

Warheads are transported to be detonated in controlled explosions in a dedicated facility
800 m below ground, Lökken Verk, Norway, 2012. © Nammo Demil Division



Burning the Bullet

INDUSTRIAL DEMILITARIZATION OF AMMUNITION

INTRODUCTION

States procure more conventional¹ ammunition than they use. To avoid depot congestion with obsolete ammunition and to reduce storage costs, they dispose of part of their stockpiles via foreign military sales and increase the use of ammunition for training purposes.² Despite these disposal initiatives, a large part of a nation's surplus ammunition stockpile will ultimately require *demilitarization*—a process by which ammunition is safely dismantled or destroyed while, ideally, its valuable materials are recovered.

In many countries, excess stockpiles of obsolete or unserviceable munitions have reached a level requiring demilitarization on an industrial scale, often in a race against time as the ammunition tends to become unsafe with age. Since states rarely have the capacity to demilitarize the surplus ammunition stockpiles of their collective security forces, they often turn to the demilitarization industry.

Policy-makers and programmers tend to be poorly informed about the demilitarization industry's markets, challenges, and techniques, for several reasons. Data pertaining to ammunition demilitarization is just as sensitive as ammunition design and procurement information. Hence, policy-relevant information is rarely distributed publicly and resides predominantly within individual ministries of defence (MoDs), their contractors, and some international bodies such as NATO ammunition working groups. Furthermore, contractors fear that discussing their activities and capacities publicly may put them at a commercial disadvantage. Finally, academia has not traditionally covered this activity.

Yet this chapter shows that US and Western European contractors routinely process significant amounts of conventional ammunition, much of which is foreign. They design, manufacture, market, and operate complex technologies that are simply outside the traditional prerogatives of most MoDs. They are also prime actors, stakeholders, and potential facilitators of international donor-funded arms control and ammunition demilitarization programmes.

This chapter provides an introductory snapshot of the world's major industrial demilitarization contractors by examining their activities, technologies, markets, and challenges. It relies on the results of industry questionnaires³ sent out in early 2012, unclassified and declassified NATO documents, and interviews with key demilitarization stakeholders in the industry, governments, and international organizations. The chapter focuses on Western and Central Europe as well as on the United States and Canada, which account for the vast majority of industrial demilitarization activity worldwide.

Among the chapter's key findings are the following:

- The demilitarization industry is currently centred in Western Europe and the United States.
- The industry operates under standard competitive tendering rules.
- While the technology exists to destroy the vast majority of ammunition types, it may not be available in the time-frame required and is generally lacking in countries that need it most.

- Aside from the United States, where a few contractors struggle to reduce the massive conventional ammunition stockpile, many NATO nations' industrial facilities have underutilized demilitarization capacity.
- Cluster munitions, especially multiple-launch rocket system (MLRS) rockets, still account for a significant part of the demilitarization activity in the United States and Western Europe.
- Most nations' ammunition destruction regimes involve a combination of both open burning and open detonation (OB/OD) as well as industrial demilitarization methods.
- The costs involved in transporting and demilitarizing large quantities of ammunition can be significant and are a heavy burden on an MoD's budget.
- There is currently no common international or European standard, legislation, or compliance mechanism that specifically addresses ammunition demilitarization by commercial contractors.
- MoDs are not automatically involved in the commercial ammunition demilitarization sector's activities, unless munitions from their national armed forces are concerned.
- In countries where industrial demilitarization is less developed and contractors do not meet prevailing safety standards, the potential for accidents is much higher during industrial processes.

A limited number of capable companies occupy the international market. This chapter begins by describing the industry's actors and the markets in which they compete, as well as opportunities that are likely to emerge in the foreseeable future. The section that follows identifies the industry's activities, its core industry processes, and its general capabilities and capacities. The third section details the industry's complex regulatory and compliance regime as well as its logistical and safety constraints. The final section highlights the ongoing debate on environmental considerations versus cost-effectiveness, discussing the advantages and drawbacks of OB/OD as well as the relevance of recover, recycle, and reuse (R3) policies.

INDUSTRY ACTORS AND MARKETS

Industry actors

The demilitarization industry's main contractors are currently based in Western Europe and the United States. In Europe, the end of the cold war triggered dramatic reductions in force levels, a build-up of surplus ammunition stockpiles, and advances in demilitarization. Most notably, the new government of the reunified Germany inherited a significant stockpile of ammunition from the East German National People's Army (Nationale Volksarmee), leading German firms to develop industrial-scale demilitarization processes to reduce it (RTO, 2010, pp. 3-22, 3-23). More recently, the Convention on Cluster Munitions (CCM) spurred the development of new processing and disassembly equipment. In the United States, research and development of industrial demilitarization capacity developed mainly in response to increasing environmental restrictions, the will to reduce reliance on OB/OD, and the federal government's push for enhanced waste prevention and recycling (MSIAC, 2006, p. 2).

A limited number of capable companies occupy the international market. Broadly speaking, the US and European demilitarization industry consists of a core group of approximately 30 major contractors that compete against, but also contract and sub-contract, each other. Table 9.1 lists a selection of European and US demilitarization companies' headquarters and processing plants that appeared regularly during the author's research as (i) international contractors with proven operational capability, (ii) equipment manufacturers, (iii) tender applicants, or (iv) potential regional demilitarization service providers.

Table 9.1 Major European and US demilitarization companies, processing plants, and/or equipment providers

Country	Company	Location
Albania	ULP Mjekes	State-owned enterprise near Elbasan*
Bulgaria	EXPAL Bulgaria JSC	Gabrovo*
France	Alsetex	Précigné
	MBDA	Bourges
Germany	EST Energetics GmbH	Steinbach
	Nammo Buck GmbH	Pinnow (near Berlin)
	SAB (Sonderanlagenbau) Nord GmbH	Elmshorn
	sonUtec GmbH	Sonneberg
	Spreewerk Lübben GmbH	Lübben
Greece	Soukos Robots S.A.	Larissa
Israel	Red Wings Ltd.	Rehovot
Italy	Esploidenti Sabino Srl	Processing plant in Casalbordino (Chieti)
Norway	Nammo NAD	Løkken Verk
Poland	JAKUSZ SZ Bogdan Jakusz	Kościerzyna
	Mesko SA	Skarzysko-Kamienna
Serbia	TRZ Kragujevac	Kragujevac*
Slovakia	KONSTRUKTA-Industry	Trencin
Spain	EXPAL	Madrid
Sweden	Dynasafe Demil Systems AB	Karlskoga
	Nammo Vingåkersverken	Vingåker
Turkey	AKANA Engineering and Trade Ltd.	Ankara
	MKE (Pirinç Fabrikası)	Kırıkkale
	ROKETSAN	Ankara
United Kingdom	EOD Solutions Ltd.	Rayleigh, Essex
	QinetiQ	Shoeburyness, Essex
United States	DynCorp International	Falls Church, Virginia
	El Dorado Engineering, Inc.	Salt Lake City, Utah
	General Atomics	San Diego, California
	Gradient Technology	Elk River, Minnesota
	General Dynamics Ordnance and Tactical Systems	Saint Petersburg, Florida
	U.S. Demil, LLC	Buffalo, New York
	UXB International, Inc.	Blacksburg, Virginia

Note: * See Gabinet (2012).

