small arms survey

Issue Brief

Number 3 ■ December 2011

Ammunition Marking

Current Practices and Future Possibilities

Introduction

The relevance of ammunition control measures and their inclusion in global agreements and instruments have sparked an animated debate in the international arms control community. Within the ammunition control debate, ammunition marking[1] is among the most contentious issues.

To fully understand the reasons for this, let us start by giving a definition of ammunition marking and describing what purposes it serves. Ammunition marking includes all the marks applied on individual cartridges and their packaging that contain all the information crucial for their identification. Thus, ammunition marking serves as a system of classification for record-keeping purposes that facilitates accounting for ammunition use, safe transportation, storage, and quality control, and it can be used to trace transfers of ammunition from one user group to another.

In the field of ammunition control, the term 'tracing transfers' refers to the capacity to identify ammunition, its origin, and patterns of transfer (Bevan, 2008). To date, most of the information vital for tracing purposes is found on the packaging, because marking technologies have thus far imposed limitations on what could be directly marked in the limited space available on the cartridge. The boxes in which ammunition is contained therefore play a crucial role. In general, if ammunition is kept in sealed factory boxes, it is likely to be traceable. The problems start once it leaves these boxes, and the consequences of this scenario have rendered the possibility of marking lot numbers on individual cartridges a central and controversial point of the international debate.

The roots of this controversy are both political and economic. From a political point of view, the capacity to identify transfer patterns would result in greater market transparency and increased state accountability. In addition, given the very high quantities of ammunition traded (hundreds of millions of rounds each year), implementing ammunition control measures would require, at least initially, a major bureaucratic effort. Thus, at this stage, the political debate is primarily among states.

The economic argument, however, involves both states and industries. From an industrial perspective, the focus is on costs. Ammunition is a relatively cheap commodity and, as such, its market is very reactive to minimal price alterations that could derive, for example, from modifying current production processes in order to fulfil possible new marking obligations. Thus, manufacturers approach this issue very carefully, because it directly affects their position in the market and their ability to compete. From states' perspective, the debate focuses on the real cost–benefit ratio of creating and implementing an ammunition control mechanism based on the marking of the lot number on each individual cartridge. While some states consider lot numbers on individual cartridges a sufficiently strong contribution to effective tracing, others argue that, from a strictly legal point of view, a system that fails to account individually for all the rounds of ammunition produced and transferred would not be robust enough to stand up in a court of law. Thus, in this latter case, lot numbers would not add any significant value to the marks already applied. In response to this objection, those who support lot number marking argue that, in the field of ammunition, 'traceability' should not be considered only as a tool for legal prosecution or in the context of crime, but also as a means to detect and monitor authorized and unauthorized transfers of ammunition among states.

Consequently, the whole picture is very complex. As a result, to date, ammunition control measures in general, and ammunition-marking provisions in particular, have been excluded from any global instrument, allowing for the creation of several different regional, sub-regional, or national marking and classification systems, thus making it more difficult to monitor and keep track of ammunition transfers.

This *Issue Brief* focuses specifically on marking as it relates to the tracing of cartridge-based ammunition, such as that used in pistols, rifles, shotguns, and machine guns, and its packaging. The goal is to contribute to the international debate by providing both a practical/technical insight into the marking process and a review of some current regulations. After this introduction, section 2 provides the necessary background to understand current marking practices, illustrates some

key definitions, explores the global trends in ammunition marking, and provides an overview of current regional approaches. Section 3 focuses on the practical aspects of ammunition marking. It provides insight into the production process and supply actors, explores what information is marked and how, and analyses the specific issue of lot-number marking. Section 4 discusses two recent technologies and describes how they could help overcome some of the limitations imposed by current practices: laser technology for marking individual rounds of ammunition at a later stage of the production process, and the use of two applications of radio frequency identification (RFID) technology to 'mark' and trace ammunition boxes of various sizes. The main findings of this study are summarized in section 5.

2. Background

Key terms and definitions[2]

This issue brief will often refer to ammunition components. Below is a simple list of these components with a brief definition for each. The assembly of all these components will be called a 'cartridge' or a 'round'.

- ***Cartridge***: a single round of ammunition consisting of the case, primer, and propellant with or without one or more projectiles. Also applies to a shot shell.
- ***Projectile:*** an object propelled from a firearm by the force of rapidly burning gases or other means.
- ***Primer:*** a cartridge ignition component consisting of a brass or gilding metal cup, priming mixture, anvil, and foil disc; the primer fires the cartridge when struck with sufficient force.
- ***Propellant:*** in a firearm, the chemical composition that, when ignited by a primer, generates gas, which in turn propels the projectile. Also called powder, gunpowder, smokeless powder, or black powder.
- ***Case:*** refers to cartridge case or shot-shell case. Shortened through common usage to simply 'case' (SAAMI, 2009).

Ammunition marking: global trends

The issue of ammunition control has been excluded from all global instruments and agreements dealing with small arms and light weapons. Consequently, there is no global regulation or system of standardization covering the specific aspect of ammunition marking. Despite this, it is possible to identify some basic and 'universal' features of cartridge-based ammunition:

- The vast majority of ammunition is marked in one way or another at the time of manufacture to fulfil different purposes (see section 3).
- Military/law enforcement forces' ammunition and civilian ammunition follow different systems of regulation.
- To date, most of those marks are applied with a headstamp. Due to the limited space available and to the limitations of the stamping technology, the information marked directly on the cartridge case is minimal.
- As a consequence of the previous point, most information used to transfer ammunition from one place to another and to store it is marked on the boxes.
- There are significant regional variations in approaches to ammunition marking (see section 2).

The distinction between governmental and civilian demand for ammunition plays a fundamental role in the field of ammunition and affects manufacturers' behaviour towards marking. In fact, focusing the debate solely on the demand side could generate misleading results. In particular, demand for ammunition can be divided into two main categories: state defence and security forces users (i.e. military and law enforcement forces) and civilian users. The differences between these two categories include not only the type and calibre of the ammunition they purchase, but also the applicable regulations and, more relevant from a business perspective, the quantities traded and the scale of contracts. In this regard, the civilian component of the demand side is characterized by its disaggregation, while governmental contracts are signed for large quantities. In brief, the following applies:

- **government demand:** military and law enforcement forces: fewer contracts, but larger quantities per contract. The procurement phase is often carried out by central agencies; and
- **civilian demand:** more contracts (and possibly larger total quantities), but smaller quantities per contract.

