Design dilemma: the challenge of future small arms and ammunition development

The US is looking ahead to the next generation of small arms, with its LDAM and CLAWS projects, while examining the ammunition these weapons should use in the related SAAC study. Other NATO nations, also facing the need to replace small arms inventories, are observing this with interest. Anthony G Williams examines the options

NATO has now been using the same infantry rifle and machine gun (MG) ammunition for more than 30 years: the 5.56 x 45 for light rifles, carbines and MGs, and the 7.62 x 51 in general-purpose machine guns (GPMGs) and sniper/sharpshooter rifles. These are backed up by the .50 calibre Browning heavy machine gun (HMG) plus some heavy rifles in the same 12.7 x 99 calibre.

More recently there has been the adoption of specialised long-range sniping rounds such as the .300 Winchester Magnum (7.62 x 66B) in US Army service and the .338 Lapua Magnum (8.6 x 70) in the British Army and in many other countries.

The conflicts of the past decade have primarily featured infantry warfare with tight rules of engagement limiting the use of heavy-fire support, thereby highlighting the performance of rifles and MGs, which often have to be used at extended ranges. As a result, the often outranged 5.56 mm weapons have been supplemented by 7.62 mm at squad/section level. Another result, due to the difficult environment, is that weapons have been wearing out at a high rate.

US programmes

In November 2013 the US Army announced two new small-arms programmes, designated LDAM (Lightweight Dismounted Automatic Machinegun) and CLAWS (Combat Lightweight Automatic Weapon System).

LDAM is seen as a replacement for the 7.62 mm M240 medium MG (the FN MAG) and, possibly, the .50 calibre M2 HMG in dismounted applications. CLAWS is intended to replace all existing 5.56 mm rifles, carbines and light machine guns with one modular weapon family with interchangeable barrels, stocks and accessories, providing the flexibility to assemble a carbine, assault rifle, squad-designated marksman rifle, and a squad automatic weapon or light machine gun (LMG) from a common kit of parts.

The ammunition to be used in the new weapons is currently being investigated in the Small Arms Ammunition Configuration (SAAC) Study, formerly known as the Caliber Configuration Study (CCS). The LDAM requirement to match the effective range of the .50 calibre HMG with much less weight indicates the likely choice of a significantly larger and more powerful cartridge than the 7.62 mm; the most obvious candidates being of .338 inch calibre. If that proves to be the case, the unavoidable
extra bulk and weight of the ammunition compared with 7.62 mm may preclude its use as a standard squad weapon, no matter how light the gun is.

CLAWS may therefore need to replace not just the 5.56 mm weapons but also some of the lighter 7.62 mm rifles such as the US M14EBR and M110 or the British L129A1 'Sharpshooter', plus LMGs such as the MK48 (FN 7.62 mm Minimi). As a result, CLAWS ammunition would need a practical range much greater than the 300-400 m of the 5.56 mm, in order to cope with the full spectrum of small-arms engagements: "from 8 to 800 m" as the US Army's PEO Soldier organisation put it.

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**Ammunition design issues**

Ammunition companies providing for the commercial markets come up with new cartridge designs so frequently that it is difficult to keep up with them. In contrast, the opportunity to design a new military small-arms cartridge occurs perhaps once in a generation, and when it is in service it may remain so for a lifetime, so its design merits careful consideration. This starts with specifying the ballistic requirements - the key driver of cartridge design.

For LDAM, this is likely to include the need to match the .50 calibre HMG in its effective range of at least 1,500-2,000 m. For CLAWS, the two comparators for effective range are the 7.62 mm NATO and the equally powerful 7.62 x 54R Russian round used in the PKM LMG and SVD rifle, which have been used in Afghanistan. That indicates an effective range of at least 1,000 m in a MG, about 800 m in a DMR/sharpshooter rifle, and up to 600 m in a standard infantry rifle.

The army is likely to want ammunition that not only meets these range criteria but also is as small and light as possible, with minimal recoil, particularly for the CLAWS application. These requirements are of course in conflict, so the search is on for the best compromise that will meet the army's needs over the wide variety of circumstances in which soldiers may have to fight in future: from the urban fighting typical of Iraq to the long-range engagements that often occurred in Afghanistan.

Achieving the best compromise will involve juggling several variables: the hit probability (a function of trajectory, flight time and wind drift) out to the maximum required range; terminal effectiveness (against hard and soft targets) at different ranges; and objectives for cartridge weight and recoil.