There is a clear link between ammunition production and demilitarization activities. Industrial demilitarization providers are often former or active ammunition producers. Nammo Buck GmbH in Germany was an ammunition factory before reunification, and has been involved in demilitarization since 1991 (Nammo, 2012, p. 2). The Spanish company EXPAL, which comprises a demilitarization division, is a subsidiary of the MAXAM group, founded by Alfred Nobel in 1872. The group develops, manufactures, and sells explosives, chemicals, and ammunition for the international civilian and defence industries. MKE, a leading company in the Turkish defence industry and supplier of the Turkish Armed Forces, also dedicates one of its 11 factories to demilitarization, reuse, and recycling processes (NIAG, 2010, p. 73). For companies that still actively produce ammunition, demilitarization seems to represent only a small part of gross income. For example, Nammo's demilitarization activity represents less than 10 per cent of the group's total turnover (Nammo, 2012, p. 2). While major demilitarization providers also manufacture their own machinery, some companies, such as Spreewerk Lübben GmbH,⁴ Dynasafe Demil Systems AB, Sonderanlagenbau Nord GmbH, and El Dorado Engineering, mainly focus on manufacturing and marketing demilitarization equipment. They then sell or lease 'turnkey' equipment to other client companies, MoDs, and international outfits that carry out the actual demilitarization contracts.

Industrial demilitarization providers are often former or active ammunition producers. Industrial demilitarization contractors operate under private, government, or mixed ownership. In Eastern and South-east Europe, the companies are often fully or partially state-owned and MoD-operated. Nevertheless, many are revenue-generating operations, which allows them to cover expenses (TRZK, 2012). In Western Europe and the United States, some of the major industrial contractors are state-owned but operate as any private company in the business. For instance, the Nordic Ammunition Company (Nammo) is jointly owned by Norway's Ministry of Trade and Industry and by the Finnish security and aerospace group Patria Holding Oyj.⁵ In 2002 the group created a demilitarization division that now comprises three processing sites: Nammo Vingåkersverken in Sweden, Nammo NAD in Norway, and Nammo Buck GmbH in Germany (Perala, 2002). Other major contractors and equipment providers—such as General Atomics, Dynasafe Demil Systems AB, DynCorp International, El Dorado Engineering, Inc., and Sonderanlagenbau Nord GmbH—are privately held corporations.⁶

Public-private partnerships are common. In some countries, the MoD (and not the industry) undertakes much of the stockpile demilitarization tasks via 'organic'—that is, state-owned, MoD-operated—facilities (Van Baalen and Honey, 2011, pp. 10-11). The military continues to rely heavily on OB/OD. Commercial contractors, on the other hand, use automated industrial demilitarization and high production rates, with a focus on R3 (see below). In practice, cost and technical efficiency require that both processes be used; therefore, commercial contractors usually work in cooperation with organic facilities (Boyer, 2012, slide 14). Within the US Armed Forces, for instance, the US Army has been the only service manager for conventional ammunition since 1997. As such, the Army conducts the majority of the ammunition demilitarization and disposal for all military services, performing this work at army storage depots and manufacturing plants. Yet commercial contractors are frequently involved as well (RTO, 2010, p. 3-24).

Markets

Contracts and tenders

Industry contractors demilitarize all types of ammunition under normal competitive tendering rules. They seek to optimize their profits, invest in new demilitarization technology, and maintain their customer base. The extent of the 'competition' largely depends on the type and quantity of ammunition to be destroyed and on the number of companies that possess the technology and equipment required to destroy the spectrum of ammunition identified by the

tender, in accordance with the country's relevant regulations. The contracts usually cover receipt, storage, internal movement, demilitarization processes, the processing of by-products, such as explosives and metals, and the disposal of all scrap materials. They can also include transportation costs from military storage to civilian demilitarization locations.

National procurement and logistics agencies publish requests for proposals (RfPs). In Germany, for instance, the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support⁷ plays an important role in the tendering process. For public tenders in the European Union (EU), procurement rules⁸ set out specific threshold values for supplies and service contracts. Consequently, oversight of routine small-scale disposal remains at the national level. Contracts within the EU that exceed threshold values go to international tender (Nammo, 2012, p. 15). Many national authorities use regional organizations to issue RfPs for large disposal programmes. This procedure frames the tenders qualitatively by ensuring that contractors operate certified quality and environmental management systems or meet specific requirements, for instance with regard to the capability of the pollution control system associated with an incinerator.

Over time, this competition can also streamline demilitarization costs (see below) and encourage contractors to innovate where commercially viable. The NATO Support Agency (NSPA),⁹ for example, manages RfPs for the disposal of surplus ammunition holdings on behalf of NATO Ammunition Support Partnership and Partnership for Peace (PfP) countries,¹⁰ monitoring these contracts until completion. NSPA handles aspects such as preparing and auditing statements of work, issuing calls for tenders, reviewing tenders and awarding contracts, and submitting progress reports as well as certificates of destruction to the sponsor nation or customer (Towndrow, 2011b).¹¹

Some regional organizations coordinate RfPs for large disposal programmes.

Contracts are negotiated on a case-by-case basis but seem to follow certain regional patterns. In the United States, the contracts involve much larger quantities of ammunition than in Western Europe, yet there appears to be limited domestic commercial competition for high-tonnage stockpile items; large corporations form consortiums to bid on big, multi-year contracts, effectively precluding competition from smaller companies.¹² In European contracts, the smaller volumes of ammunition and much lower demand limit the amount of explosives that can be recycled and sold for civilian purposes, which also results in shorter contracts and fewer incentives to invest in specialized machinery. The European demilitarization market is more fragmented, yet consequently more competitive. One consultancy report confirms this view, recommending that the US demilitarization industry continue partnering with NSPA while seeking commercial demilitarization companies outside the contiguous United States to increase competition (Boyer, 2012, slide 11).

Ammunition demilitarization costs

Several factors have a direct impact on demilitarization costs. Open-source NSPA presentations provide a good estimate of the range of contract values, revealing that they vary largely according to ammunition types (Courtney-Green, 2007, pp. 3–4). To a significant degree, the nature and quantity of the ammunition determines the technology requirements for its demilitarization. Risk and costs increase when the demilitarization process necessitates extra handling, manipulation, and the use of multiple technologies. To achieve economies of scale, contractors prefer to spread expenditures over a large quantity of ammunition of the same type, which allows the plant to optimize the demilitarization process and reduce costs. The need to comply with different states' environmental and ammunition disposal legislation also creates variations in the cost of destruction (see below).

Pricing is a sensitive topic. Open-source literature gives generic pricing examples in gross tonnes ('all-up weight'),¹³ which includes packaging but not transportation (Courtney-Green, 2005, p. 22; Peugeot, 2009, p. 22). The UN Office for

Table 9.2 Indicative ammunition demilitarization costs, 2011

Ammunition type/component	Indicative costs (EUR/tonne)
Small arms ammunition* (<20 mm calibre)	101-529 (USD 132-691)
Fuses	237-1,039 (USD 310-1,357)
Propellants**	856 (USD 1,118)
Warheads (high-explosive)***	564-610 (USD 737-797)
Cannon and medium calibre (20-105 mm)	419-757 (USD 547-989)
Pyrotechnics	1,654 (USD 2,160)

Notes:

* Dependent on technique and economy of scale.

