Small Caliber Ammunition Solutions for Reduced Range, Low Cost and Reduced Environmental Impact Training

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ABSTRACT

Firing ranges for conventional small caliber ammunition need very long and wide safety templates, even though the actual target distances operators are training to are much shorter. Targets are often located at <20% of the maximum range the bullets can fly. However, access to long training ranges capable of handling 12.7mm caliber ammunition and even medium calibers up to 40mm is more difficult than before. The paper describes new small caliber cartridge designs that maintain vital soldier marksmanship skills, while significantly reducing the size of the range required to maintain those skills. To make these training solutions possible, a mix of novel materials and innovative bullet designs are called upon to reduce damage to training range infrastructure as well as reduced impact on the environment through use of reduced toxicity components. The paper will mainly focus on novel, reduced range bullet technologies that maintain a sufficiently efficient flight path after muzzle exit to match the regular, in-service bullet flight trajectories for as long as possible. This initial flight path is followed by a flight phase having an accelerated drag coefficient, resulting in a much shorter flight path than conventional projectiles. In addition to using bullet shapes to influence bullet flight, the use of frangible type bullet materials capable of very close range training is also discussed. Finally, the paper shows how some of these new reduced range bullets can improve the skills of the operators and demonstrates the reduced environmental impact on ranges that call upon these new bullet technologies.

1.0 INTRODUCTION

Conventional small caliber rifle ammunition and many medium caliber canon ammunition requires range safety templates up to 7km in length, even though the actual target distances are rarely more than 1.5km distant from the shooters. The design of standard small caliber ranges capable of handling small caliber cartridges, both for indoor and outdoor use is well documented (US Dept of Energy, 2012). However, access to long training ranges capable of handling up to .50 caliber (12.7mm) ammunition is becoming more difficult due to encroaching civilian urban development which is reaching out further inland where training ranges used to easily find vast, unoccupied spaces. Because of this, the advent of new ammunition able to allow the modern soldiers to “train as they fight”, albeit on a smaller range, is vital to sustain soldier marksmanship skills.

These Reduced Range Ammunition natures have been included in the top acquisition priorities for the US DoD in all small caliber requirements for many years as can be found in some form or other in documentation dating back from 2014 (Hill, 2014), 2017 (Masternak, 2017), 2018 (Gonzalez, 2018) and 2019 (Rice, 2019). All new intermediary small caliber weapon programs like the 6.8mm Next Generation Soldier Weapon (NGSW) (Carbine replacement program) and the .338 Norma Lightweight Machine Gun program will request the supply of some form of mandatory reduced range ammunition be available in addition to regular service ammunition. In this paper, we describe how General Dynamics OTS - Canada approached this challenge and the solutions, which were successfully introduced or are under current development.

The impact of these new technologies on modern firing ranges is fundamental in many ways. Because the new cartridges are generally free of the more toxic heavy metals like lead, environmental and cleanup costs have the potential of being much smaller than in the past when lead filled projectiles would litter the soil of ranges over much larger areas. The possibility of using smaller ranges to fire the largest of the "small" calibers means nations wishing to train their soldiers now have the option of using ranges with smaller surface areas rather than drive their soldiers to far away ranges, reducing travel and expense costs. This paper will provide an example of how the reduced range ammunition improves training efficiency and training realism.

These innovative training solutions call upon a mix of novel materials and bullet designs that reduce damage to training range infrastructure as well as reducing the impact on the environment by the use of lower toxicity components like lead-free bullets and primers. Further environmental considerations like conformity to European REACH requirements also contributes to a lesser environmental impact by calling upon propellant formulations with more environmentally friendly ingredients, and bullet materials that reduce health and safety risks for the soldiers using the products, as well as the range clean-up teams.

One interesting challenge which will also be briefly discussed is the insertion of tracer bullets in some of these new, innovative materials.