The use of ammunition marking varies from the military to the civilian sector of the market. From a military perspective, marks on cartridges and their packaging are intended for: stockpile management, transportation, record keeping, and identification for operational needs. Conversely, while the basic principles of and systems for marking remain the same, the civilian sectors of the market, including both producers and consumers, is mainly concerned with using marks to ensure proper identification (type and calibre) and for quality assurance.

The regulations applying to these two parts of the market result from the differences described above: in the military sector, such regulations usually take the form of 'standards' that not only define the requirements, but also provide specific technical and practical indications on how markings should look and where they should be placed. On the other hand, in the civilian sector, such regulations often take the form of 'provisions of law' or, more generally, legislative requirements that lack the practical dimension that ensures uniformity of implementation.

Regional approaches to ammunition marking

The lack of global regulation or any system of standardization has been partially overcome at the regional and sub-regional levels through the establishment of regional and sub-regional regulations covering various issues related to ammunition, including marking.

Within these regional regulations, an additional distinction has to be drawn between those that apply to military ammunition and those that apply only to civilian ammunition.

This section presents some examples of these regulations for both military and civilian ammunition, providing the necessary framework to fully understand the logistical and practical aspects of marking that will be discussed in section 3.

Military regulation: the role of NATO

Depsite not being adopted globally, NATO ammunition standards to date represent the most complete standardization effort in the field of ammunition control. These ammunition standards have been formalized by NATO member states in several standardization agreements (STANAGs), each of which focuses on a specific calibre. STANAGs include a list of requirements that rounds need to satisfy to meet NATO standards, including not only their physical characteristics, but also their technical performances. Table 1 lists the most relevant STANAGs for this study.

In terms of case marking, according to the STANAGs, NATO ammunition should be marked with the following three elements:

- NATO design mark, to identify ammunition that qualifies as NATO standard;
- producer identification (ID); and
- last two digits of the year of production.

It is important to note that the lot number is *not* included as a requirement for cartridge case marking in the NATO STANAGs. As will be discussed below, this is a critical aspect to consider when analysing current practices or when thinking about possible future regulations. Figure 1 provides a visual example of a case marked according to NATO STANAGs.

Much of the information crucial for ammunition control is displayed on the packaging in which ammunition is contained, transferred, and stored. A detailed list of requirements for the identification and marking of ammunition packaging is included in the NATO Allied Ordnance Publication (AOP) 2 (NATO, 2008). According to this document, there are three different types of ammunition packaging:

- The **inner packaging** directly contains the ammunition.
- The **outer packaging** is the normal packaging used for transit and storage.
- The **intermediate packaging** is any packaging between the inner and outer packaging.

The AOP-2 includes a list of markings and symbols to be applied to packages of ammunition with a calibre up to 20 mm. In particular, all packages should include the following:

- **Nature of the projectile:** the nature of the projectile, such as tracer, ball, armour piercing, etc., should be indicated by the appropriate symbol. When the pack contains projectiles of different natures, the appropriate symbols should be used to show their arrangement.
- **Quantity of ammunition:** the quantity of the ammunition should be indicated by numerals.
- **Calibre of ammunition:** the calibre of the ammunition should be indicated by letters and numerals.
- **Packed configuration:** the packed configuration of the ammunition should be indicated by symbols. If applicable, the model of the charger, clip, belt, or link should also be indicated.
- **Lot number:** the lot number of the ammunition appearing on the outer package should be underlined. No other markings on the outer package should be underlined. The lot number should be composed of three elements: the serial number of the lot, the manufacturer's initials or recognized ID letters, and the last two digits of the year of manufacture or packing (this information should be positioned in accordance with national practice).
- **NATO design mark:** as mentioned earlier, this symbol identifies ammunition that qualifies as NATO standard.

In addition to the inclusion of these elements on all packages, some additional marks are required on the outer package only. However, these will not be discussed in detail in this study because they are not directly related to the purpose of tracing.

Figure 2 illustrates an example of minimum package markings. The standards described above were established to regulate ammunition production and transfers among NATO member states, but are often used as a reference by some non-NATO countries and for the production of non-NATO calibres by ammunition manufacturers.

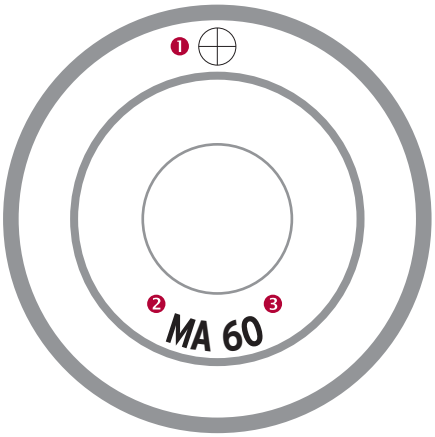
Table 1 **Key NATO standardization agreements for small arms ammunition**

STANAG	Title	Date
2310	Small Arms Ammunition (7.62 mm)	November 1976
2329	Links for 7.62 mm Ammunition (AOP-3)*	April 1982
4090	Small Arms Ammunition (9 mm)	April 1982
4172	Small Arms Ammunition (5.56 mm)	May 1993
4383	Small Arms Ammunition (12.7 mm)	July 2001

*AOP = Allied Ordnance Publication

Source: Adapted from Arvidsson (2008)

Figure 1 **Headstamp marking scheme on a NATO round case**



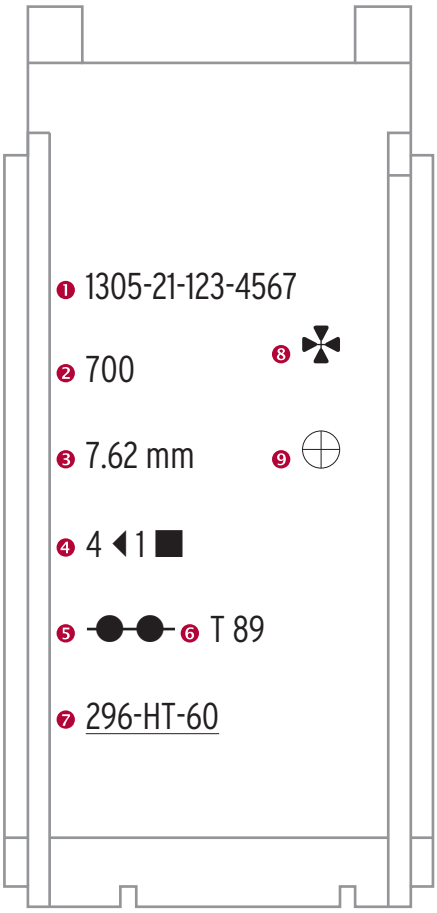
1 NATO design mark (if applicable).