** Conversion to commercial explosives may lead to cost recovery.

*** Costs after removal and destruction of cartridge cases.

Source: UNODA (2011b)

overall cost. For this study, some contractors provided rough-order-of-magnitude demilitarization prices per item in US dollars. The price ranges for each ammunition family were extremely broad, always context-specific, and rarely generically representative of the marketplace. NATO has yet to develop a unit cost basis for specific munitions types processed through specific demilitarization processes (NIAG, 2010, p. 172), yet it is generally accepted that open competition is the most effective way to control pricing.

The costs of demilitarization may be increasing. In 2004, an ammunition consultancy firm estimated the average cost of ammunition demilitarization at a European facility at approximately USD 800–1,200 per tonne depending on the type of ammunition (UNDP and Threat Resolution Ltd., 2004, p. 5.3). In 2007 the US Army estimated the average demilitarization cost of all conventional ammunition at approximately USD 1,400 per ton (Gonzalez, 2010, p. 8). One year later, a French MoD report estimated that, for complex munitions, missiles, and torpedoes, demilitarization costs ranged from EUR 1,000 to 5,000 per tonne (USD 1,350–6,700) (France, 2008, p. 10); the US Army estimated the average demilitarization cost of conventional ammunition at approximately USD 1,800 per ton, with projections over USD 2,000 per ton for 2012 (Raftery, 2008; Gonzalez, 2010, p. 8). Recent estimates put the average cost of demilitarizing a tonne of ammunition in the United States and Western Europe at approximately USD 1,600 (RTO, 2010, p. 3-3).¹⁴

Demilitarization is reportedly less expensive in Eastern Europe, where several countries receive external funding for this activity. Recent Small Arms Survey research carried out in the framework of the Regional Approach to Stockpile Reduction (RASR) initiative shows that in such contexts additional factors influencing the demilitarization price include: (i) the economic level of the host nation, (ii) local capacity, (iii) the training levels of local staff, and (iv) donor priorities. Given these variables, it is difficult to make direct comparisons. Donor-funded demilitarization projects often include weapons and ammunition and are negotiated at an overall fixed cost, applicable to all ammunition types (Lazarevic, 2012, p. 24). In most cases, start-up costs per tonne are high; subsequent destruction is much less expensive as economies of scale take effect and national capacity is built (Wilkinson, 2006).

In 2011, for example, the Albanian facility ULP Mjebes estimated that processing more than 31,000 tonnes of various munitions cost the plant less than EUR 11 million (USD 14.5 million). This would imply an average cost of approximately EUR 350 (USD 460) per tonne (Sina, 2011). TRZ Kragujevac estimates its demilitarization costs on behalf of the

Disarmament Affairs' International Ammunition Technical Guidelines note indicative demilitarization costs for Western Europe (see Table 9.2).

Contract prices are usually expressed per item of ammunition and are confidential so as not to undermine contract negotiations or otherwise put a company at a competitive disadvantage. The unit price usually reflects a net price in which the cost of processing is offset by the cash return from the sale of valuable scrap metals and other materials. Prices often include transportation from military storage to the processing plant and can represent a significant proportion of the

Serbian MoD at EUR 780 (USD 1,000) per tonne, and claims that they will fall below EUR 500 (USD 650) per tonne following the upcoming installation of an explosive waste incinerator and new disassembly machines (TRZK, 2012).

Market opportunities

Industrial demilitarization contractors unanimously point to the United States as the largest market and argue that it will almost certainly remain so for the foreseeable future. The US demilitarization stockpile is not decreasing. In the year 2000 the US Department of Defense (DoD) had more than 500,000 short tons¹⁵ of excess, obsolete, and unserviceable munitions in its demilitarization stockpile (Hsu, Pruneda, and Kwak, 2000). In 2010 the US conventional ammunition demilitarization stockpile was still estimated at 450,000–600,000 tons, representing approximately a sixth of the total stockpile (RTO, 2010, p. 3-24; NIAG, 2010, p. 82; Gibbs, 2010).¹⁶ The current annual demilitarization budget of more than USD 150 million is not diminishing the stockpile, 'but rather keeps it at the same level' (Nammo, 2012, p. 15). Although large quantities of the surplus munitions are disposed of each year, a similar quantity is declared surplus, largely as a leftover from remaining cold war stockpiles.

Few European companies have accessed the US demilitarization market. One that has, Nammo Inc., established a subsidiary called Nammo Demil LLC in 1999 to serve as the programme manager for US commercial demilitarization requirements. Since 1999 Nammo Demil LLC has worked as the principal contractor on US contracts or as subcontractor to General Dynamics–Ordnance and Tactical Systems in the framework of several five-year commercial demilitarization contracts (Nammo, 2012, p. 14).

In Western Europe, the large stockpiles of surplus cold war-era munitions have mostly been dealt with, and current stockpiles are growing at a much slower rate, except for more recent classes of munitions such as those fired by multiple-launch rocket systems, as discussed below (NIAG, 2010, p. 82). A 2008 French MoD report estimates that approximately 2,000 tonnes of conventional munitions would require demilitarization annually in France from 2009 to 2014, not including a total of 7,500 tonnes of missiles, (mostly MLRS) rockets, and torpedoes over the same period (France, 2008, p. 17).

Eastern European and Commonwealth of Independent States countries, which still harbour significant stockpiles of conventional ammunition surpluses, are seldom mentioned by Western European and US contractors as future demilitarization markets. In some of these countries, demilitarization remains a domestic activity largely inaccessible to open, international tender competition. In 2012, for example, the Russian MoD declared its intention to decommission 11 ammunition storage areas and dispose of three million tonnes of ammunition by the end of 2013 (Voice of Russia, 2012; IANS and Ria Novosti, 2012). It is unclear whether the Russian Federation has a credible national demilitarization capacity to achieve this, what quantity will be disposed by OB/OD, and whether the country will open the domestic market to international demilitarization providers.¹⁷

In similar contexts, international donor-funded demilitarization programmes are instrumental in shedding light on a country's demilitarization capacity by promoting local processing facilities wherever possible. Such is the case in Ukraine, for instance, where NSPA is currently using four Ukrainian plants¹⁸ to demilitarize 1.5 million small arms and light weapons and more than 130,000 tonnes of obsolete ammunition in the framework of a 12-year (four-phase) PFP Trust Fund project.¹⁹

Very little information on other regional markets is available. There seems to be a high demand for Western technology and capacity in Asia and the Middle East, where the industrial demilitarization market is reportedly underdeveloped. However, Western European companies need to use local contractors in order to reduce shipping and logistics costs to remain competitive, and it is unclear whether they are meeting the regional demand. African countries

International donor-funded programmes help shed light on a country's demilitarization capacity.

have requirements for explosive ordnance disposal, mine clearance, and mine disposal activities. Many states on this continent need to dispose of outdated stockpiled munitions, yet African defence budgets for industrial demilitarization tend to be quite restricted (Nammo, 2012, p. 15).