2.0 TYPES OF SMALL CALIBER REDUCED RANGE SOLUTIONS

Three types of non-standard small calibre training ammunition that simplify range design and use will be described. These new types of ammunition natures cover maximum bullet flight reductions that vary from 50% all the way down to 10% of what conventional operational cartridges normally produce. These new types of reduced range cartridges are:

- Reduced Range Ammunition (RRA) which provide long ballistic match trajectories (about 25% of the service ammunition's maximum flight distance) but with only approximately 50% maximum flight distances

- Short Range Training Ammunition (SRTA) which provide relatively short ballistic match trajectories (about 10% of service ammunition's maximum flight distance) but with only about 10% maximum flight distance

- Close Quarter Training Ammunition (CQT) which provide very short match trajectories but offer the advantage of training on simple shooting ranges that require only a minimum of infrastructure

2.1 Reduced Range Ammunition (RRA) Bullets

There are a number of ways to reduce bullet flight distance. Muzzle velocities may be reduced through the use of less propellant and/or a heavier bullet (ex: subsonic ammunition) or firing a lighter bullet or one which is less aerodynamic. Or a combination of all those **(Chaplin, 2017)**. However, the purpose of Reduced Range

Ammunition (RRA) training rounds is to simulate the same range conditions and bullet trajectories a user would encounter at the target distances he or she is likely to fire at in operation, but without having the bullet fly nearly as far as his/her service ammunition would.

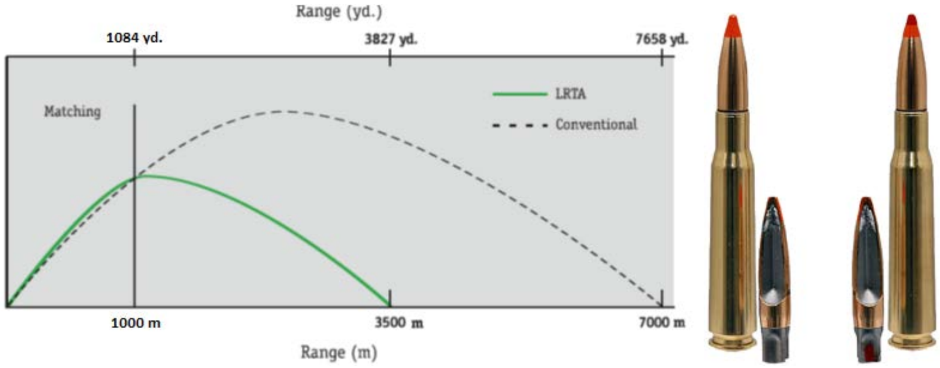


Figure 1: 12.7mm Reduced Range and Conventional Ammunition Maximum Range Comparison

Figure 1 shows an RRA bullet technology that uses fins in the back of the bullets. These 12.7mm cartridges were qualified by several world armies including in the USA **(Stanton, 2012)**. The purpose of these fins is to increase the drag coefficient, forcing a faster disruption of the bullet flight than would occur with conventional bullets not equipped with these fins. However, the fins are also designed such that the bullets maintain a sufficiently efficient flight path after muzzle exit to match the regular, in-service bullet flight trajectories for as long as possible.

