2015.
[457] Fackler, "Wounding patterns of military rifle bullets," 61.
[458] Minisi, "Soft Target Terminal Ballistic Testing Standardization for the U.S. Military," 15.
[459] MAJ Glenn Dean and MAJ David Lafontaine, "Small Caliber Lethality: 5.56mm Performance in Close Quarter Battle," *Infantry*, September-October 2006, 26.
[460] Roberts, "Time for a Change," 10.
Upset means the bullet had begun to yaw, deform/expand or fragment. See Roberts, "Wound Ballistics Research and Consulting."
[461] Ibid, 7.
Martin L. Fackler, *Wound Ballistics Research of the Past Twenty Years: A Giant Step Backwards,* 3, 4.

concern for M16 and M4 users but the M855's performance was still considered acceptable for LMG requirements.[462] Likewise, there were accounts from some British and German soldiers in Afghanistan that their SS109 ammunition designs had inconsistent terminal performance.[463]

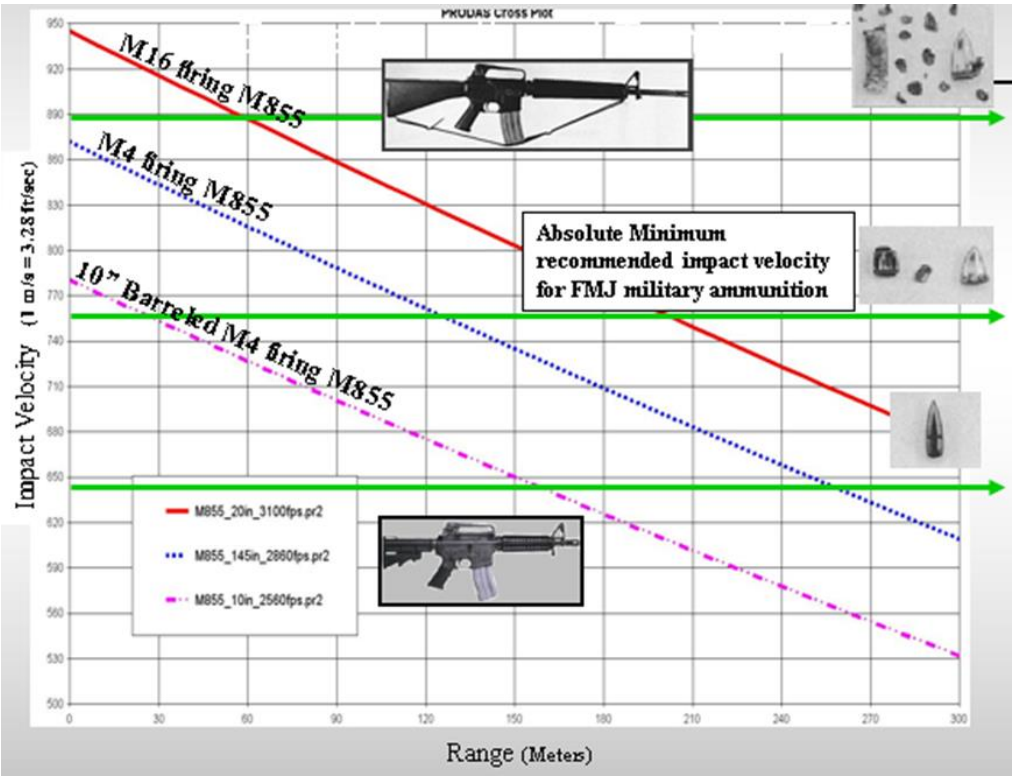

Figure 31: M855 fragmentation velocity.

The chart in Figure 31 shows the distances at which M855 would fragment after being fired from the 20 inch barrel M16A2/A4, 14.5 inch barrel M4 carbine and 10.3 inch barrel Mk 18 Close Quarter Battle Receiver (CQBR).
Source: Mark D. Minisi, "Soft Target Terminal Ballistic Testing Standardization for the U.S. Military" (presented at the National Defense Industrial Association Conference, Las Vegas, Nevada, May 10-13, 2004, http://www.dtic.mil/ndia/2004arms/session9/minisi.ppt).

5.2 The Human Body and Bullet Terminal Performance

Instantaneous incapacitation can only occur if the central nervous system (CNS) was disrupted but hitting the CNS of "fleeting or partially exposed" adversaries under combat

[462] Dean and Lafontaine, "Small Caliber Lethality: 5.56mm Performance in Close Quarter Battle," 26, 32. Roberts, "Time for a Change," 6.
[463] Nicholas Drummond and Anthony G. Williams, "Biting the Bullet" (Article, 2009), 11. Jim Schatz, "Do We Need A New Service Rifle Cartridge?: End User Perspective and Lessons Learned," *Small Arms Defense Journal* 3 (2011): 122.

conditions was not always possible.[464] If the CNS was not disrupted, then "circulatory system collapse from the severe disruption of the vital organs and blood vessels in the torso is the only reliable method of physiological incapacitation for small arms."[465] Accordingly, "bullets must penetrate at least twelve inches of tissue to ensure the disruption of the major organs and blood vessels in the torso from any angle and through intervening adipose tissue, hypertrophied muscle, or intervening anatomic structures."[466] Also, physiological incapacitation can happen more quickly when a larger amount of tissue was damaged given that "the damage occurred in some place on the body that was critical."[467] For ideal terminal performance, a rifle bullet needed to consistently "upset after one or two inches of initial tissue penetration along with maximum tissue damage during the first ten to twelve inches of travel."[468] Many rifle caliber FMJ bullet designs did not have good terminal performance and there were several cases in past conflicts where a FMJ bullet wounded rather than rapidly incapacitated an enemy combatant and such adversaries had to be shot numerous times.[469] For example, during the Battle of Khe Sanh, a US Marine had to "shoot a North Vietnamese soldier at least six times" with his 7.62mm NATO caliber M14 at close range to prevent his adversary from continuing hostilities.[470]

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[464] Ibid, 128.

[465] Roberts, "Wound Ballistics Research and Consulting."
"If the CNS is uninjured, physiological incapacitation is delayed until blood loss is sufficient to deprive the brain of oxygen. Multiple hits may be needed before an individual is physiologically incapacitated. An individual wounded in any area of the body other than the CNS may physiologically be able to continue their actions for a short period of time, even with nonsurvivable injuries." See Roberts, "Wound Ballistics Research and Consulting."

[466] Ibid.

[467] Ibid.
Dean and LaFontaine, "Small Caliber Lethality," 29.

[468] Roberts, "Time for a Change," 9.
For rifle bullets of the same caliber, those modern bullet designs that either expand or fragment in soft tissue will create a larger permanent cavity than bullets that just yaw in tissue.

[469] Martin L. Fackler, "Wound Ballistics and Soft-Tissue Wound Treatment," *Techniques in Orthopaedics* 10 (1995):166.

[470] Edward F. Murphy, *The Hill Fights: The First Battle of Khe Sanh* (New York: Presidio Press, 2003), 36.

5.3 Disadvantages of FMJ Bullets during the GWOT

While rifle bullets with improved terminal performance would have been beneficial for US and NATO soldiers in conventional wars, such bullets were urgently needed for the GWOT. When a 5.56mm bullet did not yaw and fragment in soft tissue and did not contact any major blood vessels and organs, then the resultant wound would be minimal and "rapid physiological incapacitation was unlikely."[471] This situation has placed the lives of US military personnel at risk and resulted in American casualties because fanatical terrorists and insurgents continued their hostile actions despite being wounded.[472] In addition, the wars in Afghanistan and Iraq involved Counter Insurgency (COIN) operations and "winning the local population's support by insuring the protection and welfare of the locals" was critical.[473] The need to reduce collateral damage was evident in the Tactical Directive issued by ISAF commander General David Patraeus, which stated that: "We must continue …our… efforts to reduce the loss of innocent civilian life to an absolute minimum. Every Afghan civilian death diminishes our cause. If we used excessive force or operate contrary to our COIN principles, tactical victories may prove to be strategic setbacks."[474] Since insurgents and terrorists were often intermingled with the local population, FMJ rounds that passed through enemy combatants without fragmenting posed a downrange hazard for civilians while bullets that consistently produced a short NL and fragmented or expanded in tissue may reduce such risks. Fanatics in Afghanistan and Iraq were not concerned about collateral damage and have continued to present a danger to civilians when they were wounded but not rapidly incapacitated. Rifle bullets with more consistent terminal

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[471] Roberts, "Time for a Change," 7.
[472] "J&A Number: 06-116" (Justification And Approval To Procure Using Other Than Full And Open Competition, Naval Surface Warfare Center, 2009), 2, 3.
[473] MAJ Joshua F. Berry, "Hollow Point Bullets: How History Has Hijacked Their Use In Combat and Why It Is Time To Reexamine The 1899 Hague Declaration Concerning Expanding Bullets," *Military Law Review* 206 (2010):128, 129.
[474] Ibid, 131.

performance would reduce the dangers posed to NATO soldiers and civilians because fewer shots will be required to incapacitate an adversary compared to FMJ bullets if all other factors are equal and lower the probability that stray rounds may accidentally hit civilians.[475]Also, 5.56mm FMJ rounds do not have good terminal performance against adversaries protected by "intermediate barriers such as walls, glass and vehicles commonly encountered when fighting in cities"[476] (See Figure 32).

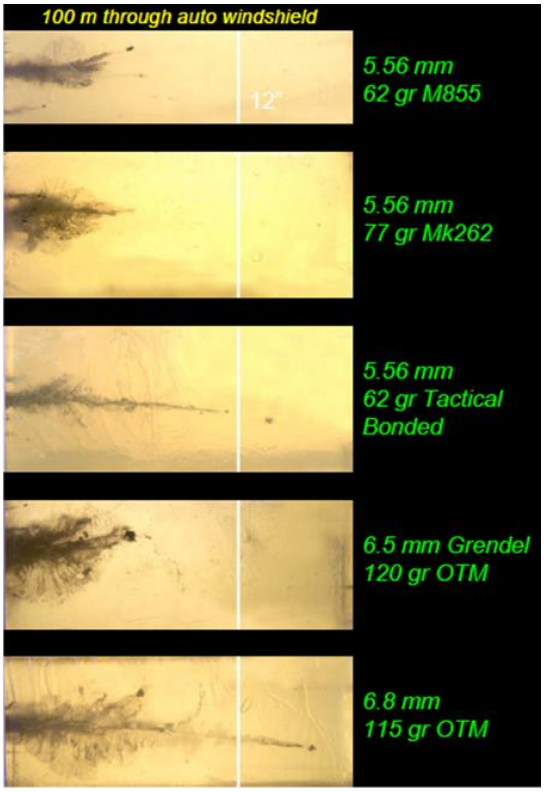

Figure 32: Penetration depth of bullets after first defeating an automobile windshield.

For the bullets shown in Figure 32, only the 6.8mm SPC 115 grain OTM and ATK's 5.56mm 62 grain Tactical Bonded JSP offer acceptable terminal performance against adversaries behind glass barriers because those two projectiles could penetrate at least 12 inches of tissue after defeating the automobile windshield. The 5.56mm Tactical Bonded JSP is a Blind to Barrier round. Despite not being a barrier blind projectile, the 6.8mm SPC 115 grain OTM displayed acceptable performance after penetrating the glass barrier.
Source: Gary K. Roberts, "Time for a Change: U.S. Military Small Arms Ammunition Failures and Solutions (presented at the National Defense Association Conference, Dallas, Texas, May 19-22, 2008, http://www.dtic.mil/ndia/2008Intl/Roberts.pdf),

[475] Ibid, 150, 153.
Roberts, "Time For Change," 24.
[476] Ibid, 13.

5.4 5.56mm Limitations during Long Range Engagements

In addition, warfare in open terrain showed that NATO militaries still needed weapons at the small unit level with the capability to effectively engage and defeat targets beyond 300m.[477] Starting in 1958, the US Army had discontinued their Known Distance Marksmanship program in favour of the Trainfire course with pop-up targets situated at distances up to 300m. This is still employed by the US Army. [478] Trainfire had "produced more soldiers trained to a lower marksmanship standard but eliminated the institutional knowledge of what was required for riflemen to engage targets to 600 meters."[479] Likewise, many NATO armies only trained their infantry soldiers to shoot to 300m with assault rifles but in Afghanistan, adversaries often engaged ISAF soldiers at ranges beyond 300m.[480] As well, artillery and air support assets may not be immediately accessible and their use had to be limited when collateral damage was a concern.[481] In 2001, the US Army introduced the Squad Designated Marksman (SDM) concept and the SDM functioned primarily as a squad member but received additional training to engage

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[477] Ibid, 13.

[478] Lt. COL David Liwanag, "Improving Army Marksmanship: Regaining the Initiative in the Infantryman's Half Kilometer," *Infantry*, July-August 2006, 27.
Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 16.
The USMC still trains its infantrymen to shoot to 500 yards with assault rifles on a known distance range. See Arthur D. Osborne and Seward Smith, *Analysis of the M16A2 Rifle Characteristics and Recommended Improvements*, 10.

[479] Ibid, 47.
General Wynam's objective was to employ Trainfire in combination with known distance training to insure that select soldiers in the squad would be able to engage threats out to 500m. See Liwanag, "Improving Army Marksmanship," 28.
But Cold War America's focus on nuclear weapons led to budgetary limitations for training and consequently all "emphasis was placed on Trainfire to the detriment of the later." See Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 16, 17.
Although the former Soviet Army adopted intermediate caliber assault rifles with an effective range of 300m, starting in the 1960s, every Soviet Motorized Rifle Platoon had a designated marksman armed with a 7.62x54R caliber SVD rifle to engage targets beyond 300m. See *FM 100-2-3 The Soviet Army: Troops, Organization and Equipment* (Washington: Department of the Army, 1991), 196.

[480] Per G. Arvidsson, "Is there a problem with the 5.56mm cartridge?" (presented at the National Defense Industrial Association Conference, Dallas, Texas, May 17-20, 2010, http://www.dtic.mil/ndia/2010armament/WednesdayLandmarkBPerArvidsson.pdf), 14.

[481] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 54.

threats from 300 to 500m. American SDMs usually employed M16 variants but 5.56mm projectiles did not have ideal terminal performance and intermediate barrier penetration at long range.[482] In an attempt to "better deal with long range and protected targets," other NATO forces such as the British and Germans have adopted semi-automatic 7.62mm NATO caliber rifles as their standard SDM rifles.[483] However, the increased recoil of 7.62mm rifles compromises the SDM's effectiveness as a squad member during close combat.[484] To more effectively engage threats behind cover and at extended distances, both the US and British Armies have also complemented their M249 SAWs and Minimis with 7.62mm NATO caliber machine guns at the small unit level in Afghanistan.[485] But soldiers armed with 7.62mm NATO weapons have to carry a significantly reduced combat load due to the increased ammunition weight and cannot share ammunition with other squad members utilizing 5.56mm weapons.[486]

5.5 Scientific Explanation for Inconsistent Terminal Performance

Moreover, the "US Army's Project Manager, Maneuver Ammunition Systems, assembled the Joint Services Wound Ballistics Board- Integrated Product Team (JSWB-IPT) to examine the issues with M855 and whether there were superior commercial alternatives."[487] Some of the US ammunition designs evaluated by the JSWB-IPT included military standard 5.56mm and 7.62mm NATO loads, 5.56mm caliber commercial bullet configurations and the 6.8x43mm SPC

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[482] Ibid, 48.
SGT K. Grant, "Closing the Gap: Developing the Sharpshooter Capability in the CF," *Canadian Army Journal* 13 (2010): 55.