Cluster munitions

Cluster munitions, especially MLRS rockets, currently represent a significant part of the demilitarization activity in the United States and Western Europe.²⁰

The capability for disposal of the cluster munitions existed before the signature of the Convention on Cluster Munitions in 2008. Western countries started destroying cluster munitions around 2000. In 2001, for instance, Nammo Buck GmbH demilitarized 8,000 BL-755 cluster bombs in a three-year, USD 2.5 million contract for the German government (Perala, 2001). In anticipation of the CCM, around 2005, governments and contractors developed automated disassembly equipment to separate bomblets from their dispensers (Zaugg et al., 2007). The United States reportedly destroyed around 7,000 tons of cluster munitions per year in 2000–10, at an average annual cost of USD 6.6 million (Bohle, 2010).

However, the CCM process—and entry into force in August 2010—generated a spike in the volume of surplus cluster munitions that exceeded most NATO nations' immediate demilitarization capacity (NIAG, 2010, p. 97). In several NATO countries, the number of surplus MLRS rockets²¹ illustrated this vividly. In 2007, several hundred thousand M26 rockets in Europe and the United States had reportedly reached the end of their lifetime and were awaiting



CBU bomblets undergo an automated demilitarization process at Joplin, Missouri, USA, 2012. © General Dynamics Ordnance and Tactical Systems (GD-OTS)

disposal within the coming ten years (Herbst, 2007). A 2008 French MoD report estimates that, after sub-munitions were prohibited by the CCM, approximately 160,000 MLRS became obsolete in Western Europe. The report states that most of the European demilitarization capacity for MLRS was in Germany, and that there was doubt as to whether it could absorb the European MLRS rocket stockpiles—including those of US forces stationed in Europe (France, 2008, p. 10).

In Europe, NSPA consolidated MLRS rocket demilitarization requirements on behalf of its NATO customers to achieve economy of scale. In 2007, NSPA contracted Nammo Buck, Nammo NAD, Esploidenti Sabino, and Spreewerk on behalf of the Netherlands and the United Kingdom to demilitarize 60,000 M26 MLRS rockets containing more than 38 million sub-munitions. The contract was spread over the period 2007–13 and is valued at approximately EUR 49 million (Towndrow, 2010, p. 20; 2011a, p. 8). Rough-order-of-magnitude demilitarization prices reportedly average EUR 600–700 (USD 800–950) per rocket²² (Courtney-Green, 2007, p. 21). In November 2011, NSPA also awarded a contract to MBDA in France for the destruction of 36,000 complex munitions, including 1,000 missiles, 22,000 M26 rockets—each containing 644 sub-munitions—and 13,000 155-mm projectiles, each containing 63 sub-munitions; all in all, more than 15 million sub-munitions are set for destruction by 2017 (MBDA, 2011; Lucas, 2012). As of late 2012, experts estimated that 95 per cent of the Western European MLRS stockpiles had been destroyed or were on contract to be processed by 2018.²³

The CCM appears to have affected the demilitarization activities of non-states parties as well. As of December 2011, six of the top ten items of the US ammunition demilitarization stockpile contained sub-munitions. The 155 mm M483 howitzer shell, a type of dual-purpose improved conventional munition,²⁴ represented the largest tonnage of the stockpile, with approximately 120,000 tons (Boyer, 2012, slide 7). In particular, the disposition of the large inventory of the MLRS pods that are reaching the end of their shelf life will reportedly be the US Army missile demilitarization programme's largest challenge over the next several years (Wright, Lee, and Gunter, 2011). In 2010 the US Army expected approximately 50,000 to 60,000 MLRS to enter the demilitarization programme, starting in the year 2012 (Dillard, 2010).

In the United States, the Army Aviation and Missile Life Cycle Management Command (AMCOM) contracts the industry to demilitarize MLRS. As of May 2012, General Dynamics–Ordnance and Tactical Systems had reportedly processed more than 51,000 rockets during the first four years of a five-year contract with AMCOM to demilitarize more than 89,000 MLRS (Meyer and Winkler, 2012, p. 2). Government-owned facilities such as the recent MLRS recycling facility at the Anniston Defense Munitions Center were also designed and built to address the MLRS demilitarization stockpile (Dillard, 2010; Wright, Lee, and Gunter, 2011). In July 2012, in Canada, media sources reported that the Department of National Defence was planning to dispose of more than 12,000 dual-purpose improved conventional munition projectiles containing more than one million bomblets in a CAD 2 million tender (USD 2 million) (Carlson, 2012).

European and US governments contract the industry to demilitarize large MLRS stockpiles.

ACTIVITIES

Core processes

Demilitarization is defined as 'the complete range of processes that render weapons, ammunition and explosives unfit for their originally intended purpose' (UNODA, 2011a, p. 8). It involves 'removing or otherwise neutralizing the military potential' of ammunition (MSIAC, 2006). The term applies equally to serviceable and to unserviceable surplus material or equipment.

Many demilitarization techniques are available,²⁵ categorized by the stage of the demilitarization process in which they are applied. Table 9.3 illustrates the basic process and applicable techniques. Demilitarization is considered complete

Table 9.3 Summary of the ammunition demilitarization process and techniques

Process stage	Description	Examples of techniques and equipment
1. Transport	Compliance with dangerous goods or hazardous waste regulations that apply to the transportation of ammunition and explosives earmarked for demilitarization.	Delivery by road, air, or sea.
2. Storage until demilitarization	Compliance with relevant quantity-distance standards.	Storage in self-contained, partially buried bunkers designed to send any blast upward and not outward to minimize damage.
3. Manual unpacking and preparation	Sorting and unpacking.	Removal of non-explosive elements for recycling.
4. Pre-processing and disassembly	Separation of projectiles, propellants, and casings; exposure of energetic material prior to removal.	Techniques include manual disassembly; delinking; defusing and depriming; automatic and semi-automatic disassembly; crushing; cryofracture; laser cutting; hydro-abrasive cutting; mechanical cutting; robotic disassembly. Equipment includes grenade shearing machines; bullet disassembly machines; fuse disassembly machines; and metal part disassembly machines.
5. Energetics* removal	Physical removal of energetic materials from their housing or casing.	Meltout: the use of autoclaves and hot water or steam to heat and melt the energetic material in munition to aid or cause its removal from casings. The process is used to remove cast high explosives such as TNT, Comp B, and Tritonal, but compositions such as RDX, HMX, and PBXs cannot be readily melted. Equipment includes US Ammunition Peculiar Equipment (APE) 1300 and 1401 (autoclave and steam meltout).
		Washout: the use of a high-pressure jet to abrade the energetic material.
6. Energetics disposal (primary destruction)	Decommissioning or destruction of energetic materials.	Open burning (OB): material is burned in the open, without control of the gasses.
		Open detonation (OD): typically, items are stacked for destruction and then a donor charge is used to initiate the items. The key requirements are the detonation of all items and the reduction of projection hazards.
		Controlled detonation chamber: material is detonated by a donor charge in a cold chamber that allows the pressure, fragmentation, and noise effects to be controlled and the emissions to be treated.