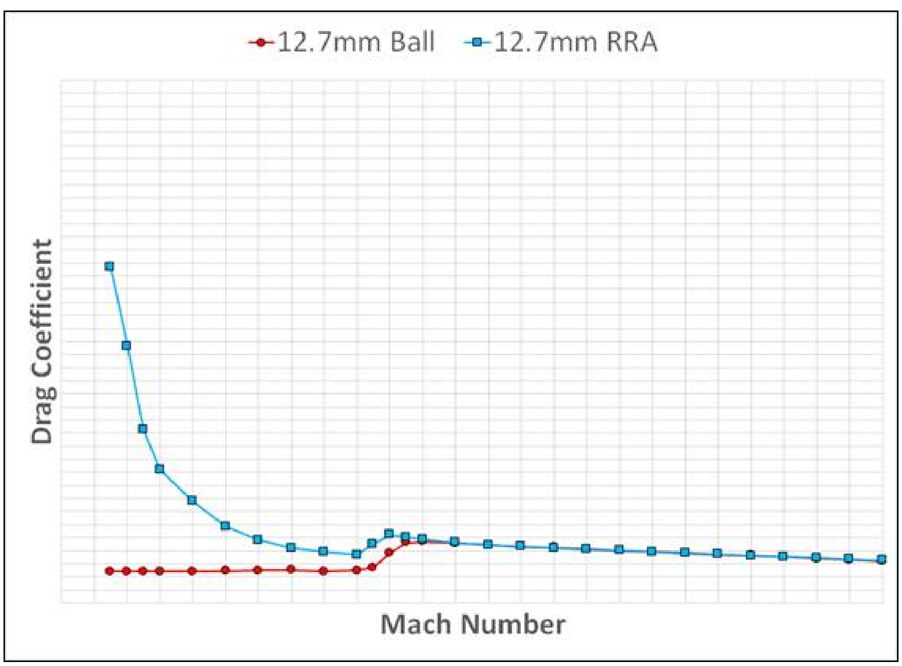


Figure 2: 12.7mm RRA and Conventional Ammunition Drag Coefficient Comparison

Figure 2 shows the comparative drag coefficient curves between 12.7mm RRA and Conventional Ammunition. As the conventional projectile decelerates and becomes transonic its drag coefficient decreases slightly until it has past the Mach number. It then decelerates and its drag coefficient remains relatively constant.

On the other hand, although the RRA projectile starts out of the muzzle with a similar drag coefficient, its flight characteristics will be modified by the fins attached to the projectile, which are spinning with it. Indeed, as the RRA projectile decelerates and becomes transonic, its drag coefficient increases significantly as it transitions to subsonic velocities, considerably reducing the length of the projectile's flight.

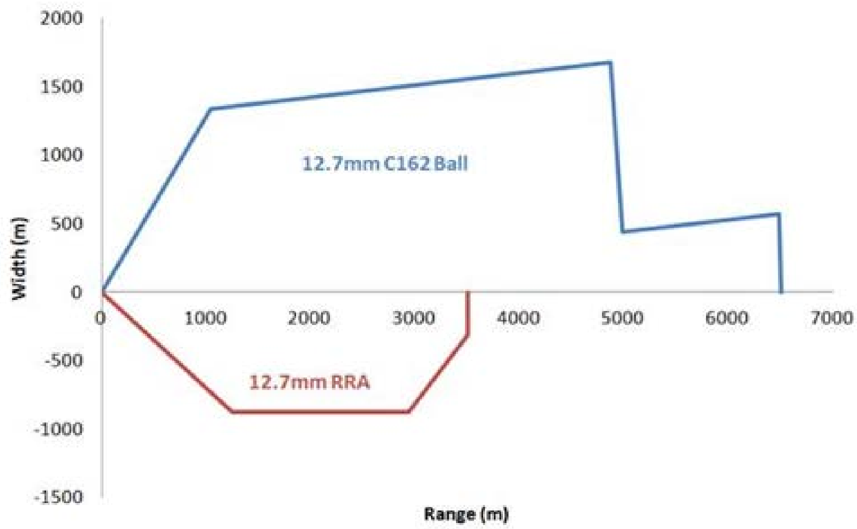


Figure 3: 12.7mm RRA and Conventional Ammunition Safety Danger Zone Comparison

Figure 3 shows a side-by-side comparison of the Safety Danger Zone (SDZ) of a conventional, 12.7mm machine gun projectile (the C162 Ball) and a 12.7mm RRA projectile. The graph shows that not only is the maximum range of the RRA projectile shorter than the C162 Ball round, its width is also much narrower, resulting in a RRA range surface area taking up about a quarter of the surface a conventional ammunition would cover.

This has important implications on a shooting range. It means that more soldiers can safely train simultaneously on available ranges than they could with conventional ammunition. They can also train in a more realistic way on ranges that use, for example, Pop Up targets. Indeed, in a conventional "bowling alley" type range, shooters must all fire in the same, linear direction because of the long SDZ required behind the targets. Unlike on the battlefield, they know the targets will appear directly in front of them. With the shorter SDZ of an RRA cartridge, it becomes possible to stagger the targets in a semi-hemicycle fan shape, forcing the shooter to scan for targets not only in front but also sideways so that they may "train as they fight".