2 Manufacturer's initials or recognized ID letters.

3 Last two digits of year of manufacture of complete round.

Source: NATO (2008)

Figure 2 **Example of the layout of minimum package markings**



1 NATO stock number: this is a 13-digit numeric code that standardizes the identification of supply items. Refer to STANAG 3150 and 3151 for further details.
2 Quantity of ammunition.
3 Calibre of ammunition.
4 Symbols representing the nature of the bullet as packed; in this case, the symbols mean four armour-piercing bullets and one tracer round.
5 Symbols for the type of pack; in this case, 'linked'.
6 Model of link.
7 Lot number: lot serial number, manufacturer initials, last two digits of the year of production.
8 NATO symbol of interchangeability (if applicable).
9 NATO design mark (if applicable).

Source: NATO (2008)

Civilian regulations: CIP (Europe) and CIFTA (the Americas)

On the civilian side of the market, regulations and legislation are even more regionalized. For example, in Europe, the Permanent International Commission for Firearms Testing (CIP) provides legally binding regulations.[3] CIP's main concern is with the safety of firearms and ammunition. Its publication on marking firearms (CIP, 1991) includes the test regulations that producers should undertake before commercializing their products. Nevertheless, CIP also determines minimum marking standards for ammunition cases and packaging.

For example, in an effort to harmonize its national legislation on civilian ammunition control with CIP regulations, Italy in 1993 established that the markings on the cartridge must include the producer's ID and the calibre (information not usually required by military standards). Additionally, the packaging should include the name or logo of the manufacturer, the name or type of ammunition, the lot number, the quantity included in the package, and the appropriate symbol verifying that the related ammunition has been tested according to CIP requirements (Italy, 1993).

In 2006 the Organization of American States presented draft model legislation for the effective application of the Inter-American Convention against the Illicit Manufacturing of and Trafficking in Firearms, Ammunition, Explosives, and Other Related Materials (CIFTA). This model legislation included a chapter covering the issue of ammunition marking and packaging that reads as follows:

> *Article 4: Marking of Ammunition*
>
> *(1) Every person who manufactures ammunition shall ensure that each cartridge is marked at the time of manufacture, in the manner set out in Article 5.1.*
>
> *(2) Every person who manufactures ammunition shall ensure that each box of ammunition is marked at the time of manufacture, in the manner set out in Article 5(3) and, as applicable, Article 5.4.*
>
> *(3) Every person who imports ammunition shall ensure that, in addition to the cartridge marking referred to in paragraph (1), each box of imported ammunition is marked in the manner set out in Article 5.3 and 5.4.*
>
> *Article 5: Manner of Marking*
>
> *(1) Each cartridge shall be permanently marked by a headstamp impressed, stamped or embossed that identifies the manufacturer, the country and year of manufacture, and a unique batch or lot number.*
>
> *(2) Headstamp markings on cartridges shall:*
>
> *(a) consist of simple geometric symbols in combination with a numeric and/or alphanumeric code;*
> *(b) be of a size that is readily legible to the naked eye; and*
> *(c) be of a quality and/or depth such that the markings cannot be readily tampered with or removed.*
>
> *(3) Each box of ammunition shall be marked with*
>
> *(a) the same identification as on the headstamp marking referred to in paragraph 2;*

Box 1 **Complicating tracing: the practice of reloading fired cartridge cases**

The legitimate practice by some sporting shooters of reloading the case of a fired cartridge is widespread throughout the world. This practice is undertaken both to cut ammunition costs and to create (remanufacture) ammunition that, in some circumstances, is more accurate than factory-manufactured ammunition. This is particularly important in competitive sports-shooting events. The practice imposes serious limitations on effective tracing efforts, however, because if it can be done for sporting purposes, it offers a source of potentially untraceable rounds to less legitimate users.

The empty cartridge case has the fired primer removed from the case and a new primer fitted, before a charge of gunpowder is placed into the cartridge case. The final step is the fitting of a new projectile. All of these steps can be easily achieved by the use of reloading tools which are readily obtainable either from sporting retailers or via the Internet. Depending on the load used and the condition of the firearm's chamber and headspace, empty cartridge cases can be used several times.

The reloading (remanufacture) of empty cartridge cases brings to the discussion of the tracing of small arms ammunition a whole new level of complexity. A situation could arise where a cartridge case (or cases) that was individually marked to identify a lot number associated with a purchaser may eventually end up in the possession (either by way of surplus sale, by theft, or simply by picking it up in conflict areas) of an individual who will reload the cartridge case and use the cartridge for illegal purposes, resulting in a law enforcement investigation. Without any further evidence to the contrary, the investigation may assume that the original purchaser was responsible for the cartridge being found at a crime scene.

(b) the unique batch or lot number of the ammunition in the box.

(4) Each box of imported ammunition shall contain, in addition to the marking referred to in paragraph 3, information that identifies the country of import, the year of import and the importer (OAS CIFTA Technical Secretariat of Group of Experts, 2006).

The approval and implementation of such model legislation is an ongoing process, because provisions on different areas of firearms and ammunition control are discussed (and approved) separately.

The next section presents an in-depth analysis of the practical and logistical aspects of the ammunition market within the context of ammunition production.

Figure 3 **Three 12-gauge shotgun cartridge bases produced by Fiocchi Munizioni and supplied to three different assemblers**

Photo courtesy of Fiocchi Munizioni. © Giacomo Persi Paoli

3. Ammunition marking: current practices

Understanding the production and supply of ammunition[4]

To fully understand the challenges and opportunities related to ammunition-marking practices, it is important to start with an overview of the production and supply processes, the significance of which has often been overlooked or underestimated in analyses of the ammunition-marking issue.

Firstly, why do producers apply marks to ammunition? From a supplier perspective, marks on cartridges and on related packages should fulfil both an internal and an external purpose. The internal purpose is to ensure proper quality and safety control, as well as efficient record keeping, through the unequivocal identification by lot number of all ammunition produced. The external purpose, which will be discussed later in this *Issue Brief*, is to meet clients' demands, whether in terms of certain regional or national requirements, or specific requests on a case-by-case basis. All this has to be accomplished at the minimum possible expense to reduce production costs and increase market competitiveness.

Given these purposes, it is important to define the different types of actors that are commonly referred to as 'producers'. Grouping all actors under the general category of 'ammunition producers' would be a significant mistake. To fully describe the complexity of the ammunition-marking issue, it is necessary to illustrate the different categories of suppliers, as each will have its own practices and will face its own challenges when it comes to ammunition marking.

The first category of suppliers in the ammunition business is represented by what are known as 'full manufacturers'. Members of this group are equipped to produce in house all the necessary components for a complete cartridge: from the raw materials—cartridge case, primer, propellant, and projectile—to the assembly of the finished round of ammunition. In this case, the marking phase is conducted by the same firm and is integrated into the whole production process.

The second category includes the so-called 'assemblers'. These suppliers do not have the capacity to directly produce components, but buy them on the market and then assemble the rounds in house. In this case, while being theoretically possible, generally the marking phase is not conducted in house, but is contracted out to the company that produces and supplies the ammunition cases.

The third category includes the 'component manufacturers' that supply one or more individual components to assemblers. In addition to specialized firms, full manufacturers are often also component manufacturers, because they sell components in addition to complete rounds. The Italian firm Fiocchi Munizioni is an example of a full manufacturer also producing individual components for assemblers (see Figure 3). In this case, the marking phase is conducted by whoever is supplying the ammunition case. Luwero Industries of Nakasongola (Uganda) is an example of the second category. As Fiocchi Munizioni's practice indicates, the first category of suppliers are often also the third category of suppliers, with primer and propellant suppliers forming the remainder of the third category.

Without going into the technical details, the production process can be simplified by dividing the 'pre-delivery life' of ammunition into four phases:

1. production of the required components;
2. assembly;
3. testing;[5]
4. packing.

A full manufacturer will carry out the whole process, assemblers will start from the 'assembly' step, and compo-

nent manufacturers will focus on step 1. A fundamental aspect of the production process is the ability to ensure safety and quality control. For this reason, ammunition producers divide their production into lots or batches. In particular, the production of each component is divided into batches: the components of the same batch are produced under similar, if not the same, conditions using uniform elements and are expected to perform in the same way. A 'lot' of complete cartridges is assembled/produced using, ideally, subsets of the same batches of components. For instance, 100 complete cartridges of the same lot should contain 100 cartridge cases of the same batch, 100 propellants of the same batch, etc. The scrupulous record-keeping of all information regarding the production batches of all components and the lots of complete rounds allows producers to utilize internal traceability mechanisms designed to identify defective and/or potentially dangerous lots.

Thus, to ensure internal traceability, it is essential to avoid any circumstance that would run the risk of mixing ammunition belonging to different lots during the transition from one step of the production process to the next. In this respect, we should note that, while the ammunition industry is moving towards the greater automation of production lines, in many cases this transition still requires the involvement of specialized workers: each item of 'work-in-progress ammunition' that exits from a machine falls into large containers that are transferred to the next stage of the production process to serve as input for the next machine.[6]

What is marked?

The impact of ammunition marking on the whole ammunition market has often been overlooked. Unlike firearms marking at the time of manufacture, which can alter the final price per weapon by a small percentage of the total cost, ammunition marking can have a proportionally greater financial impact on projection costs. This can seriously affect a firm's competitiveness in terms of a procurement opportunity. Given the very intense competition in the ammunition industry, often involving orders of millions of rounds, a difference in price as low as USD 0.01 per round could severely limit a firm's competitiveness in the market (Jacobs, 2011), where procurement contracts are often awarded through competitive bidding.

Thus, the content of the marks applied by ammunition producers to cases or packaging follows a very simple principle: producers mark only what clients ask and pay for. This implies that ammunition manufacturers by default do not mark anything that is not either included in the standards or specifically requested and paid for by clients. Consequently, from a content point of view, marking practices vary greatly, because, in the absence of globally accepted standards, demand varies. Figure 4 illustrates just a few examples of different case marks to highlight the many variations that can be found on the market.

Although there are many variations in case marking, in general the marks allow the manufacturer to be identified, either through its initials or through factory codes typically used in countries from the former Eastern bloc[7] (refer to Box 2), plus additional information depending on the intended end user. In the case of military production destined for NATO use, this additional information generally includes the year of production and the NATO design mark if the round is a NATO calibre. In the case of non-NATO calibres, e.g. the 5.7 x 28 mm round, or simply ammunition not produced for NATO use, some manufacturers replace the NATO design mark with a mark identifying the calibre. For civilian ammunition, by contrast, the information is usually limited to the manufacturer's ID, and the identification and description of the calibre.

Even in the field of packaging marking, practices vary significantly. In general, given the minimum standards that are required by the relevant regulation processes, manufacturers tend to give clients the opportunity to add personalized information to the packaging. This may include the addition of national stock numbers or codes to facilitate inclusion on national registers or, more and more often, the addition of bar code stickers to allow quicker electronic registration in national databases. Figure 5 shows an

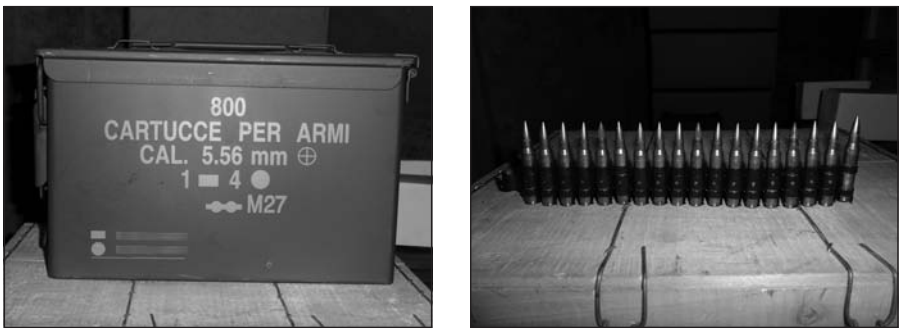
Figure 4 **Examples of case marking**

Left: a case for a .308 Winchester cartridge with (above) and without (below) the primer. As described in section 3, the same machine in a single mechanical action impresses the marks and creates the space where the primer will be installed at a later stage of the production process.

Right: 6.35 mm cases (above) with primers; an example (below) of a case marked according to NATO standards: NATO symbol, producer's ID, and year of production.

Photo courtesy of Fiocchi Munizioni. © Giacomo Persi Paoli

Figure 5 **A military ammunition box and its corresponding cartridges**



Note: In this specific case, the box contains 5.56 mm NATO cartridges, linked, with one tracer cartridge for every four ball cartridges.