Process stage	Description	Examples of techniques and equipment
		<p>Static detonation chamber (SDC, also called static kilns): hot detonation chambers heat the contents to induce burning, deflagration, or detonation without using a donor charge. Examples include Dynasafe SDC 1000, SDC 1200 CM (for chemical munitions), SDC 1500, and SDC 2000.</p> <p>Rotary kiln (explosive waste incinerator): these furnace incinerators are rarely used for disposal of propellants or explosives. The most common rotary kiln design worldwide is the US APE 1236. Rotary Kiln 418 is used for energetics, explosives, ammunition up to 12.5 mm calibre, fuses, boosters, and air bag devices.</p> <p>Oxidation processes that undergo development or validation: a) molten salt oxidation; b) alkaline hydrolysis (also known as caustic or base hydrolysis); c) supercritical water oxidation.</p>
7. Energetics disposal (secondary destruction)	Production of scrap material 'free from explosives'.	Thermal decontamination (open flame or contained).
8. Pollution control system	Compliance with regional or national environmental regulations covering noise, air, water, and land emissions, as well as waste management and recovery.	<p>Dry ceramic filtration: used for the removal of particulates.</p> <p>Afterburner: used immediately after the kiln, these generally operate in the 850-1,200°C range to destroy volatile organic compounds and dioxins.</p> <p>Baghouse system: this approach is still predominant in the United States. The system uses Gore-Tex/Teflon filter bags.</p> <p>Scrubber system: uses water with an alkaline salt added to absorb, remove, and neutralize acidic gases (including chlorine, hydrogen chloride, and sulphur dioxide) from the off-gas.</p> <p>Granulated activated carbon or active carbon filter: absorbs nitrogen-based compounds, removes heavy metals (including mercury), and treats 'pink' waste water.</p>

Notes: * This chapter defines energetic materials as the explosive compounds and chemicals used in military explosives and propellants. The most common chemicals are '2,4,6-trinitrotoluene (TNT), 1,3,5-hexahydro-1,3,5-trinitrotriazine (RDX), and 1,3,5,7-tetrahydro-1,3,5,7-tetranitrotetrazocine (HMX), which are used as high explosives, and nitrocellulose (NC), 2,4-dinitrotoluene (DNT), nitroglycerin (NG), and nitroguanidine (NO), which are used in propellants' (Johnsen et al., 2011, pp. 22-1-22-2).

Sources: Dynasafe Demil Systems AB (2012); MSIAC (2006); Nammo (2012); NIAG (2010); author correspondence with Thomas Stock, managing director, Dynasafe Germany GmbH, 10 December 2012

Box 9.1 R3: recovery, recycling, and reuse

Demilitarization contractors seek to maximize the amount of recovered material that can then be sold to offset processing costs and thus reduce the overall cost of demilitarization. This promotes a culture of recovery, recycling, and reuse, known as R3 (Van Baalen and Honey, 2011, p. 10-9). R3 methods strip the ammunition down to its basic, recyclable component parts and compounds.

One of the easiest forms of resource recovery is the reuse of scrap metal from munitions casings. Metals such as iron, steel, copper, brass, tin, lead, and tungsten are valuable and can be recovered and recycled for commercial purposes. Approximately 240 kg of aluminium, 90 kg of copper, and 1,000 kg of steel can be recycled as scrap metal for every MLRS pod²⁶ (Wright, Lee, and Gunter, 2011). But the scrap metal must be safe for reuse. Typically, scrap metal is 'flushed'—that is, heated to approximately 400°C in an incinerator to remove traces of energetic materials or toxic substances—before it is qualified as 'free from explosives' and sold (MSIAC, 2006, p. 74).

Contractors can also reclaim the propellants, explosives, and pyrotechnic ingredients for reuse in commercial applications. The difficulty of explosive recovery resides in limiting contamination and controlling the quality of the recovered explosives. There are two major non-energetic, end-use applications:

- First, energetic materials can be processed into other materials, typically fertilizers or components of fertilizers, because of their high nitrogen content. Explosive D (ammonium picrate), which has no commercial use, can be converted 'into the commercially viable products Picric Acid and Ammonium Nitrate, which are used in the leather dye and fertilizer industries, respectively' (Schmit, 2009).
- A second example is the conversion of white phosphorus (WP) into phosphoric acid, which can be sold to the soft drinks industry (RTO, 2010, p. 3-27).

Since 1989, the US military has been decommissioning WP ordnance at the Crane Army Ammunition Plant using a facility called the Ammunition Peculiar Equipment 1400 White Phosphorus-Phosphoric Acid Conversion Plant. The plant can process 5,240 kg of WP and can produce 21,800 kg of phosphoric acid per day; the resulting phosphoric acid and scrap metal are sold commercially (Peske, 2010; Walsh, Walsh, and Collins, 2011). In Europe, facilities for recovery of phosphoric acid include Alsetex, which has a modern plant in France (MSIAC, 2006, p. 76).

Recovered energetic materials are also used for energetic end-use applications, such as in the production of a wide range of commercial explosives and blasting devices for mining and quarrying. Importantly, the fact that there are examples of commercially viable uses for these materials does not mean that there is a potential market for all the materials or in all quantities.

once all residues from the reverse engineering or destruction process have been destroyed or recycled (see Box 9.1).

Not all of these steps are systematically required. For example, munitions could be destroyed without prior disassembly or removal of energetics, and some steps can be combined. For each of these processes, the industry has developed specific equipment. A single type of equipment does not, in and of itself, represent a complete demilitarization line; rather, the systems complement each other. Contractors also modify technologies to be mobile (not fixed to a permanent installation) so that they can be moved from stockpile to stockpile, or they develop modular, transportable technologies that are temporarily fixed to a platform so that they can operate in one country or region before being transferred to another (Gobinet, 2013).

The best option is seldom a single approach, but rather a combination of them. Many contractors thus use a mixture of OB/OD and other, more environmentally friendly methods that aim to recover valuable materials. The decision to choose any particular technique is based on cost, safety, environmental considerations, customer preference and time-frame, logistics, availability, the type and quantity of ammunition being destroyed, the physical or chemical condition of the ammunition, and the value of recovered material.

Capabilities and capacities

Within NATO countries, the technology exists to destroy the vast majority of ammunition types (Van Baalen and Honey, 2011, p. 10-11). Demilitarization contractors process ordnance, regardless of whether it is clearly labelled or

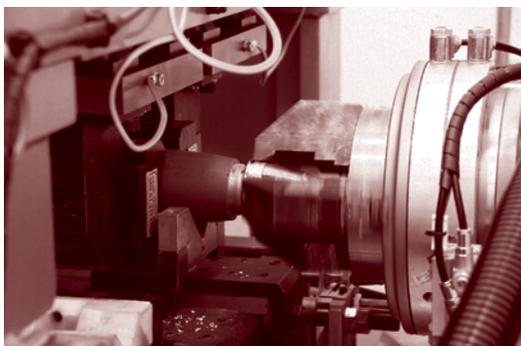


Photo (left): A projectile's nose fuse being removed remotely during the automated disassembly process, Kirikkale, Turkey, September 2007.