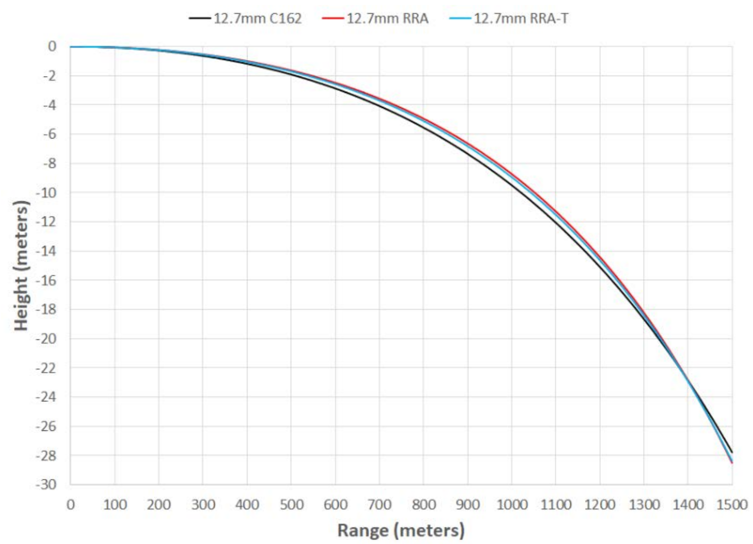


Figure 4: 12.7mm Reduced Range and Conventional Ammunition Ballistic Trajectory Comparison

Figure 4 shows a computer model comparison between the flight trajectories of conventional Machine Gun ammunition (12.7mm C162 Ball) and the most recent version of the 12.7mm RRA Ball and Tracer cartridges. As the graph shows, these RRA cartridges will almost perfectly match the service ammunition ballistic trajectory of the service ammunition up to 1500m. RRA bullet design expertise has now reached a point where these RRA bullets can be designed to fly with the same trajectory as conventional bullets; up to the maximum useful operational distances soldiers have always used these operational cartridges in battle.

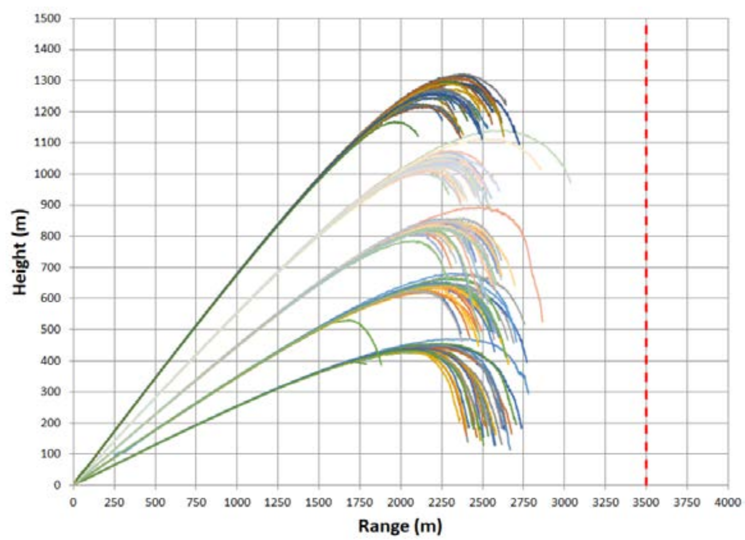
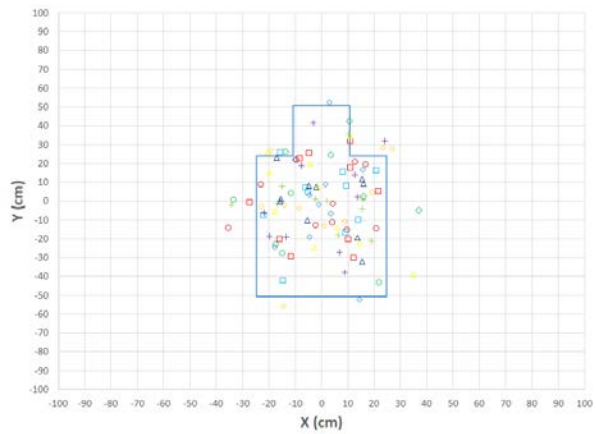


Figure 5: 12.7mm RRA Maximum Range Trajectory Radar Data from 15 to 35 deg. Gun Elevations

Figure 5 shows the maximum range trajectories of 12.7mm RRA projectiles as measured by Doppler radar, fired at five different gun elevations varying from 15 to 35 degrees. The objective was that no projectiles reach beyond 3,500m at standardized environmental conditions (sea level; 15ºC; no wind). It is clear this objective is met. A range of 3,500m is less than a 5.56mm or 7.62mm projectile will reach, allowing 12.7mm ammunition to be safely fired on ranges originally designed for 5.56mm/7.62mm calibres.



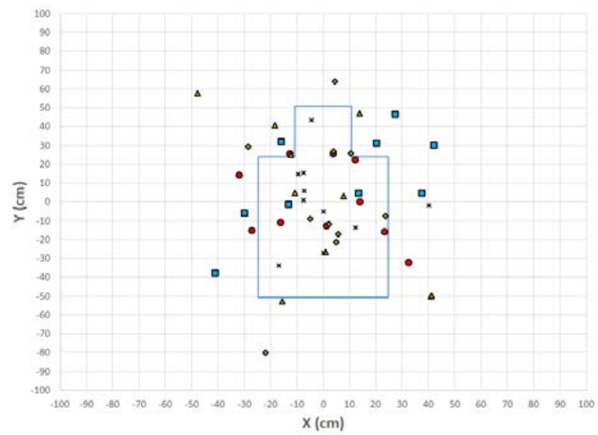


Figure 6 (left): 12.7mm C162 Machine Gun Ammunition Dispersion @ 1000m

Figure 7 (right): 12.7mm RRA Machine Gun Ammunition Dispersion @ 1000m

Figures 6 and 7 compare the dispersion of service ammunition (left) with RRA ammunition (right). At short and medium distances, there is almost no difference in dispersion but at longer ranges, the RRA impact area can swell up to 50% more than the service ammunition results. In spite of this difference it was found during firing trials at a training range at Ft Benning in the USA **(Soldier Systems an Industry Daily, 2020)** that soldiers firing RRA cartridges (5.56mm; 7.62mm; 12.7mm) with their rifles or machine guns were hitting their targets with similar or higher frequency than when they were firing with their regular service ammunition.

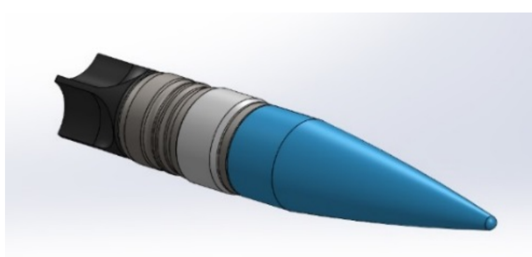


Figure 8: 30mm RRA Projectile (under development)

Medium calibre canon ammunition can also benefit from the RRA technologies described above to allow training of soldiers using vehicle-mounted canons in the 20mm to 40mm calibres. General Dynamics OTS - Canada is currently developing such a cartridge for 30mm ammunition, shown in Figure 8, for firing in either European-made Mauser or American-made Bushmaster guns. These cartridges will provide a maximum flight distance of less than 3,500m – less than half the maximum range of a regular round – and incorporate tracer and spotter-flash on impact functions. All this with excellent accuracy up to 1km.

2.2 Short Range Training Ammunition (SRTA) Frangible Bullets

Another technology to reduce training ranges even more while still providing realistic training scenarios is by the use of frangible bullets. Frangible bullets that will easily disintegrate to dust have been in use for target shooting for decades. Because they are made of lower density materials assembled using powder metallurgy, sintering or injection molding techniques, these bullets are inherently shorter in range due in part to their lower weight.

Bullets with fins made from these friable materials are called Short Range Training Ammunition (SRTA). Unlike RRA cartridges, which behave like conventional ammunition with regard to ricochets, these SRTA frangible bullets allow for shooting at very close distances. Indeed hard targets, located as close as 2 meters from the muzzle, can be fired upon without the danger of ricochet or splash back coming back towards the shooter. As Figure 9 shows, the copper/polymer frangible bullet material instantly turns to dust when it hits a hard target like a steel plate.