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Bullet design

The key to a successful cartridge design is the bullet. This has to meet various performance requirements, including accuracy and penetration, but there is a key factor that is often neglected: the value of good aerodynamics or, to use the technical term, a high ballistic coefficient (BC). The higher the BC, the more slowly the bullet loses velocity and energy. This means that to meet any given performance target at maximum effective range, the better the BC, the lower the muzzle velocity required and the less powerful the cartridge needs to be; as a result, ammunition weight and recoil can be minimised.
The BC is made up of two elements: one is the sectional density (SD), which is the bullet weight divided by the frontal area (for any calibre, double the bullet weight and you double the SD), the other is the form factor, which is a measure of the aerodynamic shape of the bullet. At supersonic velocities this is mainly concerned with the shape of the ogive or nose taper of the bullet. There are therefore two ways of improving the BC: one is to increase the bullet weight; the other is to improve the shape, with a longer and more tapering ogive. The first method increases both the ammunition weight and the recoil; the second gives extra range for little or no cost.

Two different Barnes .50 calibre solid brass bullets; the longer one has a substantially better ballistic coefficient. (Barnes)

The advantage of a high BC is illustrated by the products of US company Barnes Bullets. It make two versions of solid brass .50 calibre (12.7 mm) 48.6 g target/sniper bullets: one of standard shape to fit into the overall length limits of the 12.7 x 99 (.50 calibre BMG) round, the other designed for single loading in specialised rifles so enabling it to be longer overall, permitting a much longer ogive. Barnes’ figures show a 40% improvement in BC, which indicates that the long bullet will retain the same energy at 2,000 m as the standard one does at around 1,400 m - with no increase in muzzle velocity, ammunition weight or recoil.

The problem with adopting this solution is that the difference between the case length and the maximum permitted overall length of all NATO small-arms cartridges is not enough to accommodate aerodynamically efficient long-nosed bullets. This applies to the 5.56 mm, 7.62 mm, .300 Winchester Magnum and even the .338 Lapua Magnum. Russian ammunition is less restricted, with the 5.45 x 39 AK74 round using a notably well-shaped, long-ogive bullet.
Gun design issues

One aspect of gun design that is directly linked to cartridge design is the barrel length. The starting point for the cartridge design should be the performance requirements. One important variable is the barrel length used to measure the performance. Put simply, to achieve any given performance
there is an inverse relationship between barrel length and cartridge power, and therefore size and weight.

The .300 Winchester Magnum (.300 WM) - a common sniper rifle round - develops about 4,750 J of muzzle energy from a long barrel, compared with about 3,500 J for the 7.62 mm NATO. However, if the barrel length is reduced to 406 mm (16 inches), the .300 WM’s muzzle energy is little more than the 7.62 mm NATO achieves from a 610 mm (24 inch) barrel. In other words, to compensate for using a 406 mm rather than 610 mm barrel, you need a cartridge developing 30% more power, which is commensurately heavier, develops a lot more recoil, and generates vastly greater muzzle blast and flash, needing a much larger suppressor. This is a considerable penalty.

The difference in barrel length of 200 mm is significant, since that is typically the difference between rifles of traditional and bullpup configuration of the same length. To put it another way, for rifles of the same overall length and developing similar ballistics, you can choose a conventional carbine firing .300 WM ammunition or a bullpup firing 7.62 mm NATO.

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**Bullpup market**

Two of the three first-generation bullpups - the British SA80 and French FAMAS - are approaching the end of their service lives. The third, the Steyr AUG, was by far the most successful in terms of international sales. It has recently been brought up to date and is still being offered by Thales.

The current market leader is the IWI Tavor, which is replacing the M4/M16 in the Israeli armed forces and has been sold to more than 12 other countries. The controls of the latest Micro-Tavor or X95 version have been designed to match those of the M4 as closely as possible, so conversion training is quick and simple. It is available in several versions, varying in barrel length as required and with a purpose-designed 40 mm under-barrel grenade launcher available. This might be regarded as a breakthrough for bullpups, addressing the criticisms levelled at earlier weapons.
Other bullpups in service and still available are the FN F2000, the STK SAR-21 and the Chinese Type 97 (the export version, in 5.56 mm NATO calibre, of China’s standard 5.8 mm Type 95 rifle). Two new bullpups have been announced recently: the STK BMCR and the Polish MSBS.

The BMCR has been designed with the advantage of STK's experience with the SAR-21. The most significant change is the addition of a forward ejection system via a short tube on the right of the receiver, which guides the fired cases away from the firer’s face when shooting left-handed. As with the FN F2000, this makes the rifle fully ambidextrous without having to make any adjustments to the mechanism. At present, the BMCR is in the prototype stage.

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Polish MSBS modules. (Remigiusz Wilk)
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