Biting the Bullet

Why the time has come to acknowledge the significant limitations of 5.56 mm ammunition in British and NATO service and reconsider the case for replacing it with a larger, intermediate calibre – a solution regarded as ahead of its time when originally proposed by Britain more than 50 years ago.

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Introduction

The aim of this document is to promote awareness and discussion of the poor operational performance of NATO standard 5.56 mm ammunition in British Army service. Given that small arms and their ammunition are so fundamentally important to the offensive and defensive capabilities of our soldiers, this is a subject that deserves urgent and thorough attention.

The problems that have arisen are not isolated incidents related to the unique operational environment of Afghanistan; they represent the cumulative evidence of ballistic science supported by extensive combat experience gained since 2002. In providing a description of specific issues encountered, which also affect our American, German and other NATO allies, the document seeks to simplify a complex technical subject so that it is readily understandable by all audiences.

Criticisms directed against 5.56 mm ammunition are not a criticism of the SA80A2 assault rifle used by the British Army, even though it fires this calibre. Notwithstanding the serious issues that blunted this weapon's effectiveness prior to 2002[1], a series of modifications have now made it reliable.

Nor is this a criticism of UK procurement processes that led to the adoption of this calibre, even though these too have been censured, because Britain simply followed the selection decision ratified by other NATO members in 1980.

It is also doubtful whether the concerns that have arisen could have been anticipated without the sustained operational testing that recent conflicts have provided. Furthermore, the threat and doctrine that originally guided the development of 5.56 mm ammunition have substantively changed since it was introduced.

As many NATO armies now begin to consider what should replace aging inventories of 5.56 mm weapons, now is a good time to reconsider what is the optimal calibre for a dependable long-term solution.

Executive summary

Originally, 5.56 mm ammunition was adopted by NATO to provide a lighter rifle and machine gun round capable of supplementing existing 7.62 mm ammunition. The thinking behind the reduced calibre was that a larger number of smaller rounds fired would be more effective in suppressing, incapacitating or killing an enemy than a smaller number of larger rounds. It was envisaged that the great majority of small-arms engagements would take place within 300 metres, as had been the experience in the past.

The poor performance of 5.56 mm ammunition is attributable to the inherently small diameter, mass and energy of the bullet suggesting that this calibre is unsuitable in a military cartridge.

Despite 5.56 mm NATO ammunition coming into service in the early 1980s, there was no sustained combat use until 2002. While human targets are rarely engaged in peacetime, innumerable infantry engagements during the conflicts in Iraq and Afghanistan have provided significant feedback about the effectiveness of 5.56 mm ammunition.

Analysis of specific issues reveals that the poor performance of 5.56 mm ammunition is attributable to the inherently small diameter, mass and energy of the bullet suggesting that this calibre is unsuitable for use in a general purpose military cartridge. Criticisms of 5.56 mm ammunition fall into four categories as follows:

- **Ineffectiveness at long range**
- **Inconsistent wounding effect**
- **Poor intermediate barrier penetration**
- **Ease of deflection**

Even though it is fired at high velocity, a 5.56 mm bullet's energy and lethality rapidly fall away after about 300 metres (depending on the gun's barrel length). In Afghanistan, more than 50% of combat engagements take place at ranges of between 300 and 900 metres[2], which means that British troops often cannot return effective fire. Recent MoD data also suggests that at all ranges 5.56 mm ammunition is far less effective in suppressing an enemy by near misses than larger-calibre weapons[2].

Another problem is that the relatively small 5.56 mm bullet tends to make only a small wound channel (hole through a target) unless it yaws (upsets) after impact. When 5.56 mm bullets do yaw they will inflict more severe wounds, but sometimes they fail to upset in tissue, leading to an erratic wounding effect at both long and short ranges.

To achieve maximum effectiveness, a bullet needs to yaw as soon as possible after impact. If a small bullet travels a significant distance through a target without yawing, the size of the wound channel may not be large enough to cause rapid incapacitation. In combat situations, this means multiple hits may be required to render an enemy incapable of further offensive action.

The small size of the 5.56 mm bullet creates a third problem: it does not have sufficient momentum to reliably penetrate intermediate barriers such as car doors, mud walls, wooden blocks, dense vegetation and similar obstacles should they obscure an enemy. When a bullet's energy is absorbed en route to the target, consistency of lethality is further compromised.

Small bullets are also more susceptible to wind drift, something that affects accuracy at long ranges. As energy fades with distance, smaller bullets can also be more easily deflected by solid obstacles.

The net effect of these performance limitations is that the fundamental weight-saving advantages of 5.56 mm ammunition and weapons are purchased at a high price in combat effectiveness, especially at longer ranges.

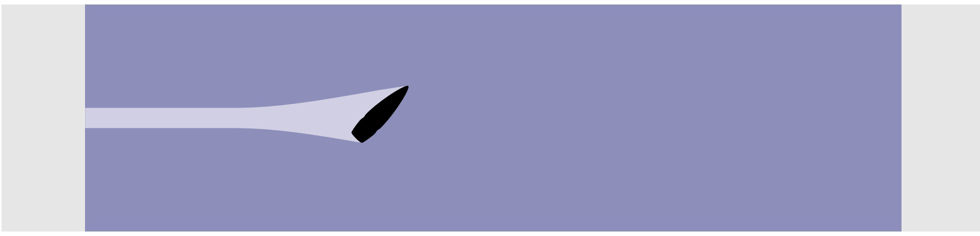
Yawing explained

Yawing describes the ballistic effect of what happens when a pointed bullet penetrates an object that is significantly denser than air. Its stability is compromised or 'upset' so that the heaviest part of the projectile, the base of the round, turns over to regain stability. This tends to cause the bullet to travel backwards through the target. The yawing effect creates a much larger wound channel than the diameter of the bullet ordinarily would, resulting in an increased likelihood of physiological incapacitation (see Figure 2).

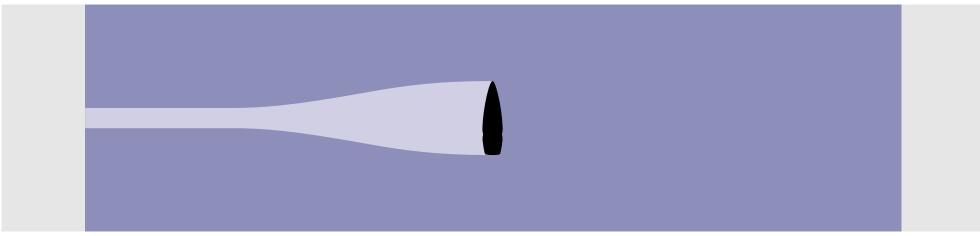
Figure 2.
How a bullet yaws

1. Bullet strikes target and begins to penetrate. Bullet travels a short distance (depending on size, shape and construction) before denser medium 'upsets' stability.