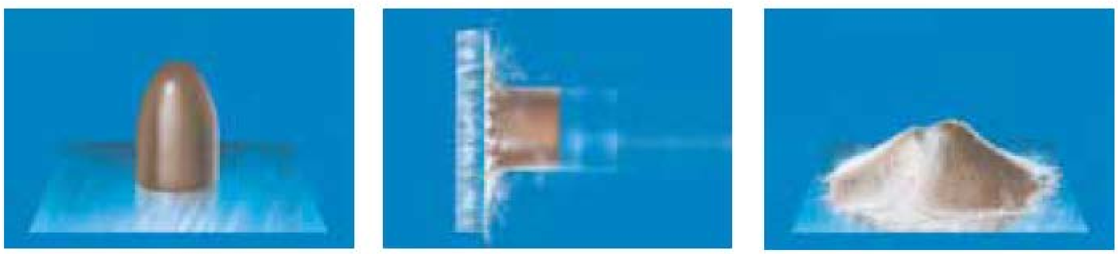


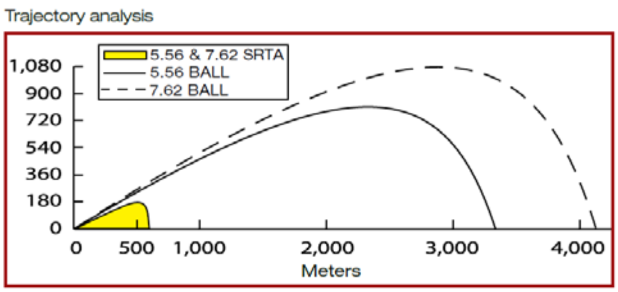
Figure 9: Frangible Projectiles Turn to a Copper Dust upon Impact

Although copper dust is not completely harmless when compared to lead, it is categorized as having an exposure limit 20 times less harmful than lead in terms of its Threshold Limit Value – Time-Weighted Average (TLV-TWA) according to the American Conference of Governmental Industrial Hygienists (ACGIH®)TLV guidelines **(ACGIH®, 2017)**.

After more than four decades of use, there are no known cases of shooters falling ill due to them specifically shooting these types of materials, including known diseases associated with copper dust and fumes like metal fever. Two studies **(Methner, 2013)** and (**Moran & Ott, 2008**) testing the effects of frangible ammunition using non-leaded primers on shooter health in partially-enclosed firing ranges found that air contaminant concentrations did not exceed occupational exposure limits. However both studies pointed to the importance of well-designed range ventilation systems in enclosed or partially enclosed ranges. General Dynamics OTS Canada is also currently compiling results from recent ammunition firing of frangible ammunition for a toxicology study to establish health and safety guidelines when using these products. The final internal report should be published in 2021.

These non-ricochet SRTA frangible projectiles can have an important impact on small caliber training on ranges. For example, it is no longer necessary to fire in an interior range having a sand berm backstop. In outdoor ranges, even side berms are unnecessary since there are no possible ricochets. Frangible projectiles can be fired directly on thin steel plates (6 to 12mm thick, depending on caliber) without risk of perforation or of ricochet. In addition there is no lead contamination.

These SRTA cartridges are now manufactured up to 12.7mm (.50 cal) calibers **(de Sousa, 2014)** and the larger projectiles can be tracer filled in spite of the frangible material they are molded from.



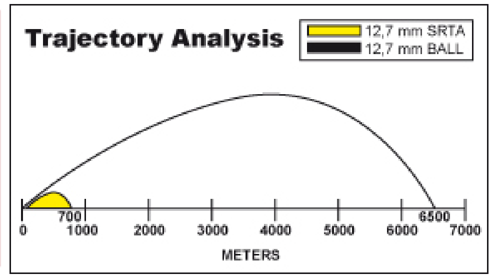


Figure 10 (left): 5.56mm and 7.62mm SRTA and Standard Ball Cartridge Maximum Range Comparison

Figure 11 (right): 12.7mm SRTA and Standard Ball Cartridge Maximum Range Comparison

Figures 10 and 11 show a comparison of the maximum flight difference between a standard Machine Gun projectiles and SRTA projectiles. Like the RRA projectiles, the SRTAs also provide a shorter maximum flight range but the flight path is even shorter than the RRAs. The SRTA projectiles use front fins in addition to a lighter projectile weight. This combination creates a maximum range between 500m and 700m, depending on caliber and fin design, which only represents about 10% of the range of a more conventional service ammunition.

Yet, the SRTA projectiles are still capable of matching the trajectory curve of the conventional service ammunition for distances of 100m to 150m. They allow soldiers to learn how to operate their weapons, clear them following weapon stoppages, change barrels when they are too hot, etc. All this on a range less than 1 km long rather than one having 4 to 7 km needed when using conventional cartridges.

Figure 12: 12.7mm SRTA Target at 30m Showing Strong Projectile Yaw

Because of their deep and large front fins, SRTA projectiles exit the muzzle of the weapons in a normal fashion but quickly adopt a strong Yaw angle. As they spin, they continue flying with a strong angle with regards to the line of flight. Some of the elongated impact marks caused by this strong inclination can be seen on the picture in Figure 12, showing a paper target 30m from the weapon. This is normal behavior but it must be explained to users on the firing range when they first use these products.