[483] Jim Schatz, Do We Need A New Service Cartridge, 121, 122.
When comparing projectiles in similar configurations such as 5.56mm M193 and 7.62mm NATO M80 FMJ rounds, the 7.62mm had superior penetration at longer ranges. See Bruce F. Kay, An Analysis of the Infantry's Need for an Assault Submachine Gun, 45.
But 7.62mm NATO FMJ rounds are not Blind to Barriers and do not have good terminal performance against targets protected by glass barriers. See Roberts, "Wound Ballistics Research and Consulting."

[484] Grant, "Closing the Gap," 55.

[485] Schatz, "Do We Need A New Service Rifle Cartridge?," 121, 122.
Sattler and O'Leary, "Analysis of Modern Section Fighting Power," 27.

[486] Grant, "Closing the Gap," 55.

[487] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 30.

round.[488] The 6.8x43mm SPC was an intermediate cartridge that was co-developed by 5th Special Forces Group and US Army Marksmanship Unit during the GWOT to address the deficiencies of 5.56mm ammunition and 5.56mm weapons could be modified to use this caliber.[489] The JSWB-IPT's evaluations were completed in 2006 and discovered the causes behind the inconsistent terminal performance reported by end users.[490] Both "Angle of Attack (AOA) variability at impact between different projectiles and fleet yaw, which is the terminal performance variation caused by inherent variability in each rifle, can substantially affect wound severity."[491] For example, "5.56mm FMJ bullets at higher AOA's, like two to three degrees, had a shorter NL and upset rapidly, thus providing adequate terminal effects."[492] But "at low AOA, like zero to one degree, 5.56mm FMJ rounds penetrated deeper than ideal prior to initial upset with significantly reduced terminal effects" (see Figure 33).[493] 5.56mm FMJ rounds such as M193 and M855 were "highly susceptible to AOA variations" and experienced greater "fleet yaw induced variability than other calibers" while "Open Tip Match (OTM) bullets were less susceptible to AOA variations" compared to bullets of FMJ configuration.[494] In the JSWB-IPT's testing, "the 6.8mm caliber had the least AOA inconsistencies and the 6.8mm SPC OTM round had less fleet yaw than other calibers and bullet configurations."[495] The JSWB-IPT's draft report stated that "the 6.8 mm projectile had a near optimal balance of mass, velocity, and configuration to maintain its

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[488] Dean and Lafontaine, "Small Caliber Lethality," 28.
[489] Roberts, "Time for a Change," 14, 15.
[490] Ibid, 26.
Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 30.
[491] Gary K. Roberts, "Review of Infantry Magazine 2006 Lethality Article" (Unpublished material).
[492] Ibid.
[493] Ibid.
[494] Ibid.
An OTM bullet "employs a precision deep drawn jacket with lead inserted from the front tip and ogival forming from the open tip mouth, which allows for better manufacturing control and more consistent quality than possible with traditional FMJ bullet designs formed from tip to base." See W. Hays Parks, "Open Tip Match: When a 'Hollow Point' is not a Hollow Point," *Small Arms Defense Journal* 4 (2012), accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=1262.
[495] Gary K. Roberts, "Review of Infantry Magazine 2006 Lethality Article."

effectiveness, even at a lower impact velocity and the 6.8mm SPC was far and above, the best performing ammunition."[496] In terms of "effective damage rankings, 6.8mm systems with 20 inch, 16 inch and 12.5 inch barrels came in first, third, fifth and six places while M855 fired from a 20 inch barrel came in tenth place."[497] Therefore, the JSWB-IPT's studies showed that the NATO Qualified M855 FMJ projectile was not optimal for rifle use and there were superior alternative calibers and bullet configurations.

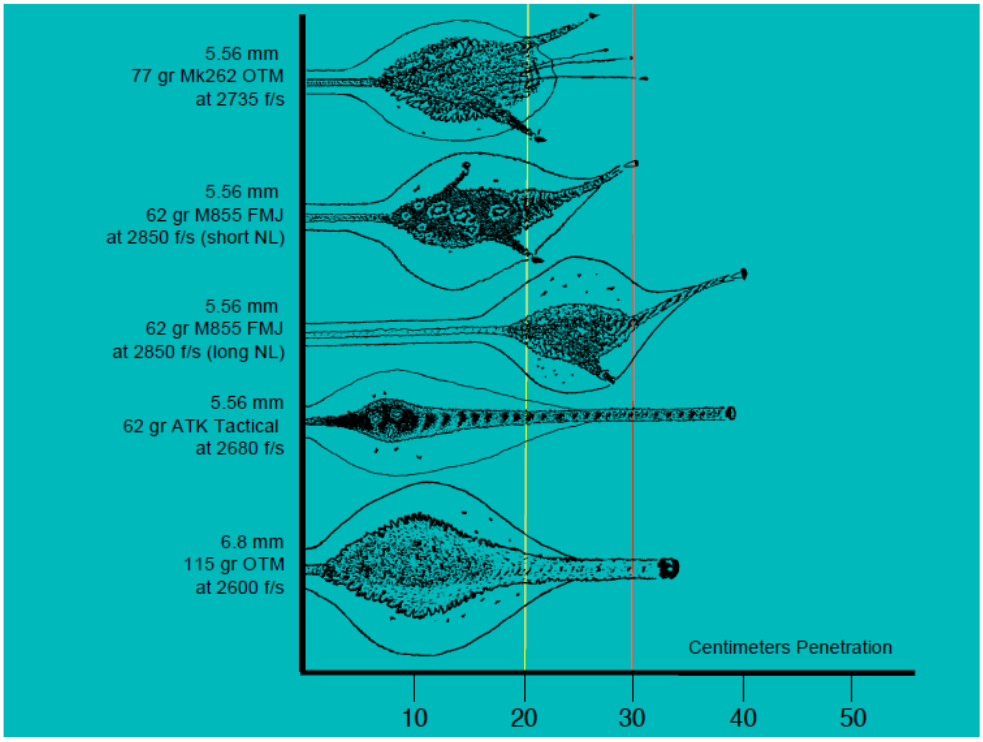

Figure 33: Wound profiles for modern intermediate cartridges.

The M855 short NL wound profile is due to M855 impacting at a high AOA. The M855 long NL does not show the average NL of M855 and is due to M855 impacting at a low AOA. 5.56mm Mk 262 OTM was developed for accurate long distance shooting and it still suffered from AOA and fleet yaw issues but to a lesser degree than FMJ designs like M193 and M855. The 5.56mm ATK Tactical JSP is a Blind to Barriers loading in use by the FBI. As shown by the wound profiles in this figure, the 6.8mm SPC OTM damaged more tissue compared to 5.56mm military and law enforcement ammunition designs and therefore had superior terminal performance.
Source: Roberts, "Time for a Change."

[496] Roberts, "Time for a Change," 13.
[497] Roberts, "Review of Infantry Magazine 2006 Lethality Article."

5.6 American 5.56mm Replacements for NATO Standard SS109

Accordingly, the issues with FMJ bullets discovered during the JSWB-IPT's testing led to the development of improved ammunition for the US military. Buford Boone of the Federal Bureau of Investigation's Ballistic Research Facility recommended his "Eight Points of Light" to dictate military ammunition performance. [498] The "Eight Points of Light" are appropriate for military needs, do not contravene international laws and state that projectiles need to:

- Be blind to impact yaw [does not experience AOA and fleet yaw issues]
- Limit penetration to 12-18 inches
- Resist yaw in tissue, with no yaw earlier than 12 inches
- Continue on shot line after penetrating tissue
- Be blind to barriers
- Limit fragmentation
- Perform consistently from 0 – 300 meters
- Be accurate enough to engage human targets to 600 meters[499]

In September of 2006, USSOCOM "awarded Alliant Techsystems (ATK) the developmental contract for the 5.56mm and 7.62x51mm Special Operations Science and Technology" (SOST) OTM bullets, which are compliant with most of Boone's criteria.[500] The SOST projectiles were designed to deliver good terminal ballistics from shorter barrel rifles, consistently produced a short NL and "limited fragmentation" to the bullet nose in order to increase tissue disruption

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[498] Roberts, "Wounding Effects of Military Small Arms during the Past Century," 13.

[499] Ibid.

[500] Chuck Marsh, Jared Stoll and David Leis, "U.S. Navy Small Arms Ammunition Advancements" (presented at the National Defense Industrial Association Conference, Las Vegas, Nevada, May 18-21, 2009, http://www.dtic.mil/ndia/2009infantrysmallarms/tuesdaysessioniii8524.pdf), 18, 19.
ATK's 5.56mm 77 grain Tactical Open Tip Match (TOTM) round is another excellent 5.56mm alternative to the M855/SS109 cartridge for rifle use. The TOTM is a blind to barriers bullet that was developed for military use and designed to meet Boone's "Eight Points of Light." The 5.56mm TOTM bullet produced a short NL and quickly upset, which increases the amount of tissue that is crushed as well as producing a large temporary cavity. See Roberts, "Time for a Change," 12.
The 5.56mm TOTM has a bonded core and this allowed the TOTM to have better terminal performance against targets protected by intermediate barriers compared to the 5.56mm Mk318 SOST. The SOST bullets were based off of the TOTM design but are not bonded projectiles. See Roberts, "Wound Ballistics Research and Consulting."

while maintaining a blind to barriers (BTB) capability (See Figure 34).[501] BTB projectiles display "minimal changes in terminal performance" against unprotected targets and those behind intermediate barriers.[502] The SOST OTM rounds were developed for present combat requirements and such BTB bullets enabled rifleman to effectively engage vehicle borne improvised explosive devices commonly encountered during the GWOT.[503]

Figure 34: SOST OTM bullets

The 5.56mm SOST is designated Mk318 Mod 0 while the 7.62x51mm SOST is Mk319 Mod 0 and the SOST bullets have reverse drawn jackets. The nose of the SOST bullet "is designed to help defeat a barrier while the rear section of the bullet is solid copper and acts as a rear penetrator."
Source: "5.56mm & 7.62mm Special Carbine, Barrier," accessed October 20, 2015, http://lem.nioa.com.au/products/download/192/presentation-556-762-special-carbine-barrier-international.pdf.

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[501] W. Hays Parks, "SOST: A Way Forward in Contemporary Understanding of the 1899 Hague Declaration on Expanding Bullets," *Small Arms Defense Journal* 5 (2013):2, accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=2109.
Kontis, "Sal Fanelli: The Interview."
The 5.56mm and 7.62x51mm SOST bullets have consistent terminal performance because they are blind to impact yaw. See Marsh, Stoll and Leis, "U.S. Navy Small Arms Ammunition Advancements," 23.

[502] Roberts, "Time for a Change," 10.

[503] "J&A Number: 06-116", 2.
Dr. Gary Roberts explained that: "recent international law of war conferences have acknowledged that the Hague Convention is only violated if the intent of projectile selection is to cause unnecessary suffering, thus acknowledging that some suffering is unavoidable on the battlefield. The language of the Hague Convention was likely created with good intention but is utterly flawed by complete ignorance of the true mechanisms of wound ballistics." See Roberts, "Wounding Effects of Military Small Arms during the Past Century," 11.
Former Senior Associate Deputy General Counsel W. Hays Parks explained that: "military bullet legality is based on the prohibition of munitions intended to cause superfluous injury, which is injury to combatants that is clearly excessive when weighed against the stated military requirement and other relevant factors. Protecting innocent civilian lives may weigh in favour of small arms ammunition causing greater harm to combatants or terrorists than standard FMJ ammunition." See Parks, "SOST," 2.

In 2010, the USMC adopted the 5.56mm SOST, which was designated Mk318 Mod 0, as an interim option to replace the M855 for assault rifle use while the M249 will continue to utilize M855.[504] Likewise, the US Army has adopted the 5.56mm M855A1 Enhanced Penetration Round (EPR) as a replacement for M855 in 2010 (See Figure 35).[505]

Figure 35: 5.56mm M855A1 EPR

Source: Lt. COL Jeffrey L. Woods, "Evolution of the M855A1 Enhanced Performance Round," accessed May 20, 2015, http://www.army.mil/article/48657/.

While the M855A1 does not experience AOA issues and has improved penetration against mild steel and cinder blocks compared to M855, it is not a BTB projectile and does not have good terminal performance after defeating intermediate barriers such as automobile glass.[506]

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[504] Kontis, "Sal Fanelli: The Interview."
Although the Mk318 is intended for assault rifle use, it can be fired from the M249 in an emergency. See Kontis, "Sal Fanelli: The Interview."

[505] John Plaster, "Testing the Army's M855A1 Standard Ball Cartridge," *American Rifleman,* May 21, 2014, accessed May 20, 2015, http://www.americanrifleman.org/articles/2014/5/21/testing-the-army-s-m855a1-standard-ball-cartridge/.

[506] Lt. COL Jeffrey L. Woods, "Evolution of the M855A1 Enhanced Performance Round," accessed May 20, 2015, http://www.army.mil/article/48657/.
Jeremy Stafford, "M855A1: Should it be the New Round for Soldiers and Marines?" *Guns & Ammo,* March 7, 2012, accessed May 20, 2015, http://www.gunsandammo.com/uncategorized/m855a1-should-it-be-the-new round-for-soldiers-and-marines/.

Moreover, M855A1 EPR's chamber pressure exceeded STANAG 4172's specified limits for chamber pressure and has "caused damage to bolts and wear on barrels."[507] Thus, the US military has adopted non-FMJ projectiles because NATO standard SS109 had deficiencies for rifle use and was not well suited for current requirements.

5.7 Alternative Intermediate Calibers for Future Military Weapons

The US military's need for ammunition with improved terminal performance was emphasized by the Army's premise that "weapon system modernization efforts must focus first on target effects."[508] Improved 5.56mm loads like Mk318 have maximized the performance of the 5.56mm caliber and the desire for further improvements in ammunition capabilities will dictate the characteristics of the M4's future successors in the US military.[509] Only a new intermediate caliber would be a significant improvement in terminal performance over 5.56mm BTB rounds and such solutions include the 6.8x46mm and 7x46mm intermediate cartridges that were designed by Cris Murray. Although the 6.8mm SPC has demonstrated improved terminal performance over 5.56mm, it was designed as a retrofit for 5.56mm weapons and this required the cartridge's overall length to not exceed that of 5.56mm magazines. This design limitation on the 6.8mm SPC cartridge's overall length had compromised both its external and terminal ballistics.[510] Murray was one of the co-designers of the 6.8mm SPC and he developed the

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[507] Email communication from Jim Schatz to author, December 3, 2014.
Carden Hedelt , "IWS civilian wins award for improved rifle ammunition work," accessed May 20, 2015, http://www.marcorsyscom.marines.mil/News/PressReleaseArticleDisplay/tabid/8007/Article/509581/iws-civilian-wins-award-for-improved-rifle-ammunition-work.aspx.
NATO's standards for 5.56mm SS109 ammunition states that "when measured at 21 degrees Celsius, the average chamber pressure shall not exceed 380 MPa (55, 114 PSI) and the average pressure plus three standard deviations shall not exceed 420 MPa (60, 916 PSI)." See NATO, *STANAG 4172*.
In contrast, the M855A1 cartridge's chamber pressure is 63,000 PSI. See Jeremy Stafford, "M855A1."
[508]Jim Schatz, "US Military Losing Edge in Small Arms," accessed November 5, 2015, http://www.nationaldefensemagazine.org/archive/2015/November/Pages/USMilitaryLosingEdgeinSmallArms.aspx
[509] Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.
[510] Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 33.