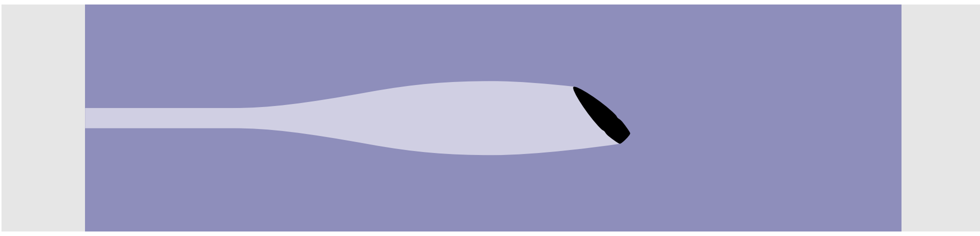
2. Bullet starts to 'yaw' to regain stability creating a larger wound channel .



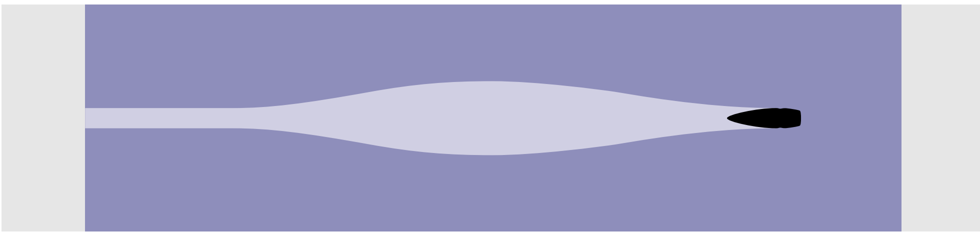
3. With weight of bullet concentrated at the base, it rotates so that heavier end faces forward.



4. Bullet continues to penetrate target as it turns to produce increased 'cavitation' effect.



5. Bullet regains stability and continues through target (and may exit if it has sufficient energy left).



If a small bullet fails to yaw, the resulting wound channel may not create sufficient damage to rapidly incapacitate.

In contrast, the greater size and weight of a 7.62 mm bullet not only provides a much longer effective range, but typically creates a larger permanent wound channel that tends to cause more rapid incapacitation than a 5.56 mm round.

The problem with 7.62 mm ammunition is its size, weight and recoil: the reasons why 5.56 mm ammunition effectively replaced it for most purposes in peacetime. Its size and weight halve the quantity of ammunition that can be carried for a given load. Heavy recoil makes 7.62 mm rifles virtually impossible to control in the shoulder when firing automatic bursts, and may even reduce accuracy and hit probability when firing semi-automatic single shots. Larger calibres also require heavier weapons to fire them.

Figure 1.
British soldier with a 7.62 mm GPMG in Afghanistan .
(Source: 3 PARA)

Despite these disadvantages, the shortcomings of 5.56 mm ammunition are such that the British, American and German armies have all reallocated 7.62 mm weapons down to section level. The British Army is also planning to acquire lightweight 7.62 mm machine guns. While these represent a valuable addition to on-the-ground firepower, only two such weapons are presently carried per section of 8 men. What do the soldiers without 7.62 mm weapons do? Dual ammunition also creates a logistics supply problem.

What soldiers need is ammunition that has the range and lethality of 7.62 mm rounds, but with significantly reduced size, weight and recoil. Britain developed such a cartridge in the late 1940s: the .280 / 7 mm round. This ‘intermediate’ solution was highly effective, but was rejected as a standard NATO round for political reasons not performance concerns[3]. More recently, two other ‘intermediate’ rounds have been developed in the USA in order to fit into modified rifles originally designed for 5.56 mm ammunition. These are the Remington 6.8 mm SPC (developed in conjunction with US Special Forces) and the Alexander Arms 6.5 mm Grendel. Both exhibit markedly superior and more consistent wounding characteristics and barrier penetration in ballistic gel tests* than existing 5.56 mm ammunition types. The 6.5 mm Grendel has the added advantage of being able to match the ballistic performance of 7.62 mm ammunition at long ranges, due to its long, aerodynamic bullet.

As one would expect, these rounds fall between the 5.56 mm and 7.62 mm in their weight and recoil. Given the performance advantages they confer over the 5.56 mm, this is justifiable. Moreover, the right intermediate cartridge would facilitate a single calibre solution for all platoon-level weapons, being an ideal light and medium machine gun round as well as excellent rifle ammunition.

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Given that the small arms inventories of many NATO armies are approaching the end of their service life, now is a good time to consider what should replace them, but also to reconsider the relative merits of intermediate calibres versus the current mix of small and large calibre small arms ammunition types.

Among future small arms ammunition options currently under development are cased-telescoped and caseless ammunition. These offer a potential ammunition weight saving of between 30%-50%. Even if this advanced ammunition proves unsuccessful, the use of stainless steel or polymer cartridge cases, also currently under development, could reduce the added weight of a new intermediate round. Either way, if an intermediate calibre were adopted for the next generation of small arms, soldiers would be equipped with a general purpose ammunition that was effective and long-ranging as well as being reasonably light and controllable.

In summary, 5.56 mm NATO ammunition has insufficient range, inadequate suppressive effect, poor barrier penetration and unreliable terminal effectiveness. These problems can only be addressed by adopting a larger calibre with a more powerful cartridge. But this can be achieved without incurring the excessive weight and recoil of 7.62 mm ammunition.

*Ballistic gel tests fire bullets through gelatine blocks designed to reproduce the homogeneity of human tissue so that energy and lethality can be evaluated.

Origins of 5.56 mm ammunition

When the NATO alliance was established shortly after the end of the Second World War, it was decided that its armies should all use a common calibre of ammunition. A competition was held to select an appropriate round with member countries submitting different proposals. Britain advocated an intermediate calibre round of .280 inches (7 mm) and developed a new weapon to fire it, the EM-2 (see Figure 3). But the USA preferred a larger calibre of .300 inch (7.62 mm), similar in calibre and performance to the .30-06 round it had used previously[3]. This was a powerful ammunition with significantly greater recoil than the British 7 mm and was adopted as the 7.62 x 51 NATO standard cartridge in 1954.