Many of these SRTA cartridges are fired out of machine guns and as is often the case, operators will sometimes need to be guided by tracer cartridges. A special proprietary process had to be developed to successfully press the tracer and igniter mix inside the bullet cavity of the friable material.

2.3 Close Quarter Training (CQT®) Ammunition

Close Quarter Training (CQT®) ammunition is a third level of small calibre training ammunition which disrupts the traditional firing range training scenarios that were used in the past to train military and law enforcement operators on learning and/or perfecting their shooting skills. The CQT® cartridges (Figure 13) evolved from the Simunition® line of marking cartridges which have been the industry standard for force on force training.

Figure 13: A 9mm CQT® Cartridge

Contrary to the RRA and SRTA cartridges described above, the CQT® cartridges generate so little chamber pressure that they require the weapons they are fired in to be converted by a weapon conversion kit. This enables the weapons to fire these low energy rounds safely while precluding the accidental chambering and shooting of a more conventional, higher pressure cartridge. These cartridges have only been designed for pistol and small rifle weapons (9mm and 5.56mm). Their training advantages when compared to conventional ammunition is undeniable when one compares the type of range infrastructure required to train with these cartridges.

After their weapons are converted the operators can train just about anywhere: an empty office, basement or garage or even outside. It is ideal for short-range target shooting, for basic firearms training or for advanced tactical shooting exercises. The 9mm CQT® cartridges produce recoil similar to, but lower than traditional service ammunition with tactical accuracy up to 10m. The 5.56mm CQT® cartridges will provide tactical accuracy up to 30m. This is accomplished with no risk or damage to the training facilities.

Unlike practicing on a conventional small caliber shooting range while firing on paper targets, the CQT® cartridges can easily be used in tactical shoot houses where shoot/no shoot decisions must be made in tactical scenarios, under the supervision of shooting instructors who may be observing close behind the shooters. The CQT® cartridges also lend themselves well to urban fighting scenarios in Military Operations in Urban Terrain

(MOUT) and/or Fighting in Built up Areas (FIBUA) type firing range scenarios.

Once operators have gone through initial training using these low energy cartridges, they can convert their weapons back to normal functioning and feel much more confident and ready they will be able to face complex situations in the missions they are called to undertake.

Officers that manage the training ranges reap the benefit of better training for their operators at reduced training costs since they do not need expensive, dedicated training ranges. The noise generated by the CQT ammunition is lower than that of conventional ammunition, so hearing loss/damage is also reduced.

3.0 Range Contamination and Clean-up

None of the new bullets described in this paper contain lead or other similarly toxic heavy metals that might be detrimental to the outside range environment in the impact area. The RRA bullets are assembled with steel cores inside gilding (copper/tin) jackets, just like any other conventional Full Metal Jacket (FMJ) projectile would. The SRTA cartridges are molded out of special copper and polymer compounds. As for the CQT® cartridges, they are made of a hard plastic molded projectile.

As for the cartridge energetics, it is possible for all these cartridges to function with lead free primers and many already do. All propellants are compatible with the European REACH requirements to ensure safe handling by workers and prevent the intentional release of toxic materials out in the environment.

The RRA bullets are either made out of solid brass or of two parts which includes a steel core inside a gilding (90% copper / 10% zinc) jacket. When fired in a sand backstop the sand can be periodically sieved to safely extract the fired projectiles (they contain no lead or other similarly toxic heavy metals) which can then be disposed of and recycled by metal recyclers.

Special bullet traps that stop and recover frangible copper/polymer dust after bullet impact have been designed and are available on the market. They allow recovery/containment of the bullet dust and prevent it from spreading out into the environment when rounds are fired outdoors. These bullet traps have been designed specifically for non-ricochet frangible bullets and may be moved around the firing range, as needed, by a range operator using simple lift equipment and trailers. They make it easier to recover and recycle the copper dust particles. This increases the versatility of the ranges to accommodate the new and innovative training methods proposed by these new frangible bullet technologies.

4.0 Training Realism

As well as increasing battle realism, it will now be described how these new technologies can also be used to allow more soldiers to simultaneously train on existing ranges than previously possible, without forcing the closure of service roads on the range or restricting training scenarios due to proximity of civil population that often surround existing training facilities.