6.8x46mm and 7x46mm intermediate cartridges when not "constrained to the overall length of 5.56mm magazines" and either of those new cartridges could replace both 5.56mm and 7.62mm NATO.[511] Both of these optimal intermediate cartridges fired 130 grain bullets at 2650 fps and have manageable recoil to enable rapid semi-automatic and automatic fire from assault rifles.[512] A general purpose rifle loading for 6.8x46mm and 7x46mm should use bullet configurations that meet Boone's "Eight Points of Light" in order to produce the most physiological damage for the best terminal ballistics. Although rifle caliber FMJ, M855A1 and SOST projectiles can all defeat soft body armor, several modern militaries issue hard body armour that can stop rifle caliber rounds in the above mentioned bullet configurations along with steel core AP rounds.[513] Only tungsten carbide core AP rounds can defeat those kinds of hard body armor and such an AP round could be developed in 6.8x46mm or 7x46mm for use against peer adversaries.[514] When utilizing bullet configurations with a high BC, both the 6.8x46mm and 7x46mm can match or exceed the long range performance of 7.62mm NATO FMJ rounds so either of those intermediate cartridges can be used in GPMGs.[515] Since these intermediate cartridges have improved long range performance over other assault rifle calibers, they are similar in concept to the .280 British cartridge that the US Ordnance Department rejected in the 1950s.

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[511] Ibid.

[512] Cris E. Murray, "7x46mm" (Unpublished material), 1.

[513] MAJ Scott J. Madore and CPT Sam M. Choi, "Personal Protective Equipment" (Advanced Planning Brief to Industry, May 12, 2011, http://nsrdec.natick.army.mil/APBI/Body%20Armor/Army_-_APBI_SoftandHard_Armor_Breakout_Brief.vfinal.pdf), 5.
Stafford, "M855A1."

[514] Ibid.
Sandra I. Irwin, "Army Has Few Options to Lessen Weight of Body Armor," accessed May 20, 2015 http://www.nationaldefensemagazine.org/archive/2009/October/Pages/ArmyHasFewOptionstoLessenWeightofBodyArmor.aspx.

[515] Cris E. Murray, email message to author, November 10, 2011.
When using a 130 grain mild steel core FMJ bullet, the 7x46mm outperformed the 7.62mm NATO FMJ round after 200m in terms of external ballistics. See Cris E. Murray, email message to author, July 25, 2010.
When using the above mentioned bullet configuration, both 6.8x46mm and 7x46mm remained supersonic out to a longer distance compared to the 7.62mm NATO M80 FMJ round. See Cris E. Murray, email message to author, November 10, 2011.

Furthermore, a study conducted by the US Army's Armament Research, Development and Engineering Command (ARDEC) in 2011 showed that a rifle caliber around 6.8mm to 7mm was superior to other calibers. ARDEC tested "identically configured solid copper and exposed steel tip projectiles in calibers of .224, .243, .257, .277 and .30 inches."[516] The ARDEC study's findings were the following:

> -larger caliber bullets do more damage to the target…increase in damage capacity is larger than increase in system weight.
> -larger caliber bullets required to penetrate certain barriers (range).
> -On barriers where smaller calibers also penetrated, larger calibers had measurably high post-barrier target damage.--.277 split top performer by weight with .30 in these tests.
> -Damage based methods and methods that focus on "good hits" will favour larger calibers--.277 caliber the best performer, by weight in this test.
> -Stowed kills:
> - Will always favour light systems
> - Disproportionately biases weight against performance
> - Mathematically, we should choose BB guns
> - Should be coupled with other gages (requirements) to be meaningful to the soldier
> - The .224 caliber was the best performer by weight when using this method.[517]

"Valid wound ballistics testing procedures measure damage because incapacitating the enemy is about rapidly inflicting sufficient physiological damage to the enemy's critical anatomic

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[516] Roberts, "Wound Ballistics Research and Consulting."

[517] Jim Schatz, "Where to Now?" (presented at XXVIIth European Small Arms and Cannon Symposium, Shrivenham, UK, August 21 2013), 19.
The ARDEC study also stated that "incapacitation-based methods that factor in misses will bias towards smaller calibers-.277 caliber had highest probability of incapacitation [P(i)] value, however, .224 had better P(i)/Weight Ratio." See Schatz, "Where to Now?"
But according to Dr. Gary Roberts: "incapacitation is something that is impossible to accurately calculate or predict. Physiological damage potential is the only factor that can be accurately measured and is the only metric that has shown to have any correlation with field results in actual shooting incidents, based on law enforcement autopsy findings along with historical and ongoing combat trauma results." See Roberts, "Review of Infantry Magazine 2006 Lethality Article."
In addition, a USMC Battalion Commander explained that: "measuring incapacitation is based on someone's guess as to a percentage of the time the target will choose to stop doing what he is doing because of a particular engagement. Everything is averaged; average target with average motivation, average hit placement, average effect on target. If any of these average values are redefined, the result is completely different. Accepting level of incapacitation is the first step down the road towards accepting the comparison of systems by stowed kills and unit lethality." See Roberts, "Review of Infantry Magazine 2006 Lethality Article."

structures in order to stop that opponent from continuing to be a lethal threat."[518]Accordingly, damage based methods "define the potential of the round, under specific circumstances, given a single engagement" and are relevant to soldiers due to "the immediate relation they can make between their weapon system and what it can do to enemy combatants."[519] In contrast, "the stowed kills metric is a balance of the killing potential of the system against the weight of the system but ultimately favours weapon systems with the lightest weight and ammunition load, even if their terminal performance in combat proves less than desirable."[520] Therefore, ARDEC's evaluation showed that the .277 inch caliber was the overall best caliber compared to other calibers tested in identical bullet configurations.

More importantly, the US Army's Soldier Weapons Strategy of 2014 showed that the Americans are currently considering non-NATO calibers for new rifles and machine guns.[521] The Army's strategy stated that "near-peer threats are moving towards a common, intermediate caliber to maximize fire-power and efficiencies for the squad in an attempt to increase lethality at close range and accuracy at long range."[522] Indeed, "potential adversaries have begun to field a common intermediate caliber, advanced performance ammunition for their assault rifles, LMGs and MMGs."[523] Due to improvements in threat capabilities, the US Army has recently initiated the Small Arms Ammunition Configuration (SAAC) study and is considering the possibility for a common caliber at the squad and platoon levels.[524] The SAAC study will evaluate the

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[518] Roberts, "Review of Infantry Magazine 2006 Lethality Article."
[519] Ibid.
[520] Ibid.
[521] Jim Schatz, "The Future of the Military Assault Rifle," *Small Arms Defense Journal* 7 (2015), accessed May 20, 2015, http://www.sadefensejournal.com/wp/?p=2941 .
[522] *Army Soldier Weapons Strategy 2014* (Washington: Department of the Army, 2013), 6.
[523] Ibid.
The new potential threat developments have "a maximum effective of 600m for assault rifles, 800m for LMGs and 1000m for MMGs." See *Army Soldier Weapons Strategy 2014.*
[524] Ibid, 8.

"intermediate ammunition calibers and configurations" and guide the Army on developing cartridges with superior terminal ballistics and extended range over current rifles and machine guns.[525] Thus, the US plans on adopting non-NATO calibers for military use in order to "ensure overmatch at the lowest tactical level in 2025 and beyond" due to the improved capabilities of potential threats.[526]

5.8 Interest of Allies in Alternative Calibers and Polymer Cased Ammunition

Moreover, several NATO states have expressed interest in alternative calibers and non-NATO cartridge designs for successor weapons. Since 2005, there were several studies directed by the British, Canadian and French governments which showed that a 6.5mm to 7mm caliber was ideal for military use.[527] Besides their own caliber studies, the UK is paying attention to the US Army's SAAC study and Germany is also interested in intermediate calibers larger than 5.56mm.[528] Likewise, Canada is considering non-NATO standard calibers for their Small Arms Replacement Program II (SARP II) to replace their current small arms in the 2020s period because "5.56mm and 7.62mm may not be suitable calibers for future operations."[529] Also, the US Army initiated the Lightweight Small Arms Technologies (LSAT) Program in 2004 to develop polymer cased telescoped ammunition (CTA), which was forty percent lighter than the baseline 5.56mm brass cased cartridge.[530] Aside from US interest in CTA, the Canadians are

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[525] Ibid.

[526] David Libersat, "Soldier Division Director" (presented at the National Defense Industrial Association, Whippany, New Jersey, June 1-3, 2015, http://www.dtic.mil/ndia/2015smallarms/Libersat_SoldierWeaponsPanel.pdf), 6.

[527] Jim Schatz, email message to author, November 25, 2015.

[528] Email communication from Jim Schatz to author, December 3, 2014.

[529] Schatz, "Do We Need A New Service Rifle Cartridge?," 122.
Andrew White, "In the line of fire: infantry weapons," *Jane's Defence Weekly*, September 18, 2009, 4.

[530] Kori Spiegel and Paul Shipley, "Lightweight Small Arms Technology" (presented at the National Defense Industrial Association, Albuquerque, New Mexico, May 15-18, 2006, http://www.dtic.mil/ndia/2006smallarms/spiegel.pdf), 3.
"Telescoped ammunition is a form of gun ammunition in which the projectile is recessed into the main body with the propellant." See CAPT I.A. McGregor, "Telescoped Ammunition: A Future Lightweight Compact Ammunition," *Canadian Army Journal* 12 (2009): 75.

developing a new assault rifle which fires polymer CTA by using technology from the LSAT program.[531] But 5.56mm caliber CTA cannot be fired from 5.56mm weapons chambered for conventional cased cartridges because weapons designed for CTA need "straight-through ejection" and a moving chamber (See Figure 36).[532] Rather than replacing their existing rifles with another 5.56mm weapon, the Canadian Army wants successor weapons to take advantage of new technologies and offer more significant improvements in capabilities over the C7.[533]

Figure 36: 5.56mm CTA round (top) and conventional brass cased ammunition (bottom).

Source: Photograph by Anthony G. Williams.

Another alternative is conventional polymer cased ammunition with brass bases and the USMC is currently developing such cases for heavy machine gun calibers with MAC, LLC. Compared to brass cased ammunition, these conventional polymer cases lower "ammunition weight by twenty to forty percent depending on caliber" and can be used in existing weapon mechanisms

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[531] White, "In the line of fire."

[532] CAPT I.A. McGregor, "Telescoped Ammunition: A Future Lightweight Compact Ammunition," *Canadian Army Journal* 12 (2009): 76.
A potential technical issue with CTA is ballistic inefficiency due to "gas blow-by that occurs as the projectile moves from the body of the round into the forcing cone where it achieves obturation of the barrel." See McGregor, "Telescoped Ammunition," 79.
Jim Schatz explained that the G11's caseless ammunition was also a telescoped ammunition design but "did not seem to suffer from" ballistic inefficiency caused by "the jump of the projectile into the bore" and believed "that a lot of it could be addressed using a well-made barrel that resists such things." See Email communication from Jim Schatz to author, June 23, 2015.

[533] Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015.
The Canadian Army believes that their standard C7A2 rifle is still adequate for their uses and chose to retain the C7A2 rather than spend millions of dollars to replace their fleet of C7A2s with the upgraded C7A3s due to their low military budget. See Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015.

(See Figure 37).[534] Adopting polymer cases will require ammunition manufacturers to change their production tooling and a US Army sponsored study showed that the cost for transitioning from existing ammunition to polymer CTA would be same regardless of the CTA's caliber. Both of the above mentioned polymer case technologies could be applied to new intermediate rifle calibers, which would bring the ammunition weight closer to that of brass cased 5.56mm while providing superior terminal ballistics and range.[535]

Figure 37: MAC, LLC conventional polymer cartridge cases.

Source: MAC, LLC Develops Lightweight Ammo," accessed March 16, 2016, https://mlsvc01-prod.s3.amazonaws.com/9a3d55a1401/aa35bf43-facd-43fa-84aa-0dc9990cc2a4.jpg.

There are currently no arrangements being made for a new standard rifle caliber at the NATO level.[536] Since the US is the most important member of NATO, other allied forces will not transition to a new standard caliber until the Americans have already done so.[537] But many alliance members already need to procure new rifles in the 2020s period and new weapons should offer significant improvements rather than the same capabilities as their predecessors in order to justify the high costs of the changeover. For example, the US Army does not want to replace their M16s and M4s with an improved 5.56mm assault rifle because such a replacement

Schatz, "The Future of the Military Assault Rifle."
[535] Ibid.
[536] Email communication from Per G. Arvidsson to author, January 29, 2015.
[537] Anthony G. Williams, "The Case for a General-Purpose Rifle and Machine Gun Cartridge (GPC), accessed November 10, 2015, http://www.quarryhs.co.uk/TNG.pdf, 31.

would cost approximately $1 billion. As a result, the Americans want successor weapons to be a major improvement in capability over existing weapons.[538] The "general consensus" is that once the US military standardizes a new rifle caliber and case configuration, other NATO members will begin adopting the new American standard caliber in the 2020s.[539] So the US should work with other NATO states that are interested in alternative calibers and polymer case technologies and "convene a joint caliber working group to form a development and test plan."[540]

5.9 Suggestions for the Future of NATO Ammunition Standardization

NATO's past experiences for major weapon systems acquisitions showed that improving the degree of standardization among the alliance's major weapons was usually feasible when the alliance was transitioning to new weapons due to the cost and time required.[541] It would not be practical for NATO to improve ammunition interchangeability for standard calibers such as 5.56mm because alliance members would have to re-ratify an existing STANAG. Once the US military adopts a new intermediate caliber, NATO will need to draft a new STANAG to enable members to share ammunition during combat and training. The alliance should take this opportunity to improve ammunition standardization for a new intermediate caliber. In order for all NATO Qualified ammunition designs of a new caliber to demonstrate enough reliability for combat use in all NATO weapons chambered for that caliber, some technical performance specifications need to be more specific than those of STANAG 4172. For example, at a given gas port location, there should be limits that the average port pressure plus two standard deviations cannot exceed and a minimum figure minus two standard deviations that the average port

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[538] Matthew Cox, "Out of Reach," *Army Times*, February 26, 2007, 15, 22.
[539] White, "In the line of fire." 4.
[540] Schatz, "Where to Now?,"42.
[541] Robert W. Komer, "Ten suggestions for rationalizing NATO," *Survival: Global Politics and Strategy* 19 (1977): 68.

pressure must meet or exceed.[542] Then, new weapon developments can be designed around ammunition that adheres to more specific requirements for certain technical performance specifications such as a narrower range of variations in average gas port pressure. Rifles with self-regulating gas systems that functions with a wide range of ammunition designs may allow for reliable operation with all NATO Qualified designs if they were tested with all STANAG compliant cartridges during development. Finally, there will be fewer obstacles towards the standardization of a common magazine when a new caliber is standardized because an optimal full radius magazine can be designed when firearms designers are freed from the limitations of the straight M16 magazine well.[543]

The experience of the US and other NATO states during the GWOT had shown that NATO standard SS109 had deficiencies for rifle use and improved 5.56mm projectiles like Mk318 are more appropriate interim solutions for current combat requirements. Indeed, the US military is planning on adopting non-NATO standard calibers for future weapons to better meet modern combat requirements and match or exceed the capabilities of improved threat developments. Also, several NATO states needed improved long range and terminal performance over 5.56mm SS109 during the GWOT and have already shown interest in alternative intermediate calibers and polymer cased ammunition. The actual intermediate caliber and polymer case configuration to be adopted by the US military will be only known after the SAAC study is completed. But the available intermediate caliber developments and testing data

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[542] "Three standard deviations is normally the maximum a value can be from the mean or average value and still be statistically still part of the sample. A more reasonable measure is probably two standard deviations, which allow for variations in the manufacturing processes. Normally, a high quality manufacturing process should be able to easily achieve a variation of one standard deviation." See Email communication from Defense Industry Professional and former Canadian Army Officer to author, August 31, 2015.

[543] A new polymer magazine should have sufficient wall thickness for durability but do not have to be as thick as those of the G36 magazines when using more durable polymer materials that are now available. Jim Schatz, email message to author, November 25, 2015.

showed that a viable option would be a 6.8mm to 7mm intermediate cartridge in a polymer case configuration that is capable of replacing both 5.56mm and 7.62mm NATO calibers.[544] After the US has selected the most suitable intermediate caliber and polymer case configuration for adoption, then the gradual standardization of the new cartridge should be implemented at the NATO level. The introduction of new ammunition and weapons would give NATO the opportunity to improve the degree of ammunition interchangeability and to standardize the best weapons interface designs.

[544] In order to replace both 5.56mm and 7.62mm NATO, a 6.8mm to 7mm intermediate caliber should have a case capacity around 41.0 grains H2O like that of the 7x46mm cartridge. See Cris E. Murray, "7x46mm," 4.

Chapter 6: Common Family of Weapons Approach to Procurement

6.1 Lack of Weapons Standardization within the US Military

NATO's efforts at standardizing a common rifle were unsuccessful in the past and their members are likely to use different weapons models in the future, which would prevent the creation of an integrated logistics system for all of the alliance's militaries. Although the US military reduced the number of types of niche weapons in service during the Cold War, end user requirements of the post-Cold War era had resulted in a return to the adoption of more niche weapons. The use of numerous niche weapons means that the US military will need to stock more types of spare parts and common operator training may not be possible if the various weapons lack common operating controls, cycles of operations and field stripping procedures. In order to avoid the problems that national armies which utilized various niche weapons had experienced during the Second World War, NATO states should improve the degree of standardization within their own militaries and procure weapons with common parts in the future.

6.2 The USMC's Need for a True Automatic Rifle

Although the M249 SAW is a LMG by design, US infantry squads employed the M249 as an individual weapon in the automatic rifleman billet rather than as a crew served LMG. As mentioned previously, the USMC's "adoption of the M249 SAW was more out of opportunity to piggy back on existing US Army procurement than need fulfillment."[545] This subsequently "led to an internal debate within the USMC" on whether the M249 in the automatic rifle role or a true automatic rifle was better suited for their requirements.[546] USMC Chief Warrant Officer (CWO) Eby explained the differences between the LMG and automatic rifle roles:

[545] Email communication from MAJ James Williamson to author, October 30, 2014.
[546] Ibid.

> The LMG is a weapon possessing interchangeable barrels in order to allow continuous high-volume fires. The high volumes are achieved by using belt-fed ammunition. The machine gun will have an effective range beyond that of rifles as impacts of rounds can be directed onto targets by other members of the machine gun team.
>
> The automatic rifle is a small arm intended for short-term automatic fire missions against point targets. It is incapable of sustained automatic fire due to the lack of a quick-change barrel, which in turn, causes overheating, and the removal of the weapon from serviceable status. An automatic rifle should be employed by an individual shooter and used in close combat. The automatic rifle, with its lower rate of fire, buffer spring, and greatly reduced recoil, gives added advantage of accuracy and shooter endurance. Unlike a LMG, an automatic rifle is designed to engage point or small area targets. It is intended to be a "mobile base of fire" around which the fire team maneuvers. The automatic rifle provides the maneuver element itself with an organic, moving volume of fire in the attack.[547]

Accordingly, the LMG was "designed to fill the void between the assault rifle and GPMG" while the automatic rifle was intended "to supplement a small unit's firepower."[548] Several USMC CWOs stated that the M249's spare barrel was not needed for the automatic rifle role because it was not viable to change barrels during the attack and the automatic rifleman's combat load of 600 rounds "was not enough to cause damage to the barrel."[549] In the automatic rifle role, the

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[547] CWO3 Jeffrey L. Eby, "Automatic Rifle Concept: Part I—History and Empirical Testing."

[548] Email communication from MAJ James Williamson to author, October 30, 2014.
"Recon Marines practice fundamentals, train as riflemen," accessed September 2, 2015, https://www.marines.com/news/-/news_story/detail/news_8apr2013_reconmarinespracticefundamentals_marinesmil.
In the 1990s, the US military adopted MAG 58 variants known as the M240B and M240G to replace the M60 GPMG because the US fleet of M60s were worn out and the M240 had superior reliability compared to the updated M60 variants of the time. See Popenker and Williams, *Machine Gun*, 313, 315.

[549] CWO2 Cannon Cargile, "M249 SAW?," *Marine Corps Gazette* (2001), accessed November 12, 2014, https://www.mca-marines.org/gazette/m249-saw.
CWO2 Jeffrey L. Eby, "M249 Employment Concepts," *Marine Corps Gazette* (2001), accessed November 12, 2014, https://www.mca-marines.org/gazette/m249-employment-concepts.
The USMC initially did not procure a spare barrel for the M249 SAW in the automatic rifle role. The earlier M249s had an adjustable gas regulator with both a regular setting and an adverse setting. The adverse setting increases the cyclic rate and was only supposed to be used if "carbon buildup in the gas port" led to malfunctions. But due to poor training, several Marines fired the M249 using the adverse setting and damaged barrels and the USMC decided to procure spare barrels rather than resolve training deficiencies. See CWO5 Ray Grundy, "The M249 Light Machinegun in the Automatic Rifle Role," *Marine Corps Gazette* (2001), accessed November 6, 2013, https://www.mca-marines.org/gazette/m249-light-machinegun-automatic-rifle-role.
But current M249 SAWs in US service have a fixed gas regulator. See Robert Ailes, email message to author, December 22, 2010.

M249 was supposed to "move with every fire team" and deliver higher sustained rates of fire than "assault rifles to break up enemy concentrations."[550] But due to the M249 SAW's weight when employed as an individual weapon, the automatic rifleman had difficulty keeping up with other squad members, especially during the attack.[551] As a result, there were instances where team leaders chose to remove M249s from the fire teams and placed them in a support by fire position to be employed as LMGs rather than automatic rifles.[552] Consequently, this meant that fire teams sometimes did not have "the firepower necessary for the final meters of the assault."[553]

In addition to its weight, the M249 in the automatic rifle role had disadvantages from the logistical and training standpoint. The 5.56mm cartridges for rifles and 5.56mm linked ammunition for the M249 are treated as different ammunition types by the US military's logistical system and there is no ammunition commonality at the fire team level. If other squad members needed to use the M249's ammunition, that ammunition would need to be de-linked, which is a time consuming process. Although the M249 can use M16 magazines if linked ammunition has been exhausted, it does not function reliably with magazines and stoppages will frequently occur.[554] Indeed, an automatic rifle that could function reliably with M16 magazines would allow ammunition commonality at the fire team level.[555] From the training perspective, the skills required for effective employment of the M249 are similar to those of GPMGs rather

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[550] CWO Eby explained that the "automatic rifle needed to be easily taken into the final assault because after supporting fires have ceased or shifted, there is no guaranteeing that all enemy crew served weapons have been suppressed." See Eby, "M249 Employment Concepts."
[551] CWO3 Jeffrey L. Eby, "Automatic Rifle Concept: Part I—History and Empirical Testing."
[552] COL (retired) Walt Ford, "Corps narrows field for new infantry automatic rifle," *Marines on Point*, Spring 2009, 14.
[553] Ibid.
[554] CWO5 Ray Grundy, "The M249 Light Machinegun in the Automatic Rifle Role," *Marine Corps Gazette* (2001), accessed November 6, 2013, https://www.mca-marines.org/gazette/m249-light-machinegun-automatic-rifle-role.
[555] Ibid.

than those of assault rifles.[556] Consequently, "the complexity of the overall operation of the M249 compared to the M16 along with insufficient ammunition and time and a high turnover rate of personnel made automatic rifleman qualification with the M249 challenging" for the USMC (See Figure 38).[557] These constraints "often resulted in either an ineffective M249 gunner" or one who lacked the knowledge to safely use the weapon.[558] Hence, USMC proponents of a true automatic rifle believed that such a solution was "a superior choice" over the M249 SAW at the small unit level due to "lighter weight, better accuracy and commonality of training."[559]

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[556] 1st Lt Robert Casper, "Training Proficient SAW Gunners," *Marine Corps Gazette* 93 (2009), accessed February 22, 2014, https://www.mca-marines.org/gazette/2009/06/training-proficient-saw-gunners.
Automatic riflemen are infantrymen and the infantrymen's Military Occupational Specialty (MOS) is 0311. Although the automatic riflemen is supposed to be a lance corporal, sometimes the most junior Marines are assigned the M249. See Casper, "Training Proficient SAW Gunners."
USMC 1st Lt Robert Casper explained that: [junior Marines assigned the M249 have] "little familiarity with the weapon and have less idea still of how to dominate the battlefield by seizing key terrain and firing positions. Just three days at the School of Infantry (SOI) is dedicated to M249 SAW instruction and familiarization. It is critical that SAW gunners receive an additional 2 weeks of formal schooling that is dedicated to equipping them with the skills needed for the deployment ahead. [In contrast,] Machine gunners (MOS 0331) receive 5 weeks of machine gun specific training at SOI." See Casper, "Training Proficient SAW Gunners."
[557] MAJ James Williamson, email message to author, November 18, 2015.
"Aside from the complexity of the overall operation of the M249 over the M16 platform, the primary challenge of the qualification and then operational use has to do with applying the proper positioning on the weapon, specifically shoulder pressure, in order to control the fire from the weapon. That takes experience and experience comes from training and ammo." See MAJ James Williamson, email message to author, November 18, 2015.
[558] Ibid.
The M249 fires from the open bolt position and "if the operating rod is accidentally released from the sear, the bolt will ride forward, strip a round from the ammunition belt and fire the round," resulting in a negligent discharge. See Cargile, "M249 SAW?"
[559] Email communication from MAJ James Williamson to author, February 24, 2015.

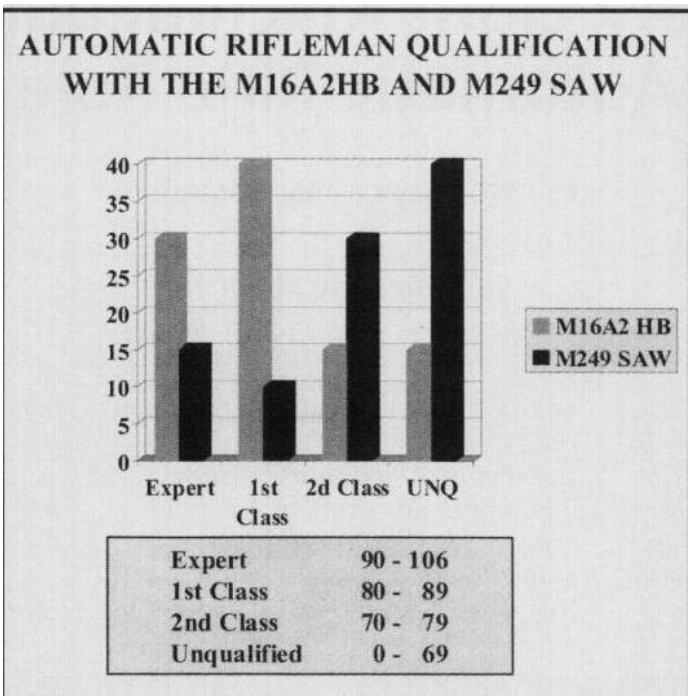

Figure 38: Automatic rifle qualification scores

The graph in Figure 38 shows the results of a test that was conducted before the USMC's Infantry Automatic Rifle competition and involved Marines using the M249 and M16A2 HB, which was a commercial variant of the M16A2 designed for the automatic rifle role. The box below the graph shows the scores required to achieve the qualification standards (unqualified, 2nd class, 1st class and expert). As shown by this graph, a larger number of Marines achieved better automatic rifle qualification standards with the M16A2 HB than with the M249 SAW.
Source: CWO5 Ray Grundy, "The M249 Light Machinegun in the Automatic Rifle Role," *Marine Corps Gazette* (2001), accessed November 6, 2013, https://www.mca-marines.org/gazette/m249-light-machinegun-automatic-rifle-role.
The image in Figure 38 is reproduced with permission of and copyright retained by the Marine Corps Gazette.

6.3 USMC Adoption of the M27 Infantry Automatic Rifle

In 2005, the USMC "issued a request for information to the defense industry for an infantry automatic rifle (IAR)" to replace the M249 in the automatic rifle role.[560] In 2001, HK began working with the US Army's elite counterterrorism unit Delta Force to develop the

[560] See Robert Bruce, "M27 From BAR to IAR: How the Marines Finally Got Their Infantry Automatic Rifle," *Small Arms Defense Journal* 4 (2012): 55.

5.56mm HK416 assault rifle because Delta Force needed a reliable compact carbine (CC) that was shorter than the M4 for close quarters combat (See Figure 39).[561]

Figure 39: HK416 assault rifle with a 10.4 inch barrel.

Source: "HK416," accessed October 20, 2015, http://hk-usa.com/hk-models/hk416/.

[561] "The HK416: The M16 has finally been fixed," accessed September 2, 2015, http://www.hkpro.com/index.php?option=com_content&view=article&id=80:hk416
Larry Vickers, "The U.S. Marines Send the M27 IAR Downrange," *Book of the AR-15,* accessed September 2, 2015, http://hk-usa.com/wp-content/uploads/HK-M27-IAR.pdf, 54.
Before the development of the HK416, a 10.3 inch barrel version of the M4 known as the Mk18 CQBR was used by Tier One US Units such as Delta Force. But the Mk18 CQBR was less reliable than the M16A4 and M4/M4A1 because it had less dwell time compared to the M16 and M4. Dwell time is the "amount of time" the gas system is pressurized and is "determined by the length of barrel between the gas port and the muzzle." See "Got Gas: A Guide to Understanding the AR-15 Gas System," accessed September 2, 2015, http://apdmarksmanshipteam.org/blog/got-gas-guide-understanding-ar15-gas-system/.
Due to the short dwell time of direct impingement AR-15 CCs, "the gas pulse supplied to the bolt carrier can be too short to deliver all of the energy that the carrier group needs" while using a larger gas port makes these CCs "extremely sensitive to differences in ammunition" and also puts more stress on their operating components. See "Got Gas: A Guide to Understanding the AR-15 Gas System" and Westrom, "Technical Note 104," 4.
Also, the Mk18 CQBR suffered from gas port erosion issues, which increased the Mk18's cyclic rate and caused "feeding issues" along with "increased bolt, spring, and part fatigue." See Email communication from Jim Schatz to author, June 23, 2015 and Lucius Taylor, "SOPMOD Program Overview" (presented at the National Defense Industrial Association Conference, Albuquerque, New Mexico, May 15-18, 2006, http://www.dtic.mil/ndia/2006smallarms/taylor.pdf#search=%22sopmod%22), 50.
Jim Schatz explained that: [the Mk18's gas port erosion issues were primarily] "caused by Colt's minimum quality barrels along with where they taped off the gas and suppressors, higher rates of sustained fire and hot test/operational conditions also added to the issue. The HK416's CHF barrel material resists gas port erosion better than others and HK's CHF barrel is also induction hardened at various points to include the area at the gas port, which helps increase life there and resist erosion." See Email communication from Jim Schatz to author, June 23, 2015.
The HK416 uses a pusher rod gas system that was based on the G36's gas system. Jim Schatz explained that: "the HK416 does not suffer from peak pressure or dwell time issues based on the design of the [pusher rod] gas system. HK was able to make the HK416 work very reliably using the same gas port position for every barrel length from 10.4 to 20 inches and using bleed holes for those barrel lengths that require it." See Jim Schatz, email message to author, November 25, 2015.
The 10.4 inch barrel HK416 has enough dwell time for its gas system to operate the weapon reliably because as long as the piston completes its short rearward travel, it will deliver sufficient energy to the bolt carrier to cycle. See Jim Schatz, email message to author, November 25, 2015.

HK submitted a 16.5 inch barrel version of the HK416 for the IAR competition because they believed that a HK416 variant "would be able to meet the USMC's IAR requirements."[562] In 2011, the USMC selected HK's candidate for adoption as the M27 IAR because it had "best met their performance specifications" (See Figure 40).[563]

Figure 40: M27 IAR

Source: "M27 IAR," accessed October 20, 2015, http://marinesmagazine.dodlive.mil/2012/05/16/m27-iar/.

The basic specifications for the M27 IAR and M249 are listed in Table 1 below:

Table 1: Comparison of basic M27 IAR and M249 SAW specifications.

[A]	M27 IAR	M249 SAW
Weight	Unloaded weapon only: 3.7kg Fully loaded weapon equipped with accessories: 5.7kg	Unloaded weapon only: 7.7 kg A fully loaded M249 equipped with accessories is over two times heavier than a

[562] Robert Bruce, "M27: The US Marine Corps' New Infantry Automatic Rifle Part I," *Small Arms Defense Journal* 4 (2012): 184.

[563] Bruce, "M27: From BAR to IAR," 57.

[A] The MRBEFF figures for the M27 and M249 were not from a side by side test and therefore cannot be directly correlated.
Email communication from MAJ James Williamson to author, October 30, 2014.
Lt. COL Ronald McLaughlin (USMC), email message to author, November 4, 2014.
"Detail Specification Machine Gun, 5.56mm: M249," accessed September 2, 2015, http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/download.php?spec=MIL-DTL-70446C_AMENDMENT-1.030073.pdf.
"M249 SAW," accessed September 2, 2015, http://www.fnhusa.com/products/machine-guns/m249-series/m249-saw/.

		fully equipped and loaded M27 IAR.
Sustained Rate of Fire	36 RPM at 120 Degrees Fahrenheit with a 600 round combat load	50 RPM
Mean Rounds Between Essential Function Failure (MRBEFF) Requirement for Class III Malfunctions (cannot be cleared by the operator)	15,000 rounds	16,000 rounds
Ammunition Feed System Capacity	30 round USGI M16 magazine	200 round belt
Mode of Fire	Semi-automatic and full automatic	Full automatic only

Compared to the M16 series' direct gas impingement system, the M27 IAR's pusher rod gas system reduces heat transfer to the bolt group. The reduced heat transfer and the use of a heavier profile CHF barrel allowed the M27 to meet the USMC's sustained rate of fire requirement and deliver a higher sustained rate of fire than the M16 and M4 assault rifles.[564]

More importantly, the M27 IAR has several advantages over the M249 in the automatic rifle role for the USMC's needs. The fielding of the M27 enabled "training across the USMC to be significantly streamlined because the differences between the M16A4, M4 and M27 IAR are very minor at the user level" and all three weapons have a common cycle of operations and operating controls.[565] As the M27 IAR has replaced the M249 SAW in the automatic rifle role,

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[564] Vickers, "The U.S. Marines Send the M27 IAR Downrange," 54.
Bruce, "M27:The US Marine Corps' New Infantry Automatic Rifle Part I," 184.
The sustained rate of fire for both the M16A4 and M4/M4A1 is 12-15 RPM. See Kirk Ross, "What Really Happened at Wanat," *US Naval Institute Proceedings Magazine*, July 2010, accessed September 2, 2015, http://www.usni.org/magazines/proceedings/2010-07/what-really-happened-wanat.
Unlike the standard direct impingement M16 and M4, the M27 IAR's pusher rod gas system does not vent hot propellant gas to the bolt group. This reduces the heat transfer to the M27's bolt group and allows those components to retain lubrication for longer intervals compared to the M16/M4's bolt group. Also, the reduced heat transfer to the M27's bolt group increased the service life of some parts compared to those of the M16/M4 when subjected to more extensive automatic fire usage. Jim Schatz, email message to author, November 25, 2015.
[565] Email communication from MAJ James Williamson to author, October 30, 2014.
The M27 IAR, M16A4 and M4 all fire from the closed bolt position while the M249 fires from the open bolt position. "At Infantry Training Battalion (where entry level infantry Marines receive their MOS training), training

select quantities of M249s are retained by the weapons company for employment as crew served LMGs and their use will be determined by the commander. Hence, M249 training was discontinued for infantryman and other military occupational specialties (MOS) and has been transferred to the machine gunner MOS.[566] Major James Williamson (USMC) explained that the M27's adoption has significantly reduced training costs for the USMC:

> Numbers of personnel are directly related to cost and we used to train all Marines going through Infantry Training Battalion on the M249 SAW, which comes to approximately 7400 per year. Now we just train the infantrymen on the M27 IAR, which comes to approximately 5000 per year. The machine gunners are the only Marines that still receive training on the M249 SAW, which comes to approximately 800 per year. We also used to train all of the other combat arms and support MOS Marines who go through Marine Combat Training Battalion on the M249 SAW. That number is about 30,000 per year.[567]

The M249 has a higher sustained rate and duration of fire while the M27 IAR improved "the portability of a system for an offensive force that is trying to close with the enemy."[568]Although the M27 had to reload more often, "when viewed against the time required to change ammunition belts on the M249 SAW and associated stoppages, the time it took for both systems to expend the same amount of ammunition was negligible."[569] Compared to the M249 SAW, the M27 IAR's greater accuracy during burst fire allowed for better "suppressive effects by providing more hits on target and the IAR also had less downtime during the assault through counterattack."[570]

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for the M27 consists of just one day of classroom instruction, followed by a live fire qualification event. The main focus of training regarding is on understanding how to employ accurate suppressive fires and utilizing the squad day optic which is slightly different than the optic issued with the M16A4 and M4." See Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.

[566] Ibid.

[567] Ibid.

[568] Ibid.
Bruce, "M27: From BAR to IAR," 53.

[569] Email communication from MAJ James Williamson (USMC) to author, February 24, 2015.

[570] Ibid.

While the USMC's adoption of the M27 IAR has allowed the automatic riflemen to have commonality of training with the M16 series, the adoption of more niche weapons has some disadvantages from the logistical and maintenance perspectives. The M27 IAR's proprietary parts include its bolt group, buffer, recoil spring and gas system, which cannot be interchanged with those of the M16 and M4.[571] Also, the M27 IAR requires different armourer tools and training for weapons repair compared to the M16 series.[572] When the US plans on replacing their entire fleet of small arms, they should improve the degree of weapons standardization within their own military by procuring IARs and assault rifles that share a high degree of parts commonality to limit the logistics issues.

6.4 US Army Program Executive Office Soldier and XM8

While the US military has not yet acquired a family of weapons that shares a high degree of parts commonality, the US Army's Program Executive Office (PEO) Soldier attempted to procure such a system during the early to mid-2000s. Starting in the 1990s, the US Army worked on the XM29 Objective Individual Combat Weapon (OICW). The XM29 consisted of a 5.56mm caliber rifle and 20mm semi-automatic grenade launcher modules and a target acquisition and

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According to USMC Deputy Commandant Charles Clark: "fire superiority is based on both accuracy and volume of fire. The greater the accuracy, the less volume of fire you need. Current doctrine is based on the belief that there is no effective acoustic suppression below the sound of a .50 caliber" (12.7mm) heavy machine gun round. See Bruce, "M27: From BAR to IAR," 63.

"In December 2009, the Marine Corps Operational Test and Evaluation Activity (MCOTEA) conducted a study on performance between the M27 and M249. The Key Metrics / Measures during the test were suppressive effects, total target exposure time, time to advance to objective from cover, ammo expended and time to reload.
In the support by fire: the M27 significantly outperformed M249 in suppression (hits on target in a compressed timeline) and used significantly less ammo than M249 to achieve the same number of hits. There were no significant differences in reload times or stoppages, though M27 did perform slightly better. From the assault through a counterattack: there were no significant differences in suppressive effects among alternatives, though M27 did perform slightly better. M27-only squads expended significantly less ammo. Average reload times not significantly different. M27 had less downtime (e.g., clearing stoppages) while the M249 had most downtime at night (seven times more downtime). The M27 had best suppressive effects." See Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.

[571] *Maintenance Manual for HK416 Enhanced Carbine & Rifle System* (Sterling: Heckler & Koch USA, 2005), 5.

[572] Ibid, 17.

fire control system (TA/FCS) (See Figure 41). ATK along with HK won the contract for the XM29 OICW and HK was the subcontractor in charge of manufacturing the grenade launcher and rifle modules. The Army believed that the OICW's 20mm air bursting grenades would defeat defilade targets and improve hit probability compared to conventional small arms.[573]

Figure 41: XM29 OICW

Source: "Alliant Techsystems / Heckler-Koch XM-29 SABR / OICW assault rifle (USA)," accessed October 20, 2015, http://world.guns.ru/assault/usa/xm29-oicw-e.html.

But the XM29 was unable to meet its weight requirements and there were problems with the 20mm grenade's effectiveness.[574] So PEO Soldier chose to "exploit the existing OICW contract to expedite the development and fielding of a new family of 5.56mm weapons" using the rifle module of the XM29.[575] In 2002, "PEO Soldier modified the OICW contract to develop the 5.56mm XM8 carbine and in 2003, the Army's Picatinny Center for Contracting and Commerce issued a contract modification to expand the XM8 to include a family of weapons."[576] In 2004, the Picatinny Center for Contracting and Commerce gave HK a sole source contract for the development, production and delivery of the XM8 family, which consisted of the carbine,

[573] "Objective Individual Combat Weapon (OICW)," accessed September 2, 2015, http://fas.org/man/dod-101/sys/land/oicw.htm.
Department of Defence Inspector General, *Program Management of the Objective Individual Combat Weapon Increment I* (Arlington: Department of Defence, 2006), 12.

[574] Scott Hiromoto, "Fundamental Capability Portfolio Management: A Study of Developing Systems with Implications for Army Research and Development Strategy" (PhD. Dissertation, Pardee RAND Graduate School, 2013), 61, 62.

[575] Email communication from Jim Schatz to author, September 16, 2015.

[576] Department of Defence, *Program Management of the Objective Individual Combat Weapon Increment I*, 2.

designated marksman/automatic rifle (DMAR) and CC variants.[577] The XM8 variants were intended to replace the M4, M16, the M249 SAW in the automatic rifle role and some handguns while the M249 would be employed in the LMG role (See Figure 42).[578]

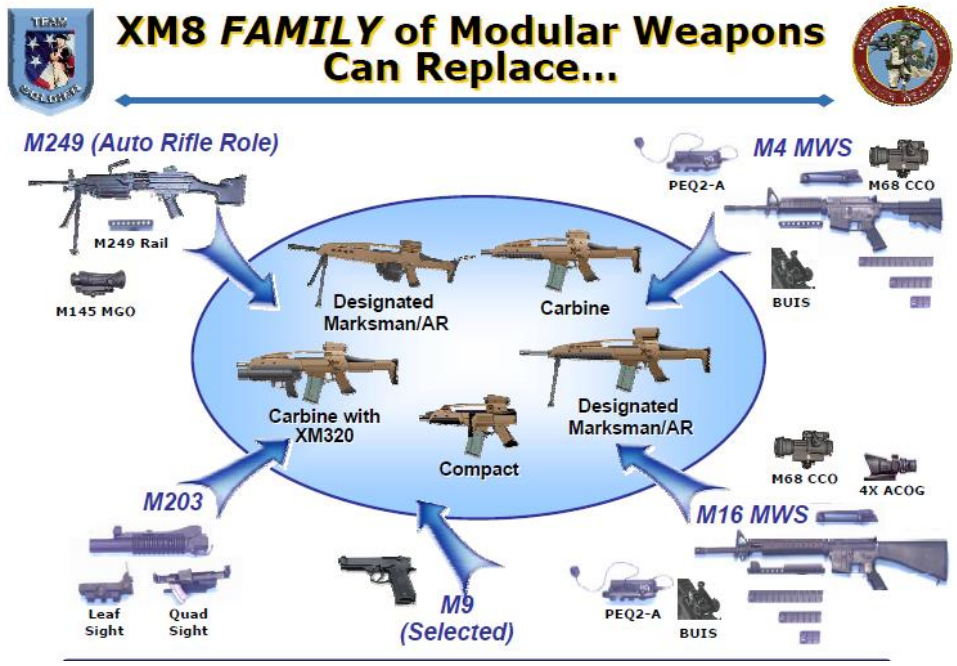

Figure 42: XM8 Family of Weapons.

Source: BG James Moran and COL Michael J. Smith, "PM Soldier Weapons Briefing for the 31st Annual Firepower Symposium" (presented at the International Armaments Technology Symposium & Exhibition, June 14-16, 2004, http://www.dtic.mil/ndia/2004armaments/06_Audette_Fire_Power.pdf).

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[577] Ibid, 15.

[578] BG James Moran and COL Michael J. Smith, "PM Soldier Weapons Briefing for the 31st Annual Firepower Symposium" (presented at the International Armaments Technology Symposium & Exhibition, June 14-16, 2004, http://www.dtic.mil/ndia/2004armaments/06_Audette_Fire_Power.pdf).

MAJ Shawn T. Jenkins and MAJ Douglas S. Lowrey, "A Comparative Analysis of Current and Planned Small Arms Weapons Systems" (MBA Professional Report, Naval Postgraduate School, 2004), 22.

The XM8 automatic rifle and designated marksman rifle variants were initially separate variants but due to recommendations during further development, it was decided to consolidate the two variants. In the automatic rifle role, the XM8 DMAR would be equipped with a 100 round drum magazine. See Jenkins and Lowrey, "A Comparative Analysis of Current and Planned Small Arms Weapons Systems," 22.

6.5 Cancellation of XM8 and OICW Increment I

However, the OICW contract modifications and XM8 contract "were not within the scope of the original OICW contract" because the XM8 was not compatible with the XM29 nor its TA/FCS and the original criteria for OICW "did not require a family of weapons."[579] Since an open competition was required before the military can proceed with the development and fielding of new weapons, competing firearms manufacturers protested against the Army's unfair contracting process for XM8.[580] Moreover, PEO Soldier developed XM8 without receiving the necessary requirements documentation because the US Army Infantry Center (USAIC), which was the "user proponent for small arms, did not have requirements for a new family of weapons."[581] The above mentioned issues were major factors that led to the cancellation of the XM8 program and in 2005, "the US Army issued requests for proposals for the OICW Increment I family of weapons."[582] The OICW Increment I family was supposed to consist of a new LMG along with designated marksman rifle, carbine and CC variants. The OICW Increment I LMG variant was required to share fifty percent parts commonality with Increment I's rifle variants and PEO Soldier "directed the OICW Increment I effort to the XM8 design."[583] Afterwards, several manufacturers "applied pressure" to cancel OICW Increment I because they believed that the "deck was stacked in HK's favour."[584] More importantly, OICW Increment I was initiated

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[579] Department of Defence, *Program Management of the Objective Individual Combat Weapon Increment I*, 14.
[580] Ibid, 11.
"US Army decides to compete OICW," *Jane's Defence Weekly*, May 19, 2005, 1, 2.
[581] Email communication from Jim Schatz to author, September 16, 2015.
Department of Defence, *Program Management of the Objective Individual Combat Weapon Increment I*, 6.
[582] "US Army decides to compete OICW,"1.
[583] Ibid.
Email communication from Jim Schatz to author, September 16, 2015.
[584] Ibid.
"US Army decides to compete OICW, Jane's Defense Weekly, 2.

without an end user requirement and appropriate requirements documentation, so the Department of Defense Inspector General decided to "suspend OICW Increment I" in October 2005.[585]

In addition to the lack of requirements for a new 5.56mm family of weapons, the requirement for the OICW Increment I rifle and LMG variants to use common parts had resulted in greater developmental risks for the program. HK's XM8 Program Manager Jim Schatz believed that the fifty percent parts commonality requirement may compromise OICW Increment I's performance because "a belt-fed LMG was a completely different weapon with a vastly different role" than the carbine, CC and DMAR variants.[586] Another problem with OICW Increment I was that the US Army did not properly formulate their requirements for parts commonality. Salvatore A. Fanelli explained those problems based on his own experiences as HK's second XM8 Program Manager:

> The Army failed to provide the definition of what they considered to be a common part. They failed to identify if this was every part in the weapon or the parts in a subassembly. As an example, if the receiver was made from 10 parts that were molded into a single plastic assembly, and some of the components were also used in the LMG, is this commonality or not? Imagine if a company decided to use 10 screws to hold a buttstock together. How do you score it? HK took the right approach and only considered components that the Army would procure as spare parts.[587]

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[585] Department of Defence, *Program Management of the Objective Individual Combat Weapon Increment I*, 6, 10. Schatz, "Time for a Change," 97.

[586] Ibid.

A LMG that shared common parts with a rifle would likely be less expensive than a purpose built LMG due to economies of scale and also reduce the spare parts that need to be stocked. See Thomas Held, Bruce Newsome, and Matthew W. Lewis, *Commonality in Military Equipment: A Framework to Improve Acquisition Decisions* (Santa Monica: RAND Corporation, 2008), 15, 16.

But the performance demands of LMGs required "their parts to be more robust than those used in assault rifles and using a significant number of LMG parts in a rifle design may result in an assault rifle that is over-engineered, more expensive and heavier than needed." Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015.

For OICW Increment I, Jim Schatz believed that "it would have been right to request similar operating controls and even interchangeable parts where that makes sense" from a performance standpoint but parts commonality requirements must "not drive and compromise the performance of either or both" types of weapons. Email communication from Jim Schatz to author, December 3, 2014.

[587] Email communication from Salvatore A. Fanelli to author, January 8, 2015.

Salvatore A. Fanelli succeeded Jim Schatz as HK's XM8 Program Manager in 2003. Salvatore A. Fanelli is currently the APdM-Engineering Supervisor at USMC IWS SYSCOM but the information he provided the author

In the early 2000s, HK had developed a purpose built 5.56mm LMG known as the MG4 for the Bundeswehr's requirements and chose a modified MG4 that shared some parts and accessories with the XM8 family for OICW Increment I (See Figure 43). But HK's OICW Increment I LMG and XM8 family did not share a common receiver and several of their major parts such as the bolt group, feed system and gas system were not interchangeable.[588] Consequently, the "first generation" OICW Increment I LMG only "achieved around forty five percent parts commonality with the XM8 family based on what HK defined as a common part" before the program was suspended.[589]

Figure 43: HK MG4 LMG

The above image shows HK's standard production MG4 LMG that is in use with the Bundeswehr and not the OICW Increment I variant.
Source: "MG4," accessed October 20, 2015, http://hk-usa.com/hk-models/mg4/.

6.6 US Military Procurement for the 2020s

While the US Army did not have a requirement for a new family of weapons when XM8 and OICW Increment I were initiated, the US military plans on procuring new infantry weapons in the 2020s period following the results of the SAAC study. The US Army is currently working

about OICW Increment I are from the standpoint of being a former HK employee and based on his own opinions and experiences working in the small arms industry and are not those officially from the USMC.
[588] Email communication from Jim Schatz to author, April 21, 2015.
[589] Email communication from Salvatore A. Fanelli to author, January 8, 2015.
HK chose to only count parts that the US Army procured as spare parts towards parts commonality. If a different definition was used for parts commonality, then the OICW Increment I LMG would "have exceeded the fifty percent parts commonality goal." See Email communication from Salvatore A. Fanelli to author, January 8, 2015.

with the USMC on the Next Generation Squad Weapon Program, which is intended to replace the M16 series.[590] As well, the US Army intends on fielding a next generation squad automatic rifle to replace the M249 in the automatic rifle role and the USMC is also involved in this program.[591] Furthermore, the US Army has planned on fielding a CC since 2006 but the procurement of such a weapon has now been delayed to the 2020s period.[592] The CC would be shorter than a M4 and replace "M16s and pistols for vehicle drivers, aircrews, armoured vehicle crews, engineers, construction teams and other soldiers whose duties require them to fight within smaller spaces."[593] In the 2020s, the US military will have to procure new assault rifles, automatic rifles and CCs because they plan on transitioning to a new intermediate caliber but their procurement process does not mandate those weapon types to share parts commonality or identical operating controls.

6.7 Advantages of a Common Family of Weapons Approach for the US Military

In order to avoid logistical and training issues associated with numerous niche weapons, the US military should develop and field a family of weapons with a higher degree of parts commonality in the 2020s period compared to legacy small arms. In order to avoid some of the problems of OICW Increment I, only parts of a gun that the US military stocks as spare parts should count towards parts commonality requirements for a family of weapons in a new intermediate caliber. A "business case analysis conducted by the US Army in August 2005

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[590] Lt COL Terry Russell, "PM Individual Weapons" (presented at the National Defense Industrial Association, Whippany, NJ, June 1-3, 2015, http://www.dtic.mil/ndia/2015smallarms/Russell.pdf), 2.
Chris Woodburn, "USMC Infantry Weapons Requirements Brief" (presented at the National Defense Industrial Association, Whippany, NJ, June 1-3, 2015, http://www.dtic.mil/ndia/2015smallarms/Woodburn_USMCWeapons.pdf), 4.

[591] Ibid.
Libersat, "Soldier Division Director," 8.

[592] Russell, "PM Individual Weapons," 2.
MAJ GEN Walter Wojdakowski, "Small Arms Strategy: Training and Modernization," *Infantry*, May-June 2006, 1.

[593] Ibid.

determined that the US could save $1.2 billion over the life of the system by replacing the legacy rifle, carbine, SAW and select handguns with a modular family of weapons" like the XM8 and OICW Increment I.[594] These significant fiscal savings for a common family of weapons comes from similar training and common parts and tooling.[595] Due to the basic operator training time saved through the common family of weapons approach, soldiers can concentrate more on advanced training tasks and "focus on higher cognitive skills related to the tactical employment" of weapons.[596] Since the US Army "is in a resource constrained environment for the foreseeable future,"[597] fielding a family of weapons with common parts would allow the US military to make the best use of their fiscal resources when starting from a clean slate. The resultant cost savings should be used to contribute to other important military needs such as improving the quality of

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[594] Schatz, "Time for a Change," 113.

[595] Email communication from Jim Schatz to author, September 16, 2015.
The XM8 rifle family reduces training time compared to current US weapons because all variants share many common parts, have identical operating controls and the same cycle of operation and type of gas system. All XM8 variants use HK's pusher rod gas system but the CC variant has a shorter pusher rod than the carbine and DMAR variants. The XM8 CC and carbine variants are equipped with an Integrated Sighting Module that has a co-aligned red dot sight and Infrared laser and illuminator, which reduces time compared to zeroing multiple aiming devices. See Email communication from Jim Schatz to author, December 3, 2014.
If an assault rifle and an open bolt LMG shared major common parts such as the gas system and feeding mechanism and used the same sights, caliber and bullet design, then the time it takes to train soldiers on both systems would be reduced. See Held, Newsome and Lewis, *Commonality in Military Equipment*, 36.
Both the XM8 rifle family and HK's OICW Increment I LMG fired the M855 FMJ and M856 tracer cartridges and both HK's OICW Increment I LMG and XM8 DMAR variant used the same advanced magnified optic, which combined a four power magnification optic and Infrared laser and illuminator. But the XM8 rifle family and HK's OICW Increment I LMG had different gas systems, bolts and bolt carriers and the XM8 rifle family was magazine fed while the LMG was belt fed. See Email communication from Jim Schatz to author, April 21, 2015.
So the amount of training time saved between the XM8 rifle family and HK's OICW Increment I LMG will not be as significant as the training time saved for the XM8 rifle variants.
But any commonality between a LMG and assault rifle will reduce training for armourers. See Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015.
As HK's OICW Increment I LMG shares some common parts with the XM8 rifle family, armourer training for those weapons will be reduced compared to armourer training for assault rifles and LMGs that share no common parts such as the M16 series and M249.

[596] *Army Soldier Weapons Strategy 2014*, 17.

[597] Ibid, 1.

training and greater ammunition allocations to enable soldiers to better maintain and improve their weapons skills.[598]

More importantly, procuring a family of weapons consisting of an assault rifle, CC, IAR and designated marksman rifle with common parts does not compromise each variant's performance. One example of a family of weapons that has demonstrated good performance would be the HK416 series, which consists of the 10.4 inch and 14.5 inch barrel variants along with the M27 IAR. All of those HK416 variants share many common parts such as the receiver, bolt, gas system, recoil spring and buffer.[599] A comparison of the basic specifications for the 10.4 inch and 14.5 inch barrel HK416 variants with the US military's standard assault rifle is shown in Table 2 below:

Table 2: Comparison of the basic specifications of the HK416 and M4.

[Δ]	HK416 10.4 inch and 14.5 inch barrel variants	M4 and M4A1 carbine
Service Life of Major Components	HK's technical terms of delivery specifies for a bolt life of 10,000-15,000 rounds	Bolt replacement recommended at 6000 rounds

[598] In order to improve infantry training for the USMC, MAJ James Williamson believes that: "more ammunition and more realism in their training would be needed. The USMC's annual qualification range is not realistic to a combat environment, but it is established and reinforces the basic principles and is easy for mass throughput. As units train for deployment, they have more opportunities to shoot more realistic ranges but the challenge is always immediate feedback to the shooter because it can be difficult to access if each shooter is hitting his target when everyone around that shooter is shooting and maneuvering too. The USMC have some ranges that do this better than others but money/ammunition allocations as well as range availability remain constants." See Email communication from MAJ James Williamson (USMC) to author, October 30, 2014.
Likewise, "feedback from operational commanders showed that weapons proficiency is critical and field feedback has indicated that higher training ammunition authorizations are needed" for the US Army. See James C. Crowley et al, *Changing the Army's Weapon Training Strategies to Meet Operational Requirements More Efficiently and Effectively* (Santa Monica: RAND Corporation, 2014), 13.
Also, if all US Army infantry soldiers were taught marksmanship beyond 300m, they would be able to fully take advantage of the capabilities of a new intermediate caliber. See Schatz, "The Future of the Military Assault Rifle."

[599] Maintenance Manual for HK416 Enhanced Carbine & Rifle System, 46, 49.

[Δ] Kirk Ross, "What Really Happened at Wanat," *US Naval Institute Proceedings Magazine*, July 2010, accessed September 2, 2015, http://www.usni.org/magazines/proceedings/2010-07/what-really-happened-wanat.
Maintenance Manual for HK416 Enhanced Carbine & Rifle System, 7.
Hk416 Armorer Inspection Checklist (Ashburn: Heckler & Koch).
David Vergun, "Beefier carbines en route to Soldiers," accessed September 2, 2015, http://www.army.mil/article/126553/Beefier_carbines_en_route_to_Soldiers/
"The HK416: The M16 has finally been fixed."

	minimum and a barrel life of 15,000 rounds minimum.[B]	and bolts should absolutely be replaced at 10,000 rounds. Barrel life: 4000-10,000 rounds depending on firing schedule.[X]
Recommended Replacement Interval for Small Parts	10,000 rounds	3000-5000 rounds
Cook off Threshold	250-270 rounds	170 rounds for M4 210 rounds for M4A1
Sustained Rate of Fire	12-15 RPM	12-15 RPM
Weight	Unloaded weight: 3.3 kg for 10.4 inch barrel variant and 3.5 kg for 14.5 inch barrel variant. The 10.4 inch barrel HK416 is available with a lighter profile barrel, which lowers the barrel's weight by 7 ounces.	Weight with back up iron sights, forward grip, empty magazine and sling: 3.38 kg for M4 and 3.51 kg for M4A1.
Modes of Fire	Semi-automatic and full automatic	M4: semi-automatic and three round burst M4A1: semi-automatic and full automatic

[B] Jim Schatz, email message to author, November 25, 2015.
The parts life figures for the HK416 and M4 are not a one to one correlation because they were not from a side by side evaluation that subjected the guns to the exact same testing conditions.
Jim Schatz explained that: "HK generally defines barrel life as the round count before the muzzle velocity V5 drops by 6% from new. HK specifies a barrel life of 15,000 rounds minimum for the HK416 but there has been endurance tests where HK416s with over 20,000 had no loss in V5 and still shot 1 Minute of Angle groups at 100m from a test fixture." See Jim Schatz, email message to author, November 25, 2015.
The USMC used erosion gauges to determine the barrel life of the M27 IAR and M16 and M4s. Using this method, barrel life for the M27 was 20,000 rounds while the barrel life for the M16A2/A4 and M4 was around 5000 rounds. See Lt. COL Ronald McLaughlin (USMC), email message to author, November 4, 2014.
But the disadvantages of barrel erosion gauges are that "they are only 60% accurate." See Taylor, "SOPMOD Program Overview," 48.

[X] Lucius Taylor, "SOPMOD Program Overview" (presented at the National Defense Industrial Association Conference, Albuquerque, New Mexico, May 15-18, 2006, http://www.dtic.mil/ndia/2006smallarms/taylor.pdf#search=%22sopmod%22), 48.
Ehrhart, "Increasing Small Arms Lethality in Afghanistan," 42.
The barrel life figures for the M4A1 shows "when the barrels are burned out; most M4A1 barrels subjected to harsh firing schedules will be burnt out between 4000 and 6000 rounds while barrels may last 10,000 rounds on milder firing schedules." See Taylor, "SOPMOD Program Overview," 48.

The 10.4 inch barrel HK416 can fill the role of CC and has demonstrated superior reliability and parts life over competing AR-15 style CCs in testing conducted by US special operation forces.[600] The 14.5 inch barrel HK416 fulfills the same role as the M4 series and while the HK416 is slightly heavier than the latter, it still met NATO's weight requirements for an assault rifle and has longer parts life compared to the M4 series.[601] In addition to meeting the USMC's IAR sustained rate of fire requirements, the M27 has demonstrated a high degree of accuracy and can meet the requirements of the designated marksman role.[602] This example shows that industry has the capability to develop a family of weapons with common parts and not compromise performance if the variants do not perform significantly different roles.

For the 2020s period, a family of rifles in a new intermediate caliber should include standard assault rifle, carbine, automatic rifle, designated marksman and CC variants in order to meet all of the US military's small arms requirements.[603] New assault rifle, carbine, automatic rifle, designated marksman and CC variants of the same caliber "should share common components such as receivers, trigger mechanisms, bolt groups and small piece parts" and utilize the same type of gas system.[604] A family of weapons that shares a significant percentage of

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[600] Email communication from Jim Schatz to author, June 23, 2015.

[601] Jim Schatz, "The 23rd Annual European Small Arms & Cannons Symposium," *Small Arms Defense Journal* 1 (2011): 2, accessed September 2, 2015, http://www.sadefensejournal.com/wp/?p=454.

[602] Charles Clark III, "USMC Update" (presented at the National Defense Industrial Association, Seattle, Washington, May 14-17, 2012, http://www.dtic.mil/ndia/2012armaments/Tuesday13939CharlesClark.pdf), 2.

[603] Schatz, "Strategic Tripartite," 11.
A carbine is an assault rifle that has a shorter barrel than the standard assault rifle.

[604] Email communication from Jim Schatz to author, December 3, 2014.
The conventional polymer cased ammunition made by MAC LLC has better cook off resistance than brass cased ammunition. During the USMC's evaluation, "MAC LLC was unable to get its Mk323 Mod 0 conventional polymer cased ammunition to cook off because the heat normally transferred through the brass case into the chamber walls does not happen in the same degree with polymer cases and instead goes down the barrel and out of the weapon." See Email communication from Jim Schatz to author, April 21, 2015.
Also, if the US military chooses weapon mechanisms that fire CTA rather than conventional polymer cased ammunition, it would still be possible to design standard assault rifle, carbine, automatic rifle, designated marksman and CC variants that share a high degree of parts commonality. See Email communication from Jim Schatz to author, April 21, 2015.

common parts allows economy of scale, which would lower the overall unit costs of the weapon variants compared to procuring several niche weapons with little or no parts commonality.[605]

During the 2020-27 period, the US Army will also evaluate new machine guns that "exceed the capabilities of the M249."[606] One solution for future machine guns would be to design a lighter GPMG chambered for either the 6.8x46mm or 7x46mm caliber to replace both 5.56mm LMGs and 7.62mm NATO GPMGs, which would be advantageous from the training and logistical standpoint compared to using two machine gun models.[607] But a new GPMG should not be required to share parts commonality with rifle variants, to insure that its performance is not compromised.[608] If some NATO militaries want to use separate weapon systems for the LMG and GPMG roles, a LMG variant that has a certain amount of parts commonality with a family of rifles may be considered if all variants can meet the required reliability and performance metrics.[609] Weapons designed specifically for the LMG role generally have a lower parts life compared to machine gun models intended to serve as a GPMG.[610] For weapons that fire conventional ammunition, Salvatore A. Fanelli's personal opinion is that the goal of designing a family of rifles that shares fifty percent spare parts

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If the US and other NATO militaries want a smaller intermediate caliber like the 6x35mm for Compact Carbines but a larger intermediate caliber (for example, 6.8x46mm or 7x46mm) for the other rifle variants, then at a minimum, the Compact Carbine and the other variants can share some common small piece parts and trigger group components along with identical operating controls. See Email communication from Jim Schatz to author, June 23, 2015.

[605] Ibid.

[606] *Army Soldier Weapons Strategy 2014*, 10.

[607] Cris E. Murray, "7x46mm," 2.

[608] The MAG 58/C6 GPMG and Minimi/C9 LMG have cross bolt safety switches while the C7 assault rifle has a lever type selector/safety switch, which does not allow for the same muscle memory. When doing familiarization training on the C9, some members of the Canadian Army's reserve infantry, who were already trained on the C7, had to make a physical glance at the C9's selector switch and had to take their eyes off the target and in certain instances breaking cheek weld and sometimes removing the C9 from the shoulder. See Email communication from former Canadian Army infantry reservist to author, November 23, 2015.

The author believes that the US military should consider lever type selector switches positioned at a similar location for new assault rifles and new GPMGs, which would allow soldiers to take advantage of some of the muscle memory from the assault rifle.

[609] The suggestion that a family of rifles and a LMG variant share a certain degree of parts commonality is for weapon designs that fire conventional polymer cased ammunition.

[610] Matthew Cox, "Spec-Ops Mk48," *Tactical Weapons*, November 2009, 24.

commonality with a LMG variant "is more feasible now because so much has been learned recently about improved metallurgy, heat treatment and plastics that a family of weapons, given reasonable performance criteria is achievable."[611] If some militaries choose to pursue this option, then the requirements for the percentage of common parts that the LMG and rifle variants would share must be realistic so that the rifle variants are not excessively heavy or expensive and the reliability of the LMG is not significantly compromised.[612]

6.8 Potential Benefits of the Common Family of Weapons Approach for NATO

As mentioned previously, the existence of different weapon models in service with NATO members has prevented all NATO militaries from having a single integrated logistical system and NATO states generally rely on their own national logistical systems.[613] Since it is unlikely that all NATO militaries will adopt the same models for every type of infantry weapon, alliance members will have to rely on their national supply systems during joint operations in the future. Also, all NATO militaries have the same overall maintenance procedures but some alliance members that use different variants of the same weapons still chose "different implementations of NATO's maintenance system" to best suit their own demands.[614] An example of this can be seen comparing the Canadian and American maintenance systems. The

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[611] See Email communication from Salvatore A. Fanelli to author, January 8, 2015.
Salvatore A. Fanelli is currently the APdM-Engineering Supervisor at USMC IWS SYSCOM but his opinions about the current feasibility of designing a LMG that shares fifty percent parts commonality with an assault rifle are his own opinions based on his experiences working in the small arms industry and are not those officially from the USMC.

[612] Only parts that a NATO military procures as spare parts should be counted towards parts commonality.

[613] Lt COL Charles A. Seland, "Evolution of Logistics: Supporting NATO's Multinational Corps" (Individual Study Project, NATO Defense College, 1991), 26.
Usually, "NATO as an entity doesn't provide services or supply stockpiles except at the strategic level for fixed infrastructure like HQ and communications systems; and strategic supply stocks such as specialized munitions like smart bombs." See Email communication from Defense Industry Professional and former Canadian Army Officer to author, September 23, 2015.

[614] Email communication from Defense Industry Professional and former Canadian Army Officer to author, September 23, 2015.
Seland, "Evolution of Logistics," 26.

"Canadian Army's first line maintenance is integral to a fighting unit," is responsible for repairs that take under two hours and can replace all components on the C7 and C8.[615] In contrast, the US military has company level armourers that conduct simple repairs like replacing springs, handguards and parts that do not require gauging while mid-level fixes such as bolt and firing pin replacement are done by battalion level armourers.[616] Unlike Canadian first line maintenance, the US military replaces M16 and M4 barrels at depot level because the tools needed for barrel removal are not available at battalion level and training armourers for major repairs on various weapons "is time consuming and expensive."[617] However, depot level maintenance for rifles is more expensive and time consuming than doing all rifle repairs at a lower maintenance level because weapons need to be shipped from units to the continental US and "the labour rate of depot contractors" is higher than those of military armourers.[618] Although there are no "procedural hurdles that would preclude formation of a joint support activity for a multinational NATO force that could offer efficiencies for nations using the same weapons," certain states might have to implement their small arms maintenance differently when part of a multinational force.[619]

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[615] Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015
"Canadian weapons maintainers are trained on everything from rifles to leopard tanks. The Canadian Forces have four levels of maintenance. First line maintenance works out of the back of a small truck, which has limited space to carry spare tools and test equipment (STTEs) and the repairs they can make is limited to the availability of STTEs. However, all of the tools that are needed for changing barrels on the C7 and C8 are available at first line maintenance and all assault rifle/carbine repairs are done at this level. An example of first line maintenance would be the maintenance platoon of an Infantry Battalion. Second line maintenance has larger trucks and does repairs that take over two hours, which requires more STTEs and probably a more permanent workshop setup in a safer area. An example of second line maintenance would be a service battalion. Third and fourth line maintenance is depot level maintenance." See Author Telephone Interview with CWO (Mr Gnr) John T. Yoshida, June 15, 2015.
[616] Email communication from MAJ James Williamson (USMC) to author, June 25, 2015.
[617] MAJ James Williamson (USMC), email message to author, November 18, 2015.
A vise, combination wrench and torque wrench are required for changing barrels on the M16 series of weapons. See *Army TM 9-1005-249-23&P Technical Manual* (Washington: Department of the Army, 1991), 3-25.
[618] Email communication from Jim Schatz to author, December 3, 2014.
[619] Email communication from Defense Industry Professional and former Canadian Army Officer to author, September 24, 2015.

The adoption of a family of weapons with common parts would be beneficial to NATO operations from the logistical and maintenance standpoint and may improve the efficiency of NATO's support systems. Procuring a family of weapons with parts commonality and an intermediate caliber GPMG would reduce both the different types of spare parts in a state's national supply system and the amount of different weapon models that armourers need to be trained to repair.[620] More importantly, a family of weapons with more parts commonality than legacy weapons may allow all rifle maintenance to be done more cost effectively by an integrated support system. Parts commonality will reduce the costs and time required for armourer training and "the economies of scale used to procure the same parts used for numerous weapons would lower the price to replace those parts more often."[621] If the US military adopts weapons with a modular architecture that allows for simpler barrel removal procedures using less specialized tools, American armourers will likely be able to overhaul all components on rifles below depot level and reduce repair costs.[622] Therefore, a modular family of weapons with common parts may allow certain NATO states with the same equipment to form an integrated support system that is more cost effective than the current maintenance procedures of certain NATO militaries.

Since the adoption of a common NATO rifle is unlikely to occur in the future, alliance members should improve the degree of weapons standardization within their own national armies

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[620] Jenkins, "A Comparative Analysis of Current and Planned Small Arms Weapons Systems," 41.
[621] Ibid.
[622] Email communication from Jim Schatz to author, December 3, 2014.
For small arms and machine guns, the US military "conducts Limited Technical Inspections and Pre-Fire Inspections before each weapon is issued out of the armory" and armourers "rely on gauges to see if a weapon is in or out of spec." See MAJ James Williamson (USMC) to author, October 30, 2014.
If the US military chooses to field a new family of weapons with common parts along with a new GPMG, they should also implement preventative maintenance by "recording the weapon's round count before the weapon is received back in the arms room" and replacing parts at given round counts. See Email communication from Jim Schatz to author, December 3, 2014.

by adopting a family of weapons with more parts commonality than their current small arms. Previous efforts at adopting a family of weapons with common parts, such as XM8 and OICW Increment I, were cancelled mainly because these programs were initiated without the proper requirement documents since USAIC had no requirements for new small arms during that period. Another major factor that led to the cancellation of the XM8 was the US Army's unfair contracting process for the program because HK was selected as the contractor without an open competition. Other problems with OICW Increment I included the US Army's failure to properly formulate a parts commonality requirement and the challenge of achieving fifty percent spare parts commonality between rifles and LMGs. Currently, the US military plans on adopting a new intermediate caliber in the 2020s period and has requirements for new assault rifles, automatic rifles, designated marksman rifles and CCs. For their next generation of small arms, the US military should procure a family of weapons consisting of assault rifle, carbine, automatic rifle, designated marksman rifle and CC variants that share common parts. Common parts would reduce costs and the logistics burden for national militaries and simplify operator and armourer training. If certain NATO states procured a family of rifles that have a simpler barrel removal procedure than the M16 series, then those alliance members can conduct all of their repairs for rifles at lower echelons, which would reduce repair costs.

Conclusion

At the beginning of the Second World War, both the Allies and Axis Powers used a variety of niche weapons because the existing types of weapons each had their own strengths and limitations. But using a variety of infantry weapons had disadvantages from the logistical and training perspectives due to the lack of commonality in ammunition, training and spare parts. The lack of ammunition commonality among all Allied forces and the Axis Powers led to some logistical problems and ammunition standardization would have improved the efficiency of their logistical systems. The Germans designed the first GPMG models which eliminated the need for separate LMG and MMG models and introduced the assault rifle as an intended replacement for the rifle and SMG during the later stages of the war. However, certain German weapons such as the MG34 GPMG were not well suited for mass production and the Germans had to introduce the new MG42 GPMG to supplement the MG34. Also, the Germans chose to produce numerous SMG models and could not take advantage of long production runs for small arms. Due to the effectiveness of the Allied bombing campaigns and production of numerous weapon models, Nazi Germany was unable to manufacture enough weapons for all their forces and had to utilize captured weapons to compensate for their shortages. Due to utilizing foreign weapons and transitioning to new weapon types and models during wartime, Germany's already strained logistical system had to deal with more different types of ammunition and weapons. Both the USSR and British Commonwealth were able to avoid some of the Axis Powers' logistical problems associated with using numerous weapons models and non-standard ammunition calibers. The Soviets managed wartime production more effectively than the Germans and increased weapons output meant that they did not have to rely on non-standard ammunition and captured weapons. The British Commonwealth standardized weapons and ammunition for their

forces and had some logistical advantages over the Axis Powers utilizing a variety of different ammunition calibers and weapon models.

In the post-war years, various NATO members attempted to reduce the number of types of niche weapons in use with their national militaries and the alliance sought to standardize a common rifle and caliber. Due to the US Ordnance Department's insistence on a full power rifle cartridge and America's central role in NATO, the alliance was forced to standardize the 7.62mm NATO cartridge instead of an intermediate cartridge for rifle use. The 7.62mm NATO cartridge was primarily designed for American GPMG requirements and had excessive recoil when fired from service rifles. Consequently, 7.62mm NATO caliber rifles had a slower semi-automatic rate of fire compared to assault rifles and their uncontrollability during automatic fire prevented them from effectively replacing previous automatic weapons. STANAG 2310 set the specifications for 7.62mm NATO ammunition but not every ammunition design that was compliant with the STANAG's requirements would have optimal reliability in rifle models that were sensitive to different ammunition types like the G3. The G3's roller delayed blowback operating system required "a pre-determined degree of recoil impulse" for reliable function but that "impulse may vary" for different 7.62mm NATO ammunition designs.[623]

In addition to the standardization of small arms calibers, the adoption of a common NATO rifle was desired by the alliance. This can be seen in Churchill's decision to abandon their indigenous .280 caliber EM-2 in favour of the Belgian designed FAL rifle as he wanted the Americans to adopt the FAL in exchange for NATO standardization of the 7.62mm cartridge. But economic considerations were a major factor that prevented the standardization of a common rifle for Anglo-American and NATO forces. The US chose to maintain their own small arms

[623] Jim Schatz, Email message to author, April 21, 2015.

industry rather than produce the FAL rifle because the Americans would have to pay royalties to FNH if US-made FALs were supplied to their allies abroad. As well, the Ordnance Department rejected the FAL because they believed that the M14 could be produced using the same production tooling as the M1 rifle. Moreover, American organizations like the Ordnance Association opposed the FAL by appealing to nationalistic sentiments by implying that the M14 would be a superior rifle due to "American genius in gun design."[624] Although FAL rifles made by FNH were procured by Germany, those rifles were replaced by HK's G3 rifle in Bundeswehr service because the Germans wanted to maintain their own domestic firearms industry rather than procure rifles from foreign manufacturers. Another reason the Germans favoured the G3 was because the design still had acceptable reliability and service life as well as being more economical to manufacture compared to competing NATO rifle designs of the period. NATO states that did not have their own firearms industries and procured rifles at a later period than the Anglo-Americans preferred to license produce foreign weapons than purchase from abroad. For example, Norway chose to procure the G3 rather than the FAL because HK was more willing to grant manufacturing licenses for their weapons compared to FNH and the G3 was less expensive than its Belgian counterpart.

Although NATO and the US military had standardized the 7.62mm cartridge, the Infantry Board and CONARC strongly supported the development of assault rifles chambered for SCHV intermediate cartridges, which provided the impetus for the development of the M16. During the Vietnam War, infantry combat often occurred at close ranges so intermediate cartridges had an advantage over the 7.62mm NATO caliber in those conditions and resulted in the widespread use of the M16 by conventional US forces. The M16A1 was chosen to become the new US service

[624] Ezell, "Cracks in the Post-War Anglo-American Alliance," 141.

rifle due to its advantages over the M14 and the failure of revolutionary infantry weapons technologies to mature. Since the M16A1 did not use the NATO standard caliber, the alliance held new ammunition and weapons trials from 1976-79.

In the 1970s, NATO attempted to procure common weapons under the doctrine of RSI and the alliance wanted to standardize a new rifle and cartridge to replace their 7.62mm caliber service rifles. But the NATO evaluators of the 1976-79 trials did not make recommendations regarding the standardization of a common rifle because the IW candidates submitted by the US and European members were of different maturity levels. The M16A1 was the most reliable IW candidate because it was a mature design while the European IW candidates were prototypes when they were evaluated by NATO, but some of those rifle models were further developed or significantly modified after the trials. Other major obstacles towards the adoption of a common rifle during the aftermath of the 1976-79 trials included the desire of European states to maintain their domestic industries and national pride. Belgium relies on their domestic manufacturer FNH for all of their military's firearms and adopted the FNC rifle as their new service rifle in order to support their indigenous gun industry. Likewise, the British refused to abandon their flawed SA80 series because they hoped that major foreign sales of the SA80 would compensate for the money spent on the weapon system's development. As well, Churchill's decision to adopt the FAL as the L1A1 was unpopular among many Labour politicians and military officers, who believed the EM-2 was the best weapon for the British soldier. The British Army wanted the L1A1's successor to be an indigenous design and RSAF Enfield's prototypes that evolved into the SA80 series were highly publicized by the British Ministry of Defence as their next generation of infantry weapons and a design that the UK could be proud of. While NATO failed to adopt a common rifle, the alliance chose to standardize the Belgium SS109 round because

their evaluators wanted a SCHV round that could meet their requirements for both assault rifle and LMG use. The SS109 had superior penetration compared to the other SCHV candidates so it was the best candidate for LMG use. Accordingly, NATO members ratified STANAG 4172, which set the standards for 5.56mm SS109 configuration bullet designs and was "aimed at ensuring ammunition interchangeability on the battlefield."[625]

However, STANAG 4172's technical criteria were insufficient to insure that all NATO Qualified SS109 ammunition designs would function reliably in all 5.56mm weapons in use by the alliance. A particular issue with STANAG 4172 was that its specifications for variations in port pressure was too broad to insure reliable operation in certain 5.56mm NATO small arms. For example, the British 5.56mm L2A2 ammunition was banned for combat use in the M16 and M4 by the US and was not an ideal substitute for US M855 ammunition for training use while the SA80A2 rifle does not operate reliably with M855 rounds. During the post-Cold War era, there have been instances where a NATO military had to use another ally's ammunition during combat and in training when a state experienced ammunition shortages. Although STANAG 4172's port pressure specifications were inadequate, it would not be feasible for NATO to improve 5.56mm ammunition interchangeability because each alliance member would need to re-ratify the existing STANAG and "this process is too complicated to do all over again."[626]A common NATO rifle is still not a feasible proposition because states with existing domestic industries are likely to want to continue to procure indigenous weapons. Indeed, the governments of Eastern European states such as the Czech Republic and Poland, have supported the involvement of their domestic industries in developing weapons compatible with NATO standards. As well, Western European countries such as Belgium and Italy still have their

[625] NATO, *STANAG 4172,* 1.
[626] Email communication from French Defense Professional to author, December 7, 2015.

domestic firearms firms and will likely procure indigenous weapons in the future to support their own industries. Due to these obstacles, NATO's current standardization efforts will focus on standardizing weapons interfaces such as magazines and accessory rails and the alliance no longer has plans for a common rifle in the near term or future.

Although the 5.56mm SS109 is still the NATO standard, it is not ideal as a general purpose rifle bullet and was primarily designed for LMG requirements of the Cold War. SS109 bullets produced inconsistent terminal ballistics due to AOA and fleet yaw issues and had reduced terminal performance after penetrating intermediate barriers. For their next generation of small arms, the US military is evaluating new intermediate calibers to improve terminal performance and developing polymer cartridge cases to reduce weight. Likewise, Canada plans on fielding non-NATO compatible future small arms for significantly improved capabilities over their predecessors. Several NATO states plan on procuring new assault rifles during the 2020s period and the US should work with NATO to standardize a new intermediate caliber that would best meet current and future end user requirements such as a 6.8mm to 7mm intermediate caliber that could replace both 5.56mm and 7.62mm. The introduction of new small arms during this period would give NATO the opportunity to improve upon the degree of standardization where the standardization of a new intermediate caliber would require a new STANAG to be drafted. Some technical performance specifications of a new ammunition STANAG need to be more specific than those of STANG 4172 to insure that all NATO Qualified ammunition designs would operate reliably in all NATO weapons of that caliber. Also, the alliance should standardize a full radius magazine for a new intermediate caliber because a new intermediate caliber that could replace 5.56mm and 7.62mm NATO cartridges would require the design of a new magazine rather than retaining the existing M16 pattern magazine. Also, states that need to

field new assault rifles, automatic rifles and CCs should procure a family of weapons with common parts to improve the degree of standardization in their national militaries. Compared to acquiring several purpose built niche weapons, a common family of weapons approach to procurement will result in significant fiscal savings, reduce the total types of spare parts that need to be stocked and simplify operator and armourer training. If the family of weapons has a modular architecture to allow barrel replacement below depot level, then NATO militaries using the same equipment can adopt more similar small arms repair procedures and form an integrated NATO force with cost effective maintenance procedures.

A complete transition to a new intermediate caliber is a lengthy process and 5.56mm and 7.62x51mm calibers, along with the new intermediate caliber, would all be in service before those existing NATO calibers are completely replaced.[627]Although having three rifle calibers in a state's logistical system will require sound management to minimize logistical inefficiencies, fielding a new intermediate caliber during smaller scale wars is feasible and need not result in negative outcomes for such conflicts. One measure that could minimize logistical issues during the transition period would be to initially equip combat arms personnel and those NATO forces involved in joint operations with infantry weapons in the new intermediate caliber.[628] Improved ammunition capabilities would give NATO combat soldiers a tactical advantage over the enemy while more rigorous STANAGs that allow for true ammunition interchangeability would give commanders more options during joint operations and logistical emergencies. More importantly, it would be beneficial for major NATO states to complete their transition to new ammunition and weapons during peacetime-before NATO faces the serious prospect of having to face a well-equipped and numerous opponent. An improved intermediate caliber in a polymer cartridge case

[627] Stanley C. Crist, "Author's Response," *Infantry*, January-April 2000, 3.
[628] Schatz, "US Military Losing Edge in Small Arms."

configuration would allow US and NATO infantry forces to match or exceed the capabilities of a peer adversary's small arms and GPMGs. Once the major NATO powers' stocks of 5.56mm and 7.62mm ammunition have been completely replaced, the alliance and its national militaries would have a greater degree of standardization and more efficient logistics, which will be beneficial for conventional forces that may need to deter a peer adversary.

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Appendix A

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Reply all

To:

Yi Le Zhou;

Thu 2016-02-18 8:35 AM

You replied on 2016-02-18 1:56 PM.

Hi David,

You are welcome to use our Tech Notes in your thesis.

Thanks,

Craig Beckman
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Strategic Armory Corps
www.sacfirearms.com
[redacted]

From: Yi Le Zhou [mailto:ylzhou@ucalgary.ca]
Sent: Wednesday, February 17, 2016 3:13 PM
To: [redacted]
Subject: May I used information from Armalite Tech Note 104 in my thesis

Hi,

I am doing a Masters of Strategic Studies thesis at the University of Calgary's Centre For Military and Strategic Studies. I want to use the technical information from TECHNICAL NOTE 104: SOME THOUGHTS ON DESIGN AND RELIABILITY OF AR-STYLE FIREARMS in my thesis but my university requires me to get permission to use copyrighted materials. May I have permission to include the information from Technical Note 104 regarding dwell time, gas port location, ammunition selection and cook off in my thesis?

Regards,

David (Yi Le) Zhou

Appendix B

[redacted]

To:
Yi Le Zhou;
Tue 2016-02-16 10:00 AM

The Editor said you have permission as follows:

The only requirement is appropriate attribution.
Please include "reproduced with permission of and copyright retained by the
Marine Corps Gazette" for whole articles, excerpts only need the author and
publication attribution.

Respectfully sent,

Beth R. Murphy
Administrative Assistant
Marine Corps Gazette
Marine Corps Association
[redacted]

Yi Le Zhou

Reply all

To:
[redacted]
Sun 2016-02-14 10:31 PM
Sent Items

M249 vs Colt AR auto rifle qualification.jpg 51 KB
Download
Save to OneDrive - University of Calgary

Hi,

I am doing a Masters of Strategic Studies thesis on NATO Infantry Weapons Standardization at the University of Calgary's Centre For Military and Strategic Studies. A few years ago, when I accessed CWO Ray Grundy's article, "The M249 Light Machinegun in the Automatic Rifle Role," it contained a table that compared the qualification results of the M249 SAW and Colt M16A2

HBAR (this is the current URL for the article but the table is no longer there https://www.mca-marines.org/gazette/m249-light-machinegun-automatic-rifle-role). I had saved an earlier version of the article and am pasting a copy of the table onto this email.

My university requires me to get permission to use images that are copyrighted. If the table showing the qualification results of the M16A2 HBAR vs M249 are copyrighted, may I get the Marine Corps Gazette's permission to use that table in my thesis?

Regards,

David (Yi Le) Zhou

Appendix C

[redacted]

Reply all

To:
Yi Le Zhou;
Wed 2016-03-16 8:17 AM
You replied on 2016-03-16 7:21 PM.

Action Items
Either will do.

----- Original Message -----

From:
"Yi Le Zhou" <ylzhou@ucalgary.ca>

To:
[redacted]
Cc:

Sent:
Wed, 16 Mar 2016 06:42:07 +0000
Subject:
Re: Question about M14 and .270 British

Thank you Mr. Williams for letting me use the photo that you took.

For my thesis, would you like me to write "courtesy of Anthony G. Williams" or "source: photograph by Anthony G. Williams" below the photo that you took?

Regards,

David Zhou

From: [redacted]
Sent: March 15, 2016 8:07 PM
To: Yi Le Zhou
Subject: Re: Question about M14 and .270 British

Yes David, it is copyrighted by Textron Systems who are quite picky about how it is used.

However, you can instead use the attached photo which I took of rounds in my own collection.

Best wishes,
Tony

Yi Le Zhou

Reply all

To:
[redacted]
Tue 2016-03-15 5:36 PM
Sent Items

Thanks for the clarification Mr. Williams. I have something else that I would like to ask you.

I want to use the image showing the LSAT Cased Telescoped Ammunition and convention 5.56mm ammo (last image) from this article: http://www.casr.ca/bg-future-small-arms-research.htm. If an image is copyrighted, my university's copyright office requires me to get the publisher's permission to use images via email.

Someone from the Canadian American Strategic Review told me the following: "By all means use the image but be aware that this was a Textron photograph that I modified. I obtained the original image from Anthony G. Williams' article "Assault Rifles and their Ammunition: History and Prospects".

On your webpage, the image of the LSAT CTA and the M855 says courtesy of Textron. Is that image copyrighted by Textron?

Regards,

David