Figure 3.
British 7 mm EM-2 rifle.
The EM-2's advanced Bullpup configuration (with the magazine located behind the pistol grip) was considered to be ahead of its time in 1951. Despite excellent trial results, the decision to adopt the weapon was reversed to align the UK with its NATO allies.

Within a few years of adopting the 7.62 mm round, however, the US Army found that the weight of such ammunition and of weapons required to fire it made it unsuitable for the escalating jungle conflict in Vietnam. Moreover, two American postwar reports analysing small arms ammunition performance had started to gain currency in US military circles.

The Hall Report (1952)[4] concluded that hit probability depended on the volume of rounds fired as much as shot placement (shooting accuracy). The Hitchman Report (1952)[5] suggested that the majority of infantry small arms engagements took place at ranges of 300 metres or less. The combined conclusion of both reports taken together was that a soldier firing a higher number of smaller bullets would have a greater chance of suppressing, incapacitating and killing an enemy than one firing fewer larger and heavier bullets.

As a response to the above, Remington developed a new small calibre high velocity (SCHV) ammunition, the .223. This was unilaterally adopted by the US Army in 1963 as the 5.56 mm M193 for use with the new ArmaLite AR-15 assault rifle (designated M16 in US service)[6].

Without a major ground conflict until 2002, NATO standard 5.56 mm ammunition was largely untested in combat.

Combat reports from the Vietnam conflict showed that the 5.56 mm M193 round was highly effective due to its tendency to upset very rapidly when hitting targets at shorter ranges (less than 200 metres), causing a significant wounding effect. However, the small diameter and low mass of the bullet meant that its energy rapidly faded at longer ranges. With most engagements taking place at close range in thick jungle, long-range performance was less of an issue. Moreover, US infantry units were also equipped with 7.62 mm M60 machine guns.

In the Philippines, the longstanding Communist Rebellion foreshadowed the problems experienced in Afghanistan today. Communist rebels using American .30-06 M1 Garand rifles were frequently able to outgun Philippines Government troops using 5.56 mm M16A1 rifles. Small calibre rifles put soldiers at a considerable disadvantage when engaged by an enemy using large calibre weapons[7].

With the US Army 's increased use of a cartridge that was different from the rest of NATO, a second competition to introduce a new standard NATO ammunition was held between 1977 and 1979. It was considered unlikely that any calibre other than 5.56 mm would be adopted, so most contenders sought to boost the long-range performance of 5.56 mm ammunition so that it could be used in machine guns as well as assault rifles. The Belgian entrant, the SS109 5.56 mm round, won the competition and was selected as the second NATO standard ammunition. It has a steel penetrator in the nose, which is designed to penetrate steel helmets but does less damage to people, especially at longer ranges[8].

The British Army adopted the current NATO standard 5.56 mm ammunition in 1986 when it fielded the SA80 small arms weapon system, consisting of the L85 rifle and L86 light support weapon (see Figure 4).

Figure 4.
Enfield L85A2 Individual Weapon. Although A1 versions of the SA80 family experienced a serious number of reliability issues that were only finally resolved in 2002 with the introduction of the A2 series, combat reports indicate that the weapons are now dependable.

Without a major ground conflict until 2002, the new NATO standard 5.56 mm ammunition (SS109/ M855) was largely untested in combat. However, the US deployment in Somalia in 1993[9] as well British deployments to Bosnia, Kosovo and Sierra Leone[10] all suggested that there were performance issues with 5.56 mm ammunition. The US experience in Mogadishu did not provide sufficient data to draw specific conclusions, while the British Army had a more fundamental problem to contend with: the unreliability of its SA80 weapons (since addressed by the introduction of the A2 series).

Issues arising from operational use

The conflicts in Iraq and Afghanistan from 2002 onwards represent the first sustained combat use of current NATO standard 5.56 mm ammunition since it was approved in 1980. Official and anecdotal[11] reports provided by British, American, German and other NATO allies[12] have all surfaced the same common complaints suggesting that issues fall into four categories as follows:

- **Ineffectiveness at long range**
- **Inconsistent wounding effect**
- **Poor intermediate barrier penetration**
- **Ease of deflection**

The total cost of Javelin missiles used in Afghanistan would probably be sufficient to re-equip the entire Army with a new small arms system.

In the open and undulating countryside of Afghanistan, Taliban forces frequently engage ISAF units at distances beyond 300 metres[2 & 10]. Using Russian made sniper rifles and machine guns firing high-powered 7.62 mm ammunition (equivalent in performance to the 7.62 mm NATO), the enemy can engage allied forces at ranges of up to 900 metres[13]. Equipped with SA80 weapons firing 5.56 mm ammunition, British troops are unable to return fire because the effectiveness of small calibre 5.56 mm rounds diminishes rapidly at ranges beyond 300 metres; even the long-barrelled L86 light support weapon is ineffective beyond 400 metres[8]. The only recourse is to call in artillery or air support to engage the enemy. But the precious time it takes to coordinate fire support invariably costs lives or allows the enemy to escape.

The economics of using an inappropriate calibre merit further comment. Infantry platoons equipped with the Javelin anti-tank missile (see Figure 5) frequently use them to engage dug-in enemy positions at ranges of 1,000 metres[10]. These are hugely effective and their ability to obliterate large areas makes them ideal for suppression even when they do not kill. But Javelin anti-tank missiles cost in excess of €100,000[14] each and with a conservative estimate of 10 missiles fired per week, the annual cost of these munitions alone is in the region of €52 million. Of the total number of missiles fired since 2002, few if any have been used to destroy an enemy tank. Indeed, the total cost of Javelin missiles fired to date would probably be sufficient to re-equip the entire British Army with a new small arms weapon system.**

Figure 5.
British troops using a Javelin anti-tank missile in Afghanistan. (Source: 1st Battalion Grenadier Guards)

**Based on a unit cost per rifle of €500 and a total quantity of 200,000 purchased equals €100 million versus an estimated €300 million spent on Javelin misiles in Afghanistan since 2002.

Up until 1985, it was standard procedure to train infantry units to fire collectively at targets at ranges of up to 600 metres[15]. This could easily be achieved with the previous service weapon, the 7.62 mm L1A1 SLR rifle (see Figure 6). With the adoption of SA80 and 5.56 mm ammunition, British soldiers could no longer do this. At the time, such a capability was no longer seen as being necessary. With more than 50% of infantry engagements in Afghanistan taking place at ranges above 300 metres[2], it is clear that long-range performance remains a desirable characteristic for general purpose small arms ammunition.

Figure 6. The British 7.62 mm L1A1 Self-Loading Rifle. Accurate and powerful, but its ammunition weighed twice that of 5.56 mm. the SLR suffered from considerable recoil and could not be controlled when fired in automatic mode from the shoulder, a disadvantage that led to a deletion of its automatic fire capability. (Source: Max Popenker)

Many of the proponents of 5.56 mm ammunition argue that it is better at suppressing an enemy than 7.62 mm ammunition due to the higher volume of fire it permits. However, recent research conducted by the MoD[2] shows that a near miss from a large calibre 7.62 mm or 12.7 mm round has a much greater suppressive effect than 5.56 mm round. Larger calibre bullets, with increased noise and visible effect, also suppress when they miss by a greater distance than 5.56 mm ammunition. These findings are supported by anecdotal feedback: “The Taliban ignore 5.56 mm, are worried by 7.62 mm and fear 12.7 mm rounds”[2].

To address problems with 5.56 mm ammunition, the MoD has re-issued limited numbers of the 7.62 mm general purpose machine gun (GPMG) and the L96 7.62 mm sniper rifle at section level[2]. There are also plans to introduce a lightweight 7.62 mm machine gun[2]. While these weapons provide a worthwhile amount of additional on-the-ground firepower, at present they only enable two members of an 8-man section to engage the enemy at longer ranges.

Dual calibre small arms create a requirement for additional training as well as logistics problems for resupply and spare parts.

When 7.62 mm weapons are needed to engage the enemy, the remaining members of the section or platoon can only take cover and watch. The re-adoption of 7.62 mm ammunition also conveniently ignores the other significant reason why this calibre was supplemented by 5.56 mm ammunition. This is the excessive size, weight and recoil of the larger calibre[8 & 16]. It is extremely difficult to control 7.62 mm weapons when firing full automatic and the 7.62 mm GPMG is very heavy (although efforts are being made to lighten it). Ultimately, however, British troops are willing to endure the additional weight and recoil of 7.62 mm weapons and ammunition because the extra firepower they provide enables them to engage the Taliban on equal terms.

Dual calibre small arms at platoon and section level create a requirement for additional training as well as logistics problems for ammunition resupply and spare parts availability. These disadvantages add extra cost to the overall budget, which could be avoided if a single ammunition type combined effective range and lethality, comparable to that of 7.62 mm, but with a significant reduction in size, weight and recoil.

The problem of 5.56 mm ammunition’s limited effective range is not uniquely a British problem. US, German, and other NATO allies operating in Iraq and Afghanistan have all experienced the same issues. It is a particular problem affecting US troops who use Colt M4 carbines with shorter 14.5-inch barrels. The US, German and Canadian armies have also re-adopted 7.62 mm weapons on a limited basis.

Inconsistent wounding effect

The majority of combat engagements in Iraq and Afghanistan have shown that when the enemy was engaged at ranges of less than 300 metres, 5.56 mm ammunition usually performed as expected. But there have also been a number of contradictory reports from British, American and German soldiers who have needed to fire multiple rounds to incapacitate an enemy. US forces have even reported instances of enemy combatants getting up and continuing to fight after having been shot with several 5.56 mm rounds [10 & 11]. While the inconsistency of lethal effect is a problem for soldiers at longer ranges, surprisingly, it is also an issue at short ranges[10,17 & 18]. After seven years of experience in Afghanistan, the steady flow of adverse reports seems sufficient to indicate that the wounding effect of 5.56 mm is unpredictable if not inconsistent.

The original design of 5.56 mm ammunition was based on a calibre for hunting small animals, so its inconsistency against human targets should come as no surprise.

There are several reasons why 5.56 mm ammunition is erratic in its terminal effect. Compared to 7.62 mm ammunition, 5.56 mm bullets have less than half the mass (4.0 g versus 9.33 g), and only half the energy at the muzzle (1,730 J versus 3,352 J)[13]. The 5.56 mm bullet is also less aerodynamic, which means it loses its initial velocity and energy more quickly. The laws of physics mean that 5.56 mm ammunition by definition has a shorter overall range, a reduced ability to retain energy at longer ranges and makes a smaller wound channel when it hits a target.

Considering that the original design was based on Remington's .222 Varmint ammunition[6], a calibre traditionally associated with shooting small animals weighing less than 40 lbs (18 kgs), its inconsistency against human targets should come as no surprise. However, the significant reduction in calibre was deemed acceptable in 1979, because 5.56 mm ammunition was intended to supplement 7.62 mm ammunition rather than replace it completely. In practice, 5.56 mm became the standard section-level calibre carried by dismounted infantry, with 7.62 mm weapons held back at a higher level; a practice which is now changing.

British SA80 weapons fire the current NATO standard of 5.56 mm ammunition (SS109) at a very high muzzle velocity: 940 m/s. At short range, a bullet can inflict severe wounds, especially if it yaws (upsets) soon after impact as described above. However, laboratory testing has revealed that sometimes a 5.56 mm bullet does not begin to yaw until after it has passed through a target. In such circumstances, the wounding effect can be relatively minor unless it hits an immediately vital area. The inconsistent performance explains conflicting accounts provided by soldiers in combat.

Given the smaller size of 5.56 mm ammunition, the propensity of the bullet to yaw is very much relied upon to transfer energy into the target. According to recent ballistic research[2 & 17], when a standard NATO 5.56 mm bullet (SS109/M855) strikes a human target it can travel up to 6 inches (15 cm) before it starts to yaw. In certain situations, this distance may not be sufficient to prevent the bullet from exiting the body before it has had a chance to cause potentially lethal tissue damage, especially when engaging the target at an oblique angle. When a small projectile passes straight through a human target - like a needle - without yawing, the resulting injuries may allow an enemy to continue fighting . This problem is exacerbated by under-nourished Taliban fighters who are often very thin[2].

The sooner a bullet can be made to yaw after striking a human target, the greater the wounding effect (see Figure 2). While ammunition designers have attempted to alter the ballistic characteristics of 5.56 mm ammunition, the number of factors that influence how a bullet will behave after it strikes a target, make it difficult to engineer predictable or consistent yawing characteristics.