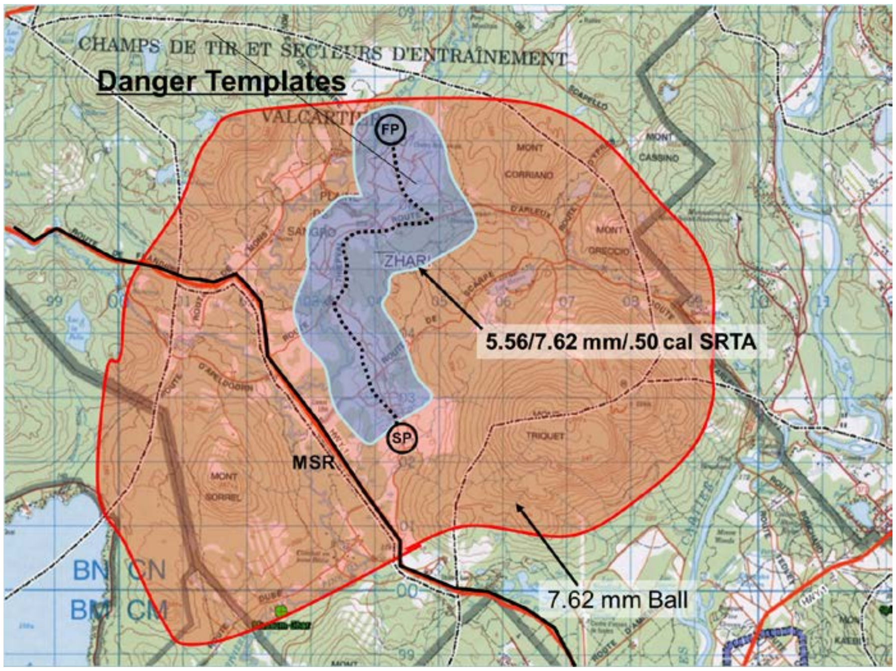


Figure 14: Example of SRTA Ammunition on Training Scenarios and Firing Range

Figure 14 shows one training scenario where the training efficiency would be greatly affected – improved- by the use of 5.56mm, 7.62mm and 12.7mm SRTA cartridges. The training range, in this example, is located at the Canadian Valcartier Military Base in the province of Québec. The training scenario's objective is to teach soldiers how to defend a convoy route, shown as a dotted line. If defending the convoy involves the use of conventional 7.62mm ball cartridges, a large area of the base would have to be closed, including a main supply route (MSR) which crosses the SDZ required for such an exercise.

By using 5.56mm, 7.62mm and 12.7mm SRTA ammunition a much smaller SDZ is generated only around the dotted convoy route. The amount of range real estate required for these exercises is considerably reduced, allowing the rest of the military base to go on with its activities, including maintaining the supply route opened, without much hindrance from the actual military exercise underway elsewhere on the base.

These RRA and SRTA cartridges also allow a safer training environment when airplanes, helicopters and even drones are required to simulate a battle environment. Indeed, since the RRA and SRTA cartridges also do not fly or ricochet as high as conventional cartridges, they allow the presence of lower flying aircraft during training exercises than if only conventional cartridges are used. The RRA and SRTA cartridges can also be fired towards ground targets out of weapons mounted on flying aircraft. The much shorter flight distances of the bullets reduces the SDZ on training ranges even when aircraft are involved.

Even though these cartridges are made from innovative materials and the bullets are slightly lighter than conventional bullets, they require no modifications to existing weapons when used. Just like their conventional cousins, some of the SRTA and RRA bullets may be supplied with or without tracers.

The RRA bullets, in particular, may also be used during military operations, particularly when a mission requires taking out a fairly close target without the risk of hitting a non-target that would become collateral damage if a conventional bullet was used. Training scenarios that take this feature into consideration can also be tested on the reduced footprint ranges.

CONCLUSION

Modern small and medium caliber reduced range ammunition of various designs may be used for an efficient and economical training of soldiers and weapon operators. These cartridges allow a more efficient use of small arms training range real estate by significantly limiting the maximum flight distances the bullets are allowed to travel. In spite of their short maximum flight distances, the same bullets nevertheless provide a sufficiently long and relevant target impact spread and ballistic match with the operational ammunition to allow the operators to "train as they fight". The operators honing their skills on larger calibers can train more frequently on nearby existing ranges initially designed for smaller calibers instead of travelling to far away ranges that could accommodate these larger calibers. By using environmentally safer materials, the firing ranges and surroundings also remain cleaner.

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