© NATO Support Agency (NSPA)

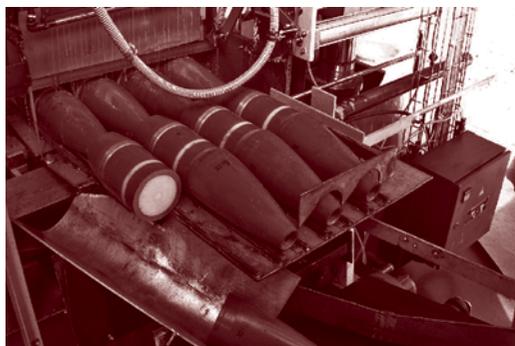


Photo (right): The saw-cutting of high-explosive projectiles to expose their energetic content; after which, the components travel on a conveyor belt to the next station to melt out the explosives, Lübben, Germany, 2012. © Spreewerk Lübben GmbH

stored in suitable conditions. This includes a wide range of conventional ammunition, from small arms ammunition to aircraft bombs, sea mines, torpedoes, and cluster munitions.

Capacities vary. Equipment capacity is dependent on the type of ammunition processed. Small arms ammunition destruction rates are highest. Destruction rates are slower for TNT-filled medium- and heavy-calibre shells, and slower still for more modern RDX- or HMX-filled shells and for guided missiles.

There is no standard unit of measurement for industrial demilitarization processing capacities (Van Baalen and Honey, 2011, p. 10-14; NIAG, 2010, p. 171). Comparing production rates is thus difficult. Since OB/OD long served as the preferred demilitarization method, weight is often used as a unit of measurement. Large differences appear when comparing unpacked with packaged munition weight. To measure maximum load rates, NATO and contractors typically use all-up weight and net explosive quantity.²⁷ Contractors also base their standard throughput rates upon clearly defined ammunition types and typically express these rates in 'rounds of specified ammunition type' per time unit. Generally speaking, a company such as TRZK can process more than 3,000 tonnes of conventional ammunition per year (TRZK, 2012); companies such as ROKETSAN Missiles Industries Inc. in Turkey and Yuzhmash missile factory in Ukraine can reportedly process around 6,000 tonnes of conventional ammunition per year. Nammo Vingåkersverken in Sweden can reportedly handle 15,000–20,000 tonnes of conventional ammunition per year (NIAG, 2010, p. 71).

Capacity is an issue in the United States, where the amount of surplus ammunition grows faster than it is being demilitarized. US figures from the 2010 Demilitarization Symposium in Tulsa indicate that, between fiscal years 1980 and 2010, US forces generated a 2.2 million-ton surplus, whereas only 1.5 million tons were demilitarized. Although 70,000 tons of ammunition were processed in the year 2010, DAC estimates that doubling the demilitarization funding of USD 146 million would only reduce the surplus ammunition stockpile by 6 per cent per year.²⁸

In contrast, most NATO nations have underutilized industrial demilitarization capacity (Van Baalen and Honey, 2011, p. 10-11). In Europe, most of the large demilitarization contractors have redundant infrastructure in the form of high-throughput equipment and multiple production lines. Nammo and Spreewerk confirm that their facilities are seldom running at full capacity (Nammo, 2012, p. 7; Spreewerk Lübben GmbH, 2012, p. 3). It could be argued that these capabilities are rarely located where they are most needed; that is, in 'client' countries in Eastern Europe with significant surplus ammunition stockpiles but no funds to address them (RTO, 2010, pp. 1-2, 4-1).

REGULATIONS, STANDARDS, AND OVERSIGHT

There is currently no common international or European standard, legislation, or compliance mechanism that *specifically* addresses ammunition demilitarization by commercial contractors.

This may complicate, and in some cases prevent, the development of a systematic, multinational approach to ammunition demilitarization.²⁹ Within NATO, Standardization Agreement 4518 provides a brief—and outdated—overview of the demilitarization process and available techniques, but it was not written to provide industry standards (NIAG, 2010, p. 171). National legislation usually does not regulate the destruction of military ammunition by civilian industrial contractors. To process military ammunition, industrial contractors must therefore apply a patchwork of civilian explosives industry legislation and for certain activities, such as OB and OD, they may adapt military guidance.

Seemingly unrelated legislation and civilian regulations affect the demilitarization industry indirectly. Changes to regulations in the areas of environment, safety, and staff training requirements can have effects on demilitarization practices. There is also a complex framework of regional, national, and even local rules subjecting demilitarization activities to various local permits and licences. In the United States, for example, the demilitarization of munitions requires compliance with numerous local, state, and federal regulations, most of which require air emissions permits and chemical release reports (Thompson, Kennedy, and Nordquist, 2004).

Logistics can account for half of the cost of some demilitarization contracts.

US and Western European contractors usually know these constraints well because they have a direct impact on their business. However, client governments and national programmers may find this regulatory framework complex and opaque. The following sections highlight three key regulatory areas—transport controls, compliance and oversight, and safety and physical security—that are not often scrutinized by the policy-maker.

Transport controls

Transporting ammunition and managing cross-border cooperation are key activities of the demilitarization industry. Surplus ammunition can be shipped to dedicated storage and demilitarization locations by road, rail, ship, or air. Transport can be a significant logistical undertaking. In 2010, for example, the EXPAL Bulgaria JSC plant in Gabrovo won two tenders from an Asian country for the demilitarization of 8,000 tonnes of ammunition in 2010 and for 4,000 tonnes (including more than 400 different types of ammunition) in 2011. In the case of the second Asian contract, 215 ISO containers were brought from Asia to the Black Sea, delivered to Burgas, then transported by road to Gabrovo. The Bulgarian police reportedly provided transport security and the transfer was made in accordance with European regulations on the transport of hazardous goods (Gobinet, 2012, p. 90).

Ammunition transport—and logistics in general—represent a large expense. In the United States, average packaging, crating, handling, and transportation costs represent an estimated 35 per cent of total demilitarization costs (Boyer, 2012, slide 6). Worldwide, it is estimated that logistics can represent as much as 50 per cent of the total cost of some demilitarization contracts. This may exclude expensive and complex insurance policies for transported weapons and ammunition, as well as additional expenses to ensure transport security (Spreewerk Lübben GmbH, 2012, p. 5).

Transportation of ammunition and explosives is principally governed by international and national legislation relating to the movement of dangerous goods. Munitions classified as dangerous goods are transported by rail and road in accordance with national legislation based on comprehensive directives and regulations such as: (i) the European Agreement concerning the International Carriage of Dangerous Goods by Road; and (ii) the UN Recommendations on the Transport of Dangerous Goods, also known as the ‘Orange Book’ (UNECE, 2009; 2011b). In a number of

former Warsaw Pact countries, whose massive ammunition stockpiles have not formally been tested or classified under the UN system, this represents a major hurdle to the demilitarization enterprise; the ammunition cannot be transported legally across borders unless it is officially classified under the UN Globally Harmonized System of Classification and Labelling of Chemicals (UNECE, 2011a). This requires a range of expensive tests.