The terminal effect of a 5.56 mm bullet after it strikes a human target usually depends on five variables:

- **Range to the target**
- **Retained energy upon impact**
- **Angle of attack**
- **Homogeneity of human tissue**
- **Distance the bullet travels before yawing**

If a bullet fails to yaw quickly upon impact, this may not matter if it strikes the central nervous system. But, if it hits soft tissue or a non-vital organ, the injury caused may not result in rapid incapacitation***. In contrast, the larger 7.62 mm bullet will create a much larger permanent wound channel in comparable circumstances, providing more reliable and faster incapacitation. Ensuring an equivalent effect with 5.56 mm ammunition requires a hit to the head, neck or upper chest which represents a smaller effective target area demanding higher standards of marksmanship. Accuracy under stress is difficult to achieve, which is why it often takes multiple hits to incapacitate an enemy.

The US version of the standard NATO SS109 bullet, the M855, differs slightly from the British L2A2 round by encasing the steel core in a thinner copper jacket. This tends to rupture at very high impact velocities, causing the bullet to fragment delivering an increased lethal effect. This benefit is not available with British specification ammunition because of a strict adherence to our interpretation of the Hague Convention, which deems such ammunition illegal.

When using a high volume of ammunition becomes the norm in all combat situations, it defeats the purpose of adopting lighter ammunition.

The US has also experimented with open tip match bullets (e.g. the Mk 262 round[17 & 18]). Although this type of bullet is not designed to expand on impact, the UK MoD has been advised that adopting an open tip bullet could be considered illegal under current International Law.

The UK's answer to the short-range lethality problem has been to adopt combat shotguns. Using solid lead slugs as well as SG pellet rounds, British troops now have very effective stopping power. However, with the addition of 7.62 mm weapons for long-range engagements, the role of 5.56 mm weapons on the modern battlefield becomes questionable.

From a practical perspective, the inconsistent wounding effect of 5.56 mm ammunition means that in most combat situations a burst of 5-6 rounds is required instead of just one or two[10]. When using a high volume of ammunition becomes necessary in all combat situations, it defeats the purpose of adopting lighter ammunition versus a heavier one with more certain effectiveness.

***Rapid incapacitation is the term used to describe the desired physiological effect of a gunshot wound and is defined as an injury that either kills or renders an enemy incapable of further offensive action in the least amount of time possible. According to the US FBI, only a hit to the central nervous system (the brain or upper spinal cord) will kill instantaneously. A hit to other vital organs, such as the heart or that severs a major artery, may be similarly lethal, but the effect is unlikely to be immediate because it relies on a catastrophic loss of blood to cause circulatory system failure. After 20% of total blood volume is lost, a lack of oxygen to the brain will result in a loss of consciousness. After 50% blood loss, death will almost certainly occur. In a combat situation, the important factor is the amount of time that elapses before a lack of oxygen to the brain causes a loss of consciousness. An average male weighing 70 kg has a total blood volume of about 4.2 litres and a cardiac output of around 5.5 litres per minute. If a bullet severs a major artery and stress causes the heart rate to double, to 11 litres per minute, then it will take a minimum of 4.6 seconds before 20% of total blood volume is lost. As blood pressure drops, the flow of blood may slow, while oxygen already in the brain may also retard a loss of consciousness. For these reasons, incapacitation may be rapid but seldom immediate. Bigger, heavier bullets that create larger wound channels are thus preferable, because they will maximise the rate of blood loss. In addition to the physiological effect of a bullet wound, there is also a psychological one. But how individual combatants react to serious wounding tends to vary. Fanatical enemies may continue to fight even when they know that their injuries are fatal, while unmotivated conscript soldiers may be paralysed by the sight of their own blood, irrespective of how serious their injuries are. The unpredictability of any psychological effect means that rapid incapacitation must rely on physiological factors. (Source: Articles by Dr Ken Newgard, Dr Gary Roberts and Dr Martin Fackler in the US Wound Ballistics Review)

The essential difference between 5.56 mm versus 7.62 mm ammunition is that the smaller calibre is fundamentally less powerful with less energy, less range and is less reliable in its terminal effectiveness, all of which can lead to a failure to speedily incapacitate an enemy.

Somewhere along the line, an urban myth appears to have post-rationalised the acceptance of an inferior calibre. This is the belief that it is better to injure an enemy rather than kill him, because it ties-up the additional manpower required to evacuate the casualty from the battlefield. While a surprising number of soldiers have mentioned this[10], there is no evidence to suggest that such a belief was ever a major factor governing the choice of this ammunition. The effect, however, is that some soldiers may not consider it unusual when a 5.56 mm round injures instead of killing an enemy.

While reported instances of failure are fortunately few, there is now enough feedback to question whether 5.56 mm is a large or powerful enough calibre for engaging human targets.

It is also most important to mention that a generation of British soldiers who have never used 7.62 mm ammunition, except in general purpose machine guns (GPMGs), is now serving. When they experience issues with 5.56 mm ammunition, many do not realise how much more effective a larger rifle calibre could be. Some of the soldiers who have been most vocal in their criticisms are those that served in Falkland Islands campaign of 1982; but there are few such soldiers left serving now. If more soldiers had used 7.62 mm prior to using 5.56 mm ammunition, perhaps the trickle of complaints would have been a flood.

Poor intermediate barrier penetration

Taliban forces in Afghanistan frequently fire from behind obstacles that offer only limited protection. These include sand banks, mud walls, wooden doors and window frames, trees and dense vegetation[10, 17 & 18]. The penetration of car doors was of particular concern in Iraq, where 5.56 mm bullets were regularly defeated by the sandwich effect of sheet metal and plastic door linings . The US Army has documented this type of failure extensively[17 & 18]. When fire is returned, 5.56 mm bullets will often fail to penetrate such barriers, and are certainly not as effective as large calibre 7.62 mm rounds, which tend to plough through such things regardless. When 5.56 mm rounds do penetrate an intermediate barrier, their small size tends to cause a rapid and sometimes total depletion of their energy. This means that they are subsequently unable to incapacitate if they succeed in reaching their intended target.

As already noted above, 5.56 mm rounds soon become unstable when passing through denser-than-air objects. Where small calibre ammunition is designed to yaw more quickly after impact, intermediate barriers may actually increase the propensity for a bullet to deplete its energy prematurely.

The second NATO competition to standardise ammunition (1977-1979) did not incorporate intermediate barrier penetration as part of the evaluation process[7]. This would appear to be a significant oversight, because the previous ammunition type, the US M193 5.56 mm round, was known to suffer from the same disadvantage.

Ease of deflection

Due to its small size, a 5.56 mm bullet can also be more easily deflected in flight on its way to a target. Thick vegetation, wooden posts and even soldiers' web equipment have all caused 5.56 mm rounds to ricochet or bounce-off harmlessly, depending on the angle of attack. This tendency increases with distance and is again attributable to the rapid loss of energy at longer ranges.