Photo: © Giacomo Persi Paoli

Box 2 Symbols, non-Western letters, and numeric codes: when interpreting marks becomes complicated

In the absence of internationally accepted standards and/or regulations, marking practices for ammunition follow regional or national rules and legislation. In this context, the interpretation of marks appearing on ammunition is not always obvious. One potential complication is caused by ammunition featuring marks applied using alphabets that can be difficult to interpret and understand outside of the country or region where that alphabet is in use (see Figure 6). Nevertheless, this complication can be resolved with the use of interpreters or with the cooperation of countries belonging to the region where the specific language is in use.

A more challenging complication is posed by ammunition featuring only numeric digits. In the former Soviet Union and the current Russian Federation, as well as in other Eastern bloc and ex-Eastern bloc countries, manufacturers' IDs are represented with the use of numeric factory codes. The list of factories and related codes is public, but there are some circumstances in which even identifying which numbers represent the producer is difficult. For example, South Africa adopted a marking system that at first glance seems to include factory codes. In fact, this is not the case, because South African ammunition marked following this scheme does not bear any producer's ID at all: what is visible on the round is the date and an abbreviated form of the cartridge name/type that could be misread as an Eastern bloc or ex-Eastern bloc factory code. For example, a South African 5.56 mm round, model R1M3, produced in 1985 would feature on the cartridge simply '85' and '13'. In this case, the number '13' could be misinterpreted as the factory code corresponding to Cuba in the (ex-)Eastern bloc marking system. The difference is in the relative position of marks that each marking system implements. While this would certainly be known to ammunition experts, such a difference may not be particularly evident for the person that finds the empty cartridge case in the first place and has to fill in the report. An erroneous identification may jeopardize the success of any further tracing effort.

Source: Ness and Williams (2011a)

Figure 6 Photograph of 7.62 x 51 calibre ammunition taken in Sudan with Arabic markings. Photo: © James Bevan, 2007

example of a military ammunition box and its corresponding cartridges.

How information is marked

While the content of the marks is diverse, the most commonly used method of applying the marks appears to be reasonably standard: stamping. In particular, this involves press stamping for marks applied on the rim of cases and roll stamping for marks applied on the sides of cases. Recently, producers have started using laser marking techniques to mark ammunition. A more detailed discussion on the benefits and limitations of this innovation will be discussed in section 4, below.

Recalling an earlier Small Arms Survey *Issue Brief* on firearms marking (Persi Paoli, 2010), stamping is a marking method that applies marks through the deformation of the material on which they are applied. In the case of press marking, this deformation happens as the result of either an impact or a compression. Roll marking is a recommended solution if tonnage requirements make a press too costly and fragile parts run the risk of being damaged by heavy stamping pressure. Data imprinted as a stamp is literally 'rolled' across the surface to be marked. The rolling process involves a single contact point between the stamp head and the part being marked. Each character in a string is individually marked as the die rolls over the part.

Marks are traditionally applied in the early steps of the production process, before the case is charged with the primer and other components. Depending on the calibre, the marks are applied by a dedicated machine or by a machine that combines different effects in the same mechanical action. This second option is illustrated in Figure 7: the case enters the machine as it appears on the right of the photo and exits with the marks and the lodging for the primer, as on the left. Recent technological innovation in the field of marking allows marks to be placed at the end of the production process, prior to the packaging phase, with the use of laser machines (see section 4).

As mentioned above, upon request and for certain calibres only, manufacturers can add marks along the side of the case using the roll-marking technique. In addition, in the case of shotgun cartridges, clients may ask to have customized information applied on the plastic part of the shell. This information, added with ink stamps, can include information on the seller, symbols, drawing, etc. Figure 8 illustrates two examples of these specific 'on demand' marks.

From a cost perspective, because marking is fully included in the production process, it is difficult to distinguish the marking cost from the total price per cartridge. Nevertheless, in qualitative terms, we can identify two ways in which marking impacts the total price: direct costs and indirect costs.

Direct costs include the costs of the marking machines and their maintenance, as well as the costs of producing and replacing the headstamps used to apply the marks. Indirect costs reflect the impact of the marking phase on the whole production process, particularly in terms of time (e.g. how long it takes to mark a certain number of cartridges, how long it takes to fabricate a headstamp die—i.e. the stamping instru-

Figure 7 **Stamping using combined action machines**

Note: In this process, stamping is added together with the primer lodging. In this particular example, it is possible to note that this case has been marked in accordance with NATO standards and features an additional mark indicating the lot number.

Photo courtesy of Fiocchi Munizioni. © Giacomo Persi Paoli

Figure 8 **Side marks and ink marks**

Source: Fiocchi Munizioni. Photo: © Giacomo Persi Paoli

Figure 9 **Ammunition packaging: a military wooden box (above) and a civilian cardboard box (below)**

Photo courtesy of Fiocchi Munizioni. © Giacomo Persi Paoli

ment—used to apply personalized marks, and how long the application of personalized marks delays the whole production process).

Regarding packaging, military ammunition usually travels in metal or wooden boxes, while civilian ammunition is contained in cardboard boxes. Marks are ink stamped or sprayed on metal and wood, while information intended for cardboard boxes is printed on stickers that are then applied to the boxes. As mentioned above, more and more frequently both military and civilian ammunition boxes also include a bar code. In the case of civilian ammunition, the bar code is included in the information printed on the stickers. In a similar vein, wooden or metal boxes carrying military ammunition feature a dedicated sticker that includes the bar code and, where relevant, other information for the internal purposes of the military in question. Figure 9 shows examples of military and civilian packaging featuring the described marks.

Thus, marking practices on packaging can be summarized as follows:

- Military ammunition:
  - ✓ outer packaging: wooden crates featuring ink-stamped/painted/stamped/sprayed marks and stickers;
  - ✓ intermediate packaging: metal tins featuring ink-stamped/painted/stamped/sprayed or metal-stamped marks and stickers;
  - ✓ inner packaging: cardboard boxes featuring ink stamping and sometimes stickers.
- Civilian ammunition:
  - ✓ outer packaging: cardboard boxes featuring printed and/or ink-stamped marks and stickers;
  - ✓ inner packaging: cardboard boxes featuring printed and/or ink-stamped marks.

The issue of lot numbers and the limitations of current practices

The obligation to include lot numbers on individual cartridges has been a key point of discussion in the context of the international debate regarding ammunition control and management. The debate is split between those who support and those who do not support such a measure. While supporting neither of these two positions, this section analyses both the advantages and the challenges related to lot number marking.

As mentioned earlier in this issue brief, an obligation to mark the lot number on each complete round of ammunition is not included in any international standard or regulation. Thus, ammunition manufacturers will not apply a lot number to each round unless specifically requested to do so and if it is paid for by clients. From a merely technical perspective, lot numbers are no different from any other personalized mark that clients may request when negotiating a contract. An example of a cartridge featuring a lot number is shown in Figure 7.

As mentioned earlier, the proponents of the various sides of the debate argue, on the one hand, that such additional information would facilitate the tracing of illegal ammunition, while others are concerned about possible increased production costs, increased state accountability, and the real benefit that such a measure would bring to actual tracing practices. It is therefore important to explore the circumstances in which ammunition lot marking could in fact facilitate ammunition tracing.

As described in section 3, ammunition producers divide ammunition into lots as a means of improving internal traceability, in particular in terms of safety and quality control. Lot numbers appear on all ammunition packaging, from the smallest (inner packaging) to the largest (outer packaging). Thus, from a producer's perspective, which assumes that single rounds leave their boxes only when they are used, marking the lot number on each round would only increase costs without resulting in any specific benefits. From a consumer's perspective, all the information required for proper record-keeping and storage is included and easily identifiable on the boxes: ammunition type, calibre, lot numbers, date of manufacture, name

Figure 10 **Ammunition that has been separated from its packaging**

Note: This photo illustrates a very common situation in many developing countries and during time of war. Once ammunition has been separated from its packing, to date there is little or no possibility of unequivocally tracing it back to its original owner/user. To avoid this situation, in theory, all ammunition that has been issued and separated from its packing should be reclassified in terms of its use (e.g. training) or destroyed. Nevertheless, in practice, this is rarely the case, because often in conflict areas ammunition is kept loaded in magazines or simply because in some countries there is a lack of stockpile management capacity.

Photo: © James Bevan

of producer, etc. This is the general theory and can be the case for developed and industrialized countries with efficient record-keeping and storage practices.

However, once a round leaves its packaging, there is no possibility of linking it to the corresponding production lot. Without the ability to do so, it becomes impossible, for instance, to identify ammunition that forms part of defective lots and remove it from service. Additionally, once the link between a round and its production lot is lost, the chances of successful tracing decrease significantly. This is a particularly sensitive issue in conflict zones and in developing countries, as well as in the field of organized crime. Nevertheless, lot numbers on ammunition cases would facilitate tracing only if the manufacturer's ID and the year of production were marked as well, assuming that the system of 'one lot, one client', described below, was implemented and that there was no further resale or redistribution after the first delivery.

Given the above context, various practical issues related to the application of lot numbers to individual cartridges should be mentioned.

Firstly, if tracing is the objective of marking, then each lot number should be linked to one client. Without the link of one lot to one client on each individual round, it is not possible to unequivocally identify the last legitimate possessor of a round of ammunition.

Current lot allocation practices vary widely from producer to producer. For example, one lot of ammunition can contain up to 500,000 complete rounds. To minimize costs, some ammunition suppliers use the same lot to cover different orders until they reach the necessary quantity, and then start the production of a new lot.[8]

Secondly, even if a producer were applying the 'one lot, one client' system, marking the lot number on each round using current standard practices would alter the production process and increase costs. As previously discussed, this would in turn impact on the final price through direct and indirect costs. Direct costs related to lot marking for full manufacturers and brass case producers would include the cost of producing specific headstamps featuring lot numbers and related spare parts. Instead, direct costs for ammunition assemblers would reflect the difference in price between buying many small lots, each one marked with the specific lot for a specific client, or bigger pre-marked quantities divided into fewer lots covering, for example, the estimated production for the whole year.

Indirect costs resulting from the marking of the lot number on each individual cartridge would reflect the longer production time. The machine that impresses the marking would have to be stopped every time there was a need to change the headstamp to apply a new lot number in order to start the production of a new contract. In addition, the whole production process would be delayed to ensure the complete separation of different lots. This would result in a longer production time and would consequently increase costs.

It is important to note that both direct and indirect costs refer to the currently most widespread marking method, stamping. With the introduction of alternative technologies like laser marking, some of these limitations could be overcome (see section 4).

In conclusion, the rationale behind the requirement to include the lot number on each round is clear and potentially very useful for tracing purposes. Nevertheless, while technically feasible, various practical aspects of ammunition lot marking need to be considered when analysing both the real effectiveness and the applicability of such a measure, given current practices and most frequently used marking techniques. In addition, it is essential to understand that it would be unrealistic to expect to be able to identify the source of diversion of illegal ammunition or to be able to unequivocally trace ammunition using only the information included in the marks. Such information provides an important lead, but needs to be contextualized and supported by other evidence such as, for example, documented transfers of ammunition to the country of interest or to its neighbours, the presence of foreign troops, documented theft from national or private stocks, etc.

In this context, considering that not all ammunition producers use the 'one lot, one client' system, even if the ammunition case were marked with the lot number, it would not identify a unique entry in the producer's records. In addition, even when the producer uses the 'one lot, one client' system, often both military/government and civilian ammunition lots are split up for resale or retransfer after their initial acquisition. Thus, while lot numbers can certainly help, they are not the turn-key solution to the ammunition-tracing problem. A realistic contribution that ammunition marking could bring to an investigation would be to provide a 'shortlist' of possible sources of diversion.

4. Emerging technologies

Some of the limitations described above could be overcome with the use of technologies whose application in the field of weapons and ammunition production is relatively recent. In particular, this *Issue Brief* describes three solutions, one for cartridge marking and two for packaging marking. These solutions, while not addressing the problems related to ammunition dissociated from its packaging, have the potential to significantly improve the traceability of ammunition and, more generally, the whole ammunition control process.

Laser marking of ammunition

The application of laser technology to firearms marking is presented in Persi Paoli (2010). Whether on firearms or on ammunition, the operating principle of this technology is the same: laser engraving is based on a focused laser beam that removes material (by burning it out) from the component without requiring physical contact.

In the field of ammunition, the innovation does not reside in the marking method per se, but in the possibilities that using this method opens up. In particular, while traditional marking practices with stamping methods force the application of marks at the early stages of the production process, before the cartridge/case is assembled with the remaining components, laser methods allow marks to be applied after the assembly is complete, just before ammunition is packaged and delivered to the customer (Martinot and Berkol, 2008).

Laser usage should not be seen as a replacement for stamping methods, but more as complementary technology. In fact, basic information such as the manufacturer's ID, the year of production, and/or any other information that remain the same for every lot could still be marked using traditional stamping methods without requiring firms to update and change their machinery. A laser head could be used just before the fully assembled rounds are packed to add specific information such as, for example, the lot number or even information about the purchaser.

The ability of laser to mark very small areas makes it possible to add the marks in the extractor groove on the cartridge, a very solid area where marks can be applied that are deep enough to prevent erasure (Martinot and Berkol, 2008).

The use of this technology was pioneered by the Brazilian arms manufacturer Companhia Brasileira de Cartuchos (CBC) in response to a new national law that called for all ammunition sold commercially in Brazil to include an identifier for the production lot and the purchaser on the casing of the cartridge. These new laser marking machines can mark 240 cartridges per minute: cartridges proceed along the production line in lots of ten, which are marked simultaneously (Martinot and Berkol, 2008).

The use of RFID technology on ammunition packaging[9]

Radio frequency identification (RFID) technology transfers data from a passive[10] tag or chip to a reader using radio waves for the purpose of identification and tracking. Compared to bar codes, which are more and more often applied as additional information on ammunition packaging and have to be visible to the reader in order to be read, passive RFID tags can be read even inside a case, carton, box, or other container, and from a distance of up to several metres. In addition, unlike bar codes, hundreds of RFID tags can be read at a time.

RFID technology requires only one or more readers, tags, or chips to be installed on the items to be monitored, and dedicated software to manage the data. Thus, it requires only minor changes to existing infrastructures.

This technology is reliable and tested—it has been used for several years in commercial applications such as inventory control, department store theft prevention, highway toll stations, and passports. Nevertheless, its application in the field of arms control is relatively recent and has also been pioneered by Brazil, followed by other Latin American countries. From an arms control perspective, the use of RFID microchips secured against improper use or unauthorized removal would allow authorized personnel to access in real time all the information recorded for a weapon such as its serial number, user ID, ownership, invoice, delivery and inventory history, etc. In other words, each weapon would carry its own 'digital history' that delivers accurate information and reduces the risk of human error.

In the specific field of ammunition, adding a microchip or a tag to each ammunition box would result in many advantages. For example, each box would be identifiable with information like the lot number, ammunition description, buyer's name, transfer authorization (if applicable), product code, etc. In addition, with the possibility of immediately linking a specific box to a specific user, such a solution would reduce opportunistic behaviour, corruption, and theft by making each person or organization involved accountable for the use, loss, or redistribution of the ammunition.

The use of chip strips technology on ammunition packaging

Finally, the latest innovation in this field is represented by the use of RFID technology in chip strips. This solution would be particularly suited to transfer monitoring. Each strip would have a unique electronic identity and would be attached to the ammunition boxes. The advantages of these strips are twofold. Firstly, they could be used to secure ammunition boxes inside a depot: cutting or removing the strip would send a signal to the hardware infrastructure and activate an alarm. Secondly, this technology would be very useful in monitoring the transfer of ammunition: given the capacity to scan ammunition boxes in a truck and given the fact that scanners feature GPS, the location and time of departure could be recorded, as well as the arrival at an intermediate or final destination. This method would make it possible to record data indicating the quantity transferred, the location and time of departure of the consignment, the quantity that arrived, the location and time of arrival, and the time taken to make the transfer (to immediately identify suspect or unjustified stops).

5. Findings

The absence of international standards regulating ammunition marking results in a wide range of different practices among ammunition producers and their clients. For a number of military calibres, the lack of a single international standard is overcome by the presence of well-established and precise NATO standards. In terms of civilian ammunition, several regional regulations exist, e.g. CIP regulations, that set minimum requirements for information to be marked on ammunition cases and packages.

This *Issue Brief* has explored the issue of ammunition marking from various angles: market actors, regulations, current practices, and future opportunities. Given that the international community is split between those in favour and those not in favour of creating global ammunition control and management measures, and that both sides of the debate are able to bring strong arguments to the table, what kind of principles should drive the debate on global ammunition-marking regulations? Should regulations target the supply or the demand side? For example, should such regulations call for producers to mark ammunition with the respective lot number or for governments to require that all ammunition bought be marked with the respective lot number?

The response to the first possible requirement ('producers to mark ammunition with the respective lot number') can be seen in terms of feasibility (or applicability) and acceptability. The issue of feasibility should not be limited to technical requirements, but should also include considerations of the impact that such regulations would have on the whole production process, as described in section 3. In addition, to be acceptable—and consequently to encourage/guarantee implementation—new regulations would need to provide producers with incentives to comply by giving them a stronger position in the market than those who decide not to comply with such regulations. This reflects the fact that altering the production process, e.g. by marking lot numbers, will result in higher production costs and, consequently, higher prices. Conversely, those producers that do not mark lot numbers would be able to charge lower prices and, consequently, attract more clients. Regulations are required to prevent these less scrupulous producers from benefitting from not complying.

This consideration suggests the following answer to the second possible requirement ('governments to require that all ammunition bought be marked with the respective lot number'): bearing in mind that ammunition producers will only do what they are required to do, effective regulations should aim at harmonizing countries' requests in terms of marking (the demand side) by promoting the harmonization of national legislation on ammunition control or the development of internationally accepted and implemented standards in order to persuade producers to comply with such a regulation.

Regulating the supply side of the market will not be as effective. In the absence of an obligation to mark certain information, countries might not request that additional marks be applied. This would create a significant share of the ammunition market for which companies not complying with the regulations would have an advantage by being able to charge a lower price, as described above, compared to those who comply.

Finally, given that the lack of international standards led to the development of regional standards that are now well rooted and accepted in both the supply and demand sides of the market, the success of any future international effort to standardize ammunition marking and packaging relies on harmonization with such regional standards.

Thanks to the recent application of modern technologies to the field of ammunition and arms control, much could be done to improve current practices with a view to improving ammunition traceability. Nevertheless, a universal goal cannot be achieved without an international regulatory framework that is globally accepted; obtained through multilateral negotiations involving all stakeholders, including the ammunition industry, NATO, and representatives from civilian regional organizations; and aimed at the harmonization of requirements from the demand side. ■

Endnotes

1 For the purpose of this study, unless otherwise specified, the expression 'ammunition marking' refers to marking on both individual complete cartridges and their packaging.

2 These definitions are based on the 'Glossary of Industry Terms' drafted by the Sporting Arms and Ammunition Manufacturers' Institute (SAAMI, 2009).

3 CIP member states are mainly, but not limited to, European, including Austria, Belgium, Chile, the Czech Republic, Finland, France, Germany, Hungary, Italy, the Russian Federation, Slovakia, Spain, the United Arab Emirates, and the United Kingdom.

4 This section is based on private consultations between the author and representatives from several ammunition industries. These consultations were complemented with a visit to the production site of the Italian manufacturer Fiocchi Munizioni.

5 It is likely that each individual component is tested, but for the purposes of this study we consider only the testing of a complete round.

6 Information from author's interview with a European ammunition manufacturer and on-site visits, April/May 2011.

7 Numerical codes that denote a particular manufacturer (or factory) are common to most manufacturers that have their origins in the Soviet system of ammunition marking. This includes, in historical order: the Russian Federation and former Soviet republics, Warsaw Pact states, China, Chinese clients, and states that have acquired production technology from the aforementioned.

8 Author interviews with various ammunition manufacturers, April/May 2011.

9 This section is based on a private interview between the author and a representative from the company Aid Technology, which supplies several RFID solutions for arms control. Information was also drawn from the company's promotional brochures and PowerPoint presentations.

10 'Passive' means that tags do not require any form of energy supply to function; e.g. no battery is needed.

Bibliography

Arvidsson, Per G. 2008. 'NATO Infantry Weapons Standardization.' Presentation by the NATO Army Armaments Group at the International Infantry and Joint Services Small Arms Systems Symposium, Exhibition and Firing Demonstration. Dallas, Texas, 19–22 May. <http://www.dtic.mil/ndia/2008Intl/Arvidsson.pdf>

Bevan, James, ed. 2008. *Conventional Ammunition in Surplus: A Reference Guide*. Geneva: Small Arms Survey.

Brazilian MoD (Ministry of Defence). 2011. 'Tracing of Weapons and Ammunition in Brazil.' Presentation at the Meeting of Governmental Experts of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons and All Its Aspects. New York, 9–13 May.

CIP (Permanent International Commission for Firearms Testing). 1991. 'Marking Firearms' and Council Directive 91/477/EEC of 18 June. <http://www.europarl.europa.eu/hearings/20061004/imco/genco_en.pdf>

Dreyfus, Pablo. 2008. 'Conventional Ammunition Marking.' In James Bevan, ed. *Conventional Ammunition in Surplus: A Reference Guide*. Geneva: Small Arms Survey, pp. 31–41.

Italy. 1993. Norme per il controllo sulle munizioni commerciali per uso civile. Law No. 509. 6 December. <http://www.tsncascina.it/leggi/9.pdf>

Jacobs, Thierry. 2011. Presentation on behalf of FN-Herstal at the Meeting of Governmental Experts of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons and All Its Aspects. New York, 9–13 May.

Ness, Leland S. and Anthony G. Williams. 2011a. *Ammunition Handbook 2010–2011*. Coulsdon: Jane's Information Group.

King, Colin. 2011b. *Explosive Ordnance Disposal 2010–2011*. Coulsdon: Jane's Information Group.

Martinot, Pierre and Ilhan Berkol. 2008. *The Traceability of Ammunition*. Brussels: Groupe de Recherche et d'Information sur la Paix et la Sécurité (GRIP).

NATO (North Atlantic Treaty Organization). 2008. *Allied Ordnance Publication (AOP) – 2(c): The Identification of Ammunition*.

NATO MAS (Military Agency for Standardization). 1976. *Standardization Agreement No. 2310, 'Small Arms Ammunition (7,62mm)'*. 3rd edition.

—. 1993. *Standardization Agreement No. 4172, 'Small Arms Ammunition (5,56mm)'*.

OAS (Organization of American States) CIFTA (Inter-American Convention Against the Illicit Manufacturing of and Trafficking in Firearms, Ammunition, Explosives and Other Related Materials) Technical Secretariat of Group of Experts. 2006. Draft Proposed Model Legislation on the Marking and Tracing of Firearms and Ammunition. Washington, DC: OAS.

OSCE (Organization for Security and Cooperation in Europe). 2007. *Best Practice Guide on Ammunition Marking, Registration and Record-Keeping*. <http://www.osce.org/fsc/33383>

Persi Paoli, Giacomo. 2010. *The Method behind the Mark: A Review of Firearm Marking Technologies*. Issue Brief No. 1. Geneva: Small Arms Survey.

SAAMI (Sporting Arms and Ammunition Manufacturers' Institute). 2009. 'Glossary of Industry Terms.' Accessed July 2011. <http://www.saami.org/glossary/index.cfm>

UNGA (United Nations General Assembly). 2008. *Report of the Group of Governmental Experts Established Pursuant to General Assembly Resolution 61/72 to Consider Further Steps to Enhance Cooperation with Regard to the Issue of Conventional Ammunition Stockpiles in Surplus*. A/63/182 of 28 July. <http://www.poa-iss.org/DocsUpcomingEvents/a-63-182-e.pdf>

US DoD (United States Department of Defense). 1998. *Ammunition Lot Numbering and Ammunition Data Card*. MIL-STD-1168B. http://www.jmc.army.mil/DCG/Quality/mil1168b.rtf

About the Small Arms Survey

The Small Arms Survey serves as the principal international source of public information on all aspects of small arms and armed violence, and as a resource centre for governments, policy-makers, researchers, and activists. In addition to Issue Briefs, the Survey distributes its findings through Research Notes, Issue Briefs, Occasional Papers, Special Reports, a Book Series, and its annual flagship publication, the *Small Arms Survey*.

The project has an international staff with expertise in security studies, political science, international public policy, law, economics, development studies, conflict resolution, sociology, and criminology, and works closely with a worldwide network of researchers and partners.

The Small Arms Survey is a project of the Graduate Institute of International and Development Studies, Geneva. For more information, please visit: www.smallarmssurvey.org.

This *Issue Brief* has been made possible through the support of Germany's Federal Foreign Office.

Author:
Giacomo Persi Paoli

Copy-editor:
Alex Potter

Proofreader:
Donald Strachan

Design and layout:
Richard Jones (rick@studioexile.com)

Small Arms Survey
47 Avenue Blanc
1202 Geneva
Switzerland

t +41 22 908 5777
f +41 22 732 2738