Where the ammunition is being transported for the purpose of demilitarization, some nations have additionally applied legislation and procedures for the control of hazardous waste. Transportation and storage of ammunition classified as hazardous waste are subject to further regulation and permit requirements typically administered by national environmental agencies. Those involved in issuing permits are rarely familiar with explosives or the demilitarization industry and the permitting process can become a significant burden. A boundary between the two regimes is usually easy to determine: is the ammunition both properly packaged and labelled (that is, safe to move), or does the transport involve some other material, no longer classified as ammunition, that may thus be subject to hazardous waste legislation? For example, the transport of explosive-contaminated material to be incinerated at another facility may be subject to hazardous waste legislation and procedures. Another consequence of classifying munitions as hazardous waste is the application of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, which restricts the export of hazardous waste, in particular from developed countries to developing countries (UNEP, 1989).

Demilitarization contractors and other stakeholders need to understand whether and when obsolete ammunition is categorized as hazardous waste. In the United States, the 1997 Environmental Protection Agency Military Munitions Rule provides clarification by stating that serviceable ammunition earmarked for disposal is not considered waste until it is actually demilitarized. Ammunition storage and transportation by the DoD are thus exempt from the US Environmental Protection Agency's Resource Conservation and Recovery Act³⁰ requirements, but they remain subject to strict DoD regulations. Under EU law, the definition of waste is broader; obsolete munitions or expended munitions can more easily be considered hazardous waste. However, with the reported exception of Sweden, current EU regulations³¹ do not apply to military munitions being transported for demilitarization in Europe because, as in the United States, there is an assumption that such munitions are regulated more strictly than hazardous waste. In contrast to the United States, however, there is no 'Munitions Rule' to make this understanding explicit (MSIAC, 2006, p. 23).

Demilitarization companies do not own the ammunition until a certificate of destruction is delivered.

Compliance and oversight

Contractors must demonstrate to customers that they have management systems in place to cover aspects such as budgeting, health and safety, and quality. Internationally recognized certifications for quality management standards (ISO 9001:2008), environmental management systems (ISO 14001:2004), occupational health and safety assessment standards (OHSAS 18000),³² and NATO contracts quality assurance requirements (AQAP 2130)³³ are routinely accepted as evidence of a mature management system, but they do not necessarily guarantee compliance with a particular technical standard.

Industrial demilitarization implies the withdrawal of the weapons or ammunition from service and a transfer of responsibility, and eventually ownership, to the demilitarization industry. As a rule, demilitarization companies do not own the ammunition until they deliver a certificate of destruction. The original owner of the ordnance can monitor its destruction, or delegate verification to a government quality assurance representative. After demilitarization, ownership of the remaining material normally passes to the contractor. The certificate of demilitarization, duly signed by the nominated quality assurance representative, is typically considered as effective proof of transfer of property from the country's

armed forces to the contractor. However, this transfer of property is not automatic. National authorities may request ownership of any recyclable material, such as metallic scrap and explosive residues, and decide whether to destroy them or sell them to fund future demilitarization programmes.

Various national authorities and ministries oversee the activities of demilitarization contractors. While MoDs usually have oversight of the disposal of their own armed forces' munitions, they are not systematically involved in all of the industrial demilitarization contractors' activities. Research for the RASR initiative shows that the activities of demilitarization firms are usually overseen by ministries of industry, trade, or interior, which accredit and monitor them, but less often by MoDs (Gobinet, 2012). Indeed, while MoDs usually have oversight whenever munitions from national armed forces are concerned, they are otherwise not systematically involved in the private demilitarization sector's activities. Consequently, the MoDs are not always aware of the capabilities and capacities of commercial demilitarization facilities operating in their country.

This is especially true for the cross-border transport—that is, import and export—of surplus and excess ammunition. A written contribution by Nammo gives an idea of the complexity and variety of interlocutors. For Nammo Vingåkersverken Sweden, exports are overseen by the Inspectorate of Strategic Products, and imports are overseen by the Swedish Contingencies Agency MSB. The MoD is involved only when handling national demilitarization contracts. Otherwise oversight is provided by audit by national authorities regarding environmental, energetic, and site permission



compliance. For Nammo Norway NAD, exports and imports are overseen by the Directorate for Civil Protection and Emergency Planning and by the Ministry of Foreign Affairs. The Norwegian MoD is only involved in ammunition from the Norwegian armed forces; audits are performed by agencies other than the MoD. Meanwhile, Nammo Buck GmbH's main interlocutors are the Bundesministerium für Wirtschaft und Technologie (Ministry for Economics and Technology) and Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office for Economy and Export). The MoD is not involved for ammunition but oversees weapons and military systems. Oversight is executed by the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support acting as the MoD's procurement agency (Nammo, 2012).

Safety and physical security

When appropriate risk management processes are applied, dismantling ammunition is not inherently risky. Industrial demilitarization lines tend to expose the minimum number of people to the smallest quantity of explosives for the shortest period of time, consistent with operational needs. When built to NATO standards, facilities confine all explosive damage to the workshop where an incident occurs.

Explosions can occur during processing, even in NATO-standard facilities.

Yet the nature of demilitarization means that explosions can occur during processing, even in NATO-standard facilities. In its reply to the Survey's 2012 questionnaire, Spreewerk Lübben GmbH reported one accident causing four deaths (date unspecified) (Spreewerk Lübben GmbH, 2012, p. 8). Nammo reported four accidents. Its Swedish subsidiary, Nammo Vingåkersverken, suffered an explosion in 2000 during a clean burning operation. The plant reported only material damage. Nammo Buck GmbH reported three accidents that claimed two lives (Nammo, 2012, p. 18).³⁴ More recently, on 2 January 2012, a blast killed four persons at the NSPA-commissioned demilitarization plant in the Turkish province of Kirikkale.³⁵ On 11 January 2012, one woman died and a man was injured during an explosion at the EXPAL-operated plant in Gabrovo, Bulgaria, while processing anti-personnel landmines.³⁶

Explosions can also occur during storage. Since demilitarization facilities also need to store large amounts of ammunition before processing it, they must meet strict quantity–distance standards, such as those in the *Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives*, in the US Army's Ammunition and Explosives Safety Standards, and in the International Ammunition Technical Guideline 02.20 Safety and Quantity Distances (NATO, 2010; USDA, 2011; UNODA, 2011c). The bunkers used to store explosives are self-contained, partially buried, and designed to send any blast upwards and not outwards to minimize damage.

In countries where industrial demilitarization is less developed, involving contractors that do not meet Western European or US standards, there is greater potential for accidents. Poor MoD oversight over inexperienced private demilitarization companies may result in them developing, selling, or using non-functional or unsafe demilitarization equipment. Another risk is that ammunition storage, handling, and operating areas are not kept free of debris. Other procedures that are designed to prevent the ignition and spread of explosive materials are not always applied. Risks are heightened when demilitarization companies are also producers; production accidents can spread to storage areas or demilitarization lines if the two processes are not properly separated.