The small size and mass of the bullet also makes it increasingly prone to the effects of wind drift, affecting accuracy at all ranges[13]. This requires increased corrections for wind versus 7.62 mm ammunition. The need for soldiers to adjust their aim depending on wind speed and range to the target and under the stress of battle, demands high marksmanship standards.

Summary of negative feedback

The true measure of 5.56 mm ammunition's effectiveness is whether it will suppress, incapacitate or kill a human target. It will certainly achieve these requirements, but only to a limited range. The crux of the problem is 5.56 mm ammunition's inconsistent effectiveness, especially when compared to 7.62 mm ammunition. While reported instances of failure are fortunately few and far between, there is now enough feedback to question whether 5.56 mm is a sufficiently large or powerful enough calibre for engaging human targets across the range of engagement types soldiers face today.

The most tangible evidence of the failure of 5.56 mm ammunition is the increasing re-adoption of 7.62 mm weapons among all combat units serving in Afghanistan.

If you want to shoot all types of deer in the UK, you need a minimum of 6 mm calibre and 2,360 J muzzle energy (the 5.56 mm produces around 1,730 J). You are also required to use expanding bullets (illegal for military use), which are designed to create much larger wound channels than typical military full metal jacket (FMJ) types. You can get away with using less powerful 5.56 mm weapons on small deer, but you still need to use expanding bullets. In the USA, it is illegal to shoot deer with 5.56 mm ammunition. As already noted, 5.56 mm ammunition is similar to commercial hunting rounds limited to shooting animals weighing less than 40 lbs (18 kgs), so it is hardly surprising that such a calibre is inconsistent when used to engage human targets.

One further factor merits consideration and this is the almost universal adoption within NATO of optical sights mounted on top of standard infantry small arms. The British SA80 family was designed for use with a 4x telescopic sight from the start, which has been recently updated with an improved model. Other advanced technologies, such as thermal imaging devices also aid long-range target acquisition. In other words, it has become much easier for ordinary infantrymen to engage an enemy at ranges of 300 metres and beyond making long-range performance relevant and achievable today in a way it never was before.

The information provided in this document comes from three primary sources: interviews with soldiers who have direct operational experience of 5.56 mm ammunition; official reports and briefings from the MoD, British Army and US Army; and press articles based on interviews with soldiers who have served in Iraq and Afghanistan. While it does not purport to be a full and scientific analysis of the issues described., we believe it provides sufficient fact-based insight to suggest that they are real and deserve further exploration by the people best positioned to address them.

The most tangible evidence, if not tacit admission, of the failure of 5.56 mm ammunition is the increasing re-adoption of 7.62 mm weapons among all combat units serving in Afghanistan (see Figure 7).

Figure 7.
British soldiers using 7.62 mm L96 sniper rifles (Source: 1st Battalion Irish Guards)

The case for an intermediate calibre

While the US Army (the key to the introduction of any replacement cartridge) currently maintains that 5.56 mm ammunition is adequate, many observers feel that recent feedback makes a strong case for the type of intermediate cartridge advocated by Britain in the early 1950s.

The British 7 mm cartridge, developed in the early 1950s, could be adopted now and would immediately be more powerful and reliable than 5.56 mm ammunition.

A more potent, larger calibre ammunition that provided more consistent performance, increased long range effectiveness and improved barrier penetration, but generating only moderate recoil to permit controllable automatic fire, might also deliver another side-benefit: its performance could be close enough to that of the 7.62 mm NATO to permit the new cartridge to replace both existing 5.56 mm and 7.62 mm ammunition. This would provide considerable benefits in terms of small-arms acquisition costs, training and support.

Is it possible to achieve a suitable common cartridge? Historical evidence suggests strongly that it is. The British aimed to do this with the 7 mm x 43 cartridge half a century ago, and by all accounts succeeded admirably[3]. This provides an upper calibre limit. Ballistic analysis suggests that no useful increase in performance over the 5.56 mm can be achieved with anything smaller than a 6 mm calibre. This provides a lower limit.

After the calibre, the key elements of performance are bullet weight and velocity. Bullets of different calibres can be compared via their sectional densities (the ratio between their weight and diameter). Other things being equal, the heavier the bullet, the higher its sectional density and the better it will be at retaining its velocity out to long range. It is necessary to specify a bullet sectional density of at least .230 in order to retain a velocity superior to that of 7.62 mm calibre (whose 9.33g bullet has an SD of 0.217, whereas the 5.56 mm SS109 bullet has an SD of 0.174) and an even higher figure of around .250 would be preferable to deliver the long-range performance required.

We also need a muzzle energy (determined by bullet weight and velocity) of no more than 2,500 J to provide the right balance of power and recoil. Taking into account that smaller calibres need less energy to penetrate armour, this provides a range of possible ammunition choices with appropriate bullet weights in common calibres (see Figure 8).

Figure 8.
Potential intermediate calibre rounds.

Calibre	Bullet weight for SD .230-.250	Velocity	Energy
7 mm / .276”	8.4-9.1 g (130-141 grains)	772-741 m/s (2,533-2,431 fps)	2,500 Joules
6.8 mm / .270"	8.0-8.7 g (124-134 grains)	782-750 m/s (2,570 fps)	2,445 Joules
6.5 mm / .258”	7.3-7.9 g (112-122 grains)	800-769 m/s (2,625-2,523 fps)	2,335 Joules
6.35 mm / .250”	6.9-7.5 g (106-115 grains)	810-777 m/s (2,657-2,549 fps)	2,265 Joules
6 mm / .240”	6.2-6.7 g (96-104 grains)	838-806 m/s (2,749-2,644 fps)	2,175 Joules
Current NATO standard calibres for comparison			
7.62 mm / .300”	9.3 g (144 grains)	848 m/s (2,756 fps)	3,352 Joules
5.56 mm / .220”	4.0 g (62 grains)	940 m/s (3,100 fps)	1,767 Joules

Any of the above five new calibre options would be more effective than 5.56 mm ammunition, and the larger ones could match the long-range ballistics of the 7.62 mm. The choice between them will depend on the preferred balance of characteristics: the greater effectiveness of large calibres versus the lighter weight and lower recoil of the smaller ones.

Although an ideal cartridge length would be around 65 mm (assuming conventional ammunition technology), in order to combine a long aerodynamic bullet with a cartridge case of optimum shape and capacity, any of these options could if necessary be accommodated within the current 57 mm cartridge length of NATO standard 5.56 mm rounds – to allow a larger calibre to be easily retrofitted into existing weapon actions.

Indeed, the British 7 mm cartridge developed in the early 1950s (9.0g bullet at 736 m/s) could be adopted as is, today[19] – sufficient research had been carried out by 1951 for it to be ready for reliable deployment – and the Army would immediately have an ammunition more powerful and more reliable than 5.56 mm. Since the EM-2's 7 mm ammunition is longer overall than the cartridge length required to fit into weapons designed for 5.56 mm, it would require new rifles to fire it.

Figure 9.
After successful trials, Britain officially adopted the 7 mm cartridge and EM-2 rifle in 1951. This decision was reversed for political reasons rather than performance concerns.

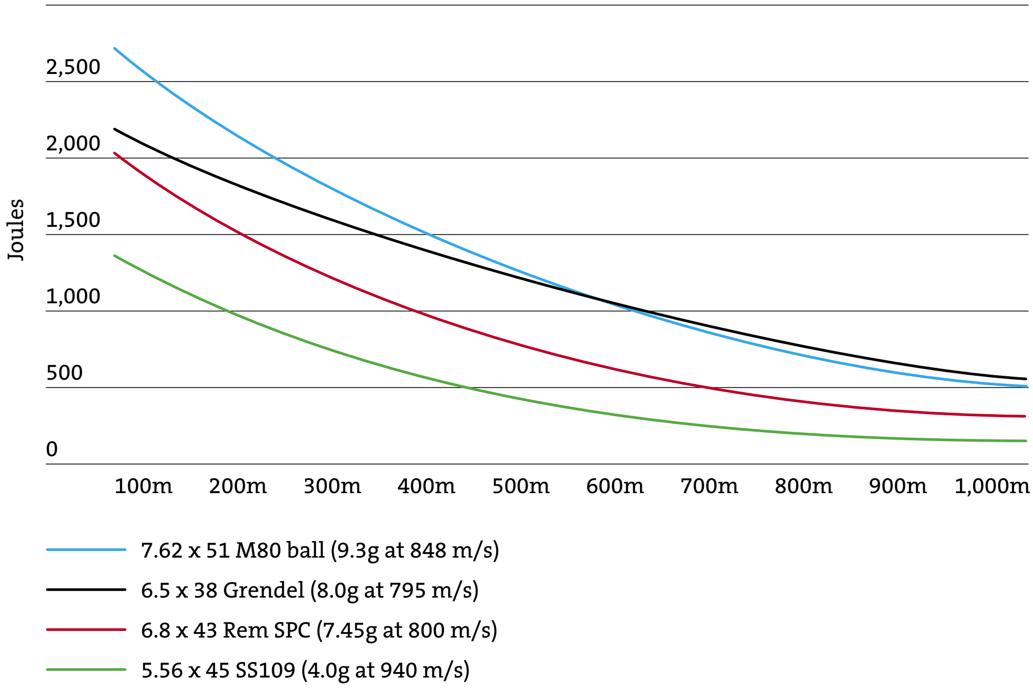
The British experimented with a second intermediate round prototype in 1970. This was a 6.25 mm calibre round [8 & 13] (6.48g at 817 m/s) which was based on the 7 mm cartridge, but optimised for shorter ranges of up to 600 metres. It was claimed to match the effectiveness of 7.62 mm within this range while having recoil closer to that of the 5.56 mm.

In the USA, SOCOM units have gone a step further and commissioned Remington to develop a new intermediate calibre round called the Remington 6.8 mm SPC cartridge[17 & 18]. Ballistic gel tests and limited combat evaluation have shown that this ammunition delivers more consistent inapacitation effectss and much better barrier penetration than existing 5.56 mm ammunition types. It also has a superior long-range performance to 5.56 mm rounds, but is clearly inferior in that respect to 7.62 mm and accordingly could not replace that cartridge.

A second US firm, Alexander Arms, has developed an even more promising intermediate cartridge, the 6.5 mm Grendel. This not only provides increased lethality over existing 5.56 mm ammunition, it can provide a ballistic performance at 1,000 metres which is comparable to that of a 7.62 mm round.

The performance of different calibres can be summarised by comparing their energy values (see Figure 10).

Figure 10.
Energy values of different calibres.



The above graph shows the bullet energies at ranges of 100 to 1,000 metres for the four cartridges listed. As can be seen, the differences between the 5.56 mm, 6.8 mm and 7.62 mm are gradually magnified as the range increases, with the 6.8 mm producing 1.5x the energy of the 5.56 mm at 100 m, but 2.1x at 1,000 m, while the 7.62 mm develops 2x the 5.56 mm's energy at 100 m and 3.4x at 1,000 m. The more aerodynamic bullet of the 6.5 mm Grendel means that its initial advantage of 1.6x the 5.56 mm's energy at 100 m increases dramatically to 3.8x at 1,000 m – greater even than the 7.62 mm M80.

Both the 6.8 mm and 6.5 mm rounds are designed to fit the actions of existing M4/ M16 weapons, so that current inventories could easily be upgraded to a larger calibre if desired. Intermediate rounds do, of course, carry a weight penalty versus 5.56 mm ammunition. You can pack 25 to 27 rounds of 6.8 mm ammunition into the same volume as 30 rounds of 5.56 mm ammunition. Though they will be heavier than 5.56 mm ammunition, they will still be significantly lighter than 7.62 mm ammunition.

While both 6.8 and 6.5 mm ammunition still need further development before their suitability as military cartridges is proven, with very limited development budgets they have already shown that they are capable of delivering a superior and more consistent performance than current NATO standard 5.56 mm ammunition. Moreover, both rounds have validated accumulated ballistic knowledge on both sides of the Atlantic which shows the larger a bullet's calibre the greater the lethality at all ranges.

The comparative size and weight of 7.62 mm NATO and 5.56 mm NATO versus intermediate calibre options shows that an ideal compromise between the larger and smaller calibre can easily be achieved (see Figures 11a and 11b).

Figure 11a.
Comparison of cartridges calibres discussed above with overall weights and lengths (from left to right): 7.62 mm NATO (24g, 71 mm), 5.56 mm NATO (12g, 57 mm), 6.8 mm Remington SPC (17g, 56 mm), 6.5 mm Grendel (17g, 57 mm), 7 mm EM-2 (20g, 65 mm), 6.25 mm British (18g, 59 mm).

7.62 x 51 5.56 x 45 6.8 x 43 6.5 x 38 7 x 43 6.25 x 43

Figure 11b.
Comparison of bullets discussed with weights and lengths, (from left to right): 7.62 mm NATO (9.5g, 28 mm), 5.56 mm NATO (4.1g, 23 mm), 6.8 mm Remington SPC (7.5g, 25 mm), 6.5 mm Grendel (7.8g, 30 mm). (These weights are from measured examples and may differ slightly from others quoted in this report.) The length of the 6.5 mm bullet accounts for its excellent aerodynamics and long-range performance.

7.62 mm 5.56 mm 6.8 mm 6.5 mm

Recommendations

So how can present issues with 5.56 mm ammunition be resolved? Three potential solutions are envisaged:

Upgrade existing small-calibre 5.56 mm ammunition to improve its performance.
This is the simplest and least expensive option – if it can be accomplished. The USA has already tried to improve its standard 5.56 mm ammunition with the Mk 262 OTM bullet. With increased bullet mass and propellant loading in the cartridge, it provides better performance out of shorter barrels. But the bullet is still relatively small and underpowered to provide long-range lethality. It should also be noted that the bullet does not have a steel penetrator in the tip, reducing its armour penetration. Other newer US developments include the Mk 318 barrier blind round and the M855 LFS round. These have reportedly both been designed to deliver improved effectiveness, but no detailed performance data has yet been released. In the UK, the MoD is also developing an improved round. Like the US developments, the new British L2A3 round has reportedly also been designed to yaw more quickly upon impact. However, the performance improvements achievable by the use of any legally compliant bullets in the 5.56 mm cartridge are likely to be marginal. The reliance on a smaller round's ability to yaw after impact to inflict lethal injury versus the mass, energy and size of wound channel created by a larger intermediate or full calibre round means that 5.56 mm ammunition will remain a fundamentally less reliable option. It is also impractical to provide a significant improvement in long-range performance.

Widespread re-adoption of full-calibre NATO 7.62 mm ammunition.
This is the most certain option to give troops increased firepower as soon as possible. The British Army has already reallocated 7.62 mm weapons on a limited basis. Both the USA and Germany have also retained stocks of older 7.62 mm weapons, while newer designs such as the FN Herstal SCAR-H and Heckler & Koch HK417 offer an inexpensive means of fielding new off-the-shelf 7.62 mm weapons. But, as already noted, 7.62 mm ammunition is not without disadvantages. Although battle proven by British troops during the Falklands War and in other post-war conflicts, this ammunition and the weapons that fire it impose considerably greater weight penalties and recoil forces. Furthermore, 7.62 mm weapons are heavier and more difficult to shoot accurately, with young or small soldiers frequently flinching from the recoil. Rifles in this calibre are also effectively limited to firing semi-automatically (one shot for each trigger pull) because they become uncontrollable when firing on automatic.

Adopt a new intermediate-calibre round of between 6 mm to 7 mm.
Although this would appear to be the most expensive and risky option, much of the necessary development work has already been done[19]. With the accumulated knowledge in Britain alone, it would not be difficult to select and perfect an ideal solution. While brand new weapons would be desirable, if necessary, many 5.56 mm weapons currently in production could be modified to accept ammunition such as 6.8 mm or 6.5 mm discussed here. Many of the latest generation of assault rifle designs are modular, encompassing a range of calibres, e.g. FN Herstal 5.56 mm SCAR-L and 7.62mm SCAR-H or Heckler & Koch 5.56 mm HK416 and 7.62 mm HK417. Also, if a cartridge with a suitable long-range performance were selected, a cost saving would be achieved by the fact that a 7.62 mm ammunition as a secondary calibre would no longer be required for general purpose machine guns.

Of these possible options, a new intermediate calibre would appear to represent the best compromise in terms of required range and lethality versus the need for low recoil and weight. As other NATO countries also begin to respond to negative feedback about 5.56 mm ammunition or generally consider the need to replace their ageing small arms weapon inventories, now is an opportune moment to reconsider the ideal calibre. Certainly, no future 5.56 mm small arms system should be developed without evaluating it against an intermediate calibre and 7.62 mm ammunition.

Moreover, various new weapon technologies have started to emerge and need to be evaluated objectively in the light of recent operational experience. Of these, the US Lightweight Small Arms Technology (LSAT) program to develop case-telescoped and caseless ammunition looks promising[20], because, if it succeeds, it will offer significant weight-saving advantages (30%-40%) for overburdened infantryman (see Figure 12).

A radically different ammunition technology such as this will require new

Figure 12. LSAT prototype machine gun with plastic-cased and (sectioned) caseless ammunition (Source: Anthony G. Williams)

weapons and thus could provide an ideal opportunity to select a more appropriate calibre. It also needs to be said, however, that current LSAT prototypes envisage the retention of 5.56 mm calibre ammunition[20]. If the need for ammunition with increased range and lethality is desirable, adopting a new weapon system that fails to provide it is likely to lead to a procurement failure. Furthermore, there are still major technical hurdles that need to be addressed before such an advanced system is ready for fielding. Even if caseless ammunition proves unsuccessful, other new developments, such as the use of stainless steel or polymer cartridge cases could reduce the added weight of a new intermediate round[20].

It is possible that NATO may hold a third competition to select a new standard rifle/ MG round. Given that the two previous occasions to do this resulted in controversial choices, forced upon NATO armies by the reluctance of the USA to accept anything that did not conform to US DoD needs or originate in that country, there is a danger of Britain being once again railroaded into accepting a system unsuited to our requirements.

It remains essential for the UK and the USA (as well as the rest of NATO) to use a common military calibre. To achieve this goal, it is important that Britain's considerable knowledge and experience in this area is leveraged to influence any future choice.

In the final analysis, as many unsuccessful defence procurement programmes have proven, selecting the best option at the outset is invariably less expensive in the long-term than choosing something that doesn't work properly and needs to be replaced or improved soon after purchase. If an intermediate calibre had been selected in 1951, it would probably still be in service today, albeit in modified form to take advantage of new propellant developments.

Next steps

Conduct an independent study to understand the extent to which 5.56 mm ammunition has performed inadequately in British and allied service

Develop performance criteria with the aim of informing options for the specification of a new cartridge

Understand the potential operational cost savings of adopting a new round

Evaluate the appetite of other NATO allies to partner with the UK to develop a new ammunition.

Develop work plan and timeline to develop and field new ammunition and small-arms weapon system.

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