There are several examples of accidents in situations of substandard storage and demilitarization practice. It is not always clear whether the explosion occurred during the ammunition manufacturing, storage, or demilitarization process. Much of the information remains restricted and details of follow-up investigations are legally and politically sensitive. One example occurred in Niksic, Montenegro, in July 2006, with the explosion of 200 tonnes of military explosives that

a private contractor had imported and intended to transform into explosives for civilian use.³⁷ An enormous blast occurred in March 2008 at a demilitarization site near Gërdec, Albania, killing 26 people and injuring more than 300. A series of explosions also rocked VIDEX JSC's Midzhur factory, located near Gorni Lom, Bulgaria, in February 2010. When a depot containing ten tonnes of ammonite accidentally ignited, a large part of the factory was destroyed and the blast spread to a nearby compound where Greek anti-personnel mines awaited demilitarization. The Gerdëc and Midzhur explosions are the object of detailed case studies (Lazarevic, 2012).

While demilitarization may involve the risk of an accident, failure to demilitarize or destroy aged and surplus ammunition stockpiles can—and does—lead to significant unplanned explosions. The Survey's Unplanned Explosion at Munitions Sites database reveals that more than 400 ammunition depot explosions³⁸ were recorded from 1987 to 2012, affecting almost half of all UN member states (Small Arms Survey, 2012).

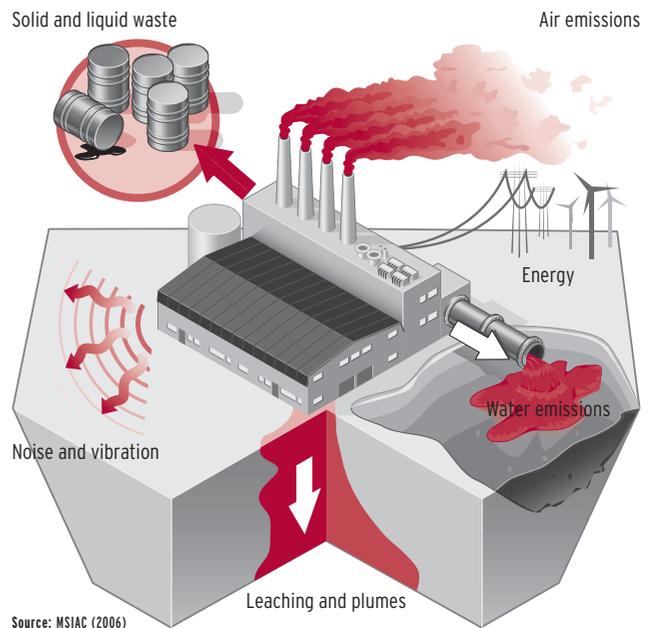
Demilitarization plants are vulnerable to the theft and diversion of weapons and ammunition during storage and transport. To date, accounts of demilitarization contractors breaking their contracts and reselling expired ammunition elsewhere remain anecdotal and unverifiable. Nevertheless, surplus stockpiles are an easy source of diversion in many countries (Gobinet and Gramizzi, 2011).

Surprisingly, this subject is not often discussed among demilitarization practitioners. This may reflect the fact that in the United States and Western Europe demilitarization contractors are confident that they exercise good stewardship of the ammunition and explosives under their control. Large contractors have clearly implemented security operating procedures, such as regular inventory checks of ammunition and components. They invest in perimeter security infrastructure and employ specialized security personnel (Nammo, 2012). Some contractors also rely on host nation security forces to secure and safeguard munitions during demilitarization activities.

ENVIRONMENTAL CONSIDERATIONS VERSUS COST EFFECTIVENESS

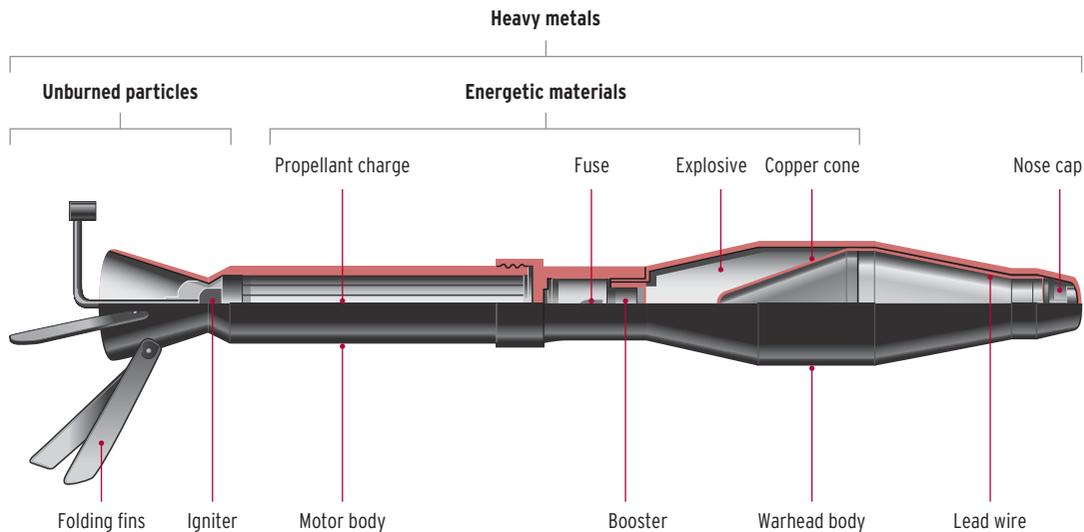
Many munitions and propellants are harmful to the environment (see Figures 9.1 and 9.2). Demilitarizing large quantities of ammunition requires the rigorous control and processing of toxic substances such as ammonium perchlorate, mercury fulminate, WP, and lead compounds.³⁹ The packaging material can also require handling and treatment to contain the heavy metals and persistent organic pollutants that were often used as preservatives in wooden ammunition packaging before it was banned. Some of the demilitarization processes themselves generate additional environmental hazards, such as air pollutants, pink water, and other hazardous secondary

Figure 9.1 **Environmental hazards from industrial demilitarization**



Source: MSIAC (2006)

Figure 9.2 Demilitarization waste products generated by a 66 mm M72 lightweight anti-armour weapon (LAW) high-explosive anti-tank (HEAT) rocket



materials.⁴⁰ Any demilitarization process must ensure that there is appropriate control of the materials at all stages, and particularly the final disposition of any hazardous waste stream.

All of these substances have been the subject of regional or national environmental regulation covering noise, air, water, and land emissions, as well as waste management and recovery. Concerning air emissions, for example, the EU Waste Incineration Directive, which is also implemented in Canada, sets common emissions standards for incinerators in EU countries (EU, 2000; MSIAC, 2006). NSPA incorporates this legislation into all its demilitarization contracts awarded in EU countries and aims to achieve similar standards in contracts awarded in PFP countries; that said, strict adherence to these standards is not always possible given these countries' local demilitarization capacities and national legislation, which may be less demanding.⁴¹

The EU Industrial Emissions Directive superseded the EU Waste Incineration Directive on 6 January 2011 and was to be ratified by member states by January 2013 (EU, 2000; 2010). The equivalent US regulations are the Standards for Hazardous Waste Incinerators (United States, 2004). These regulations are broadly similar to their EU counterparts, although significant differences exist in a number of areas, such as destruction efficiency, categorization of metal emissions, and nitrogen oxides and sulphur dioxide threshold emissions (MSIAC, 2006, p. 17).

The relationship between the industry and environmental legislation has both stimulated and limited demilitarization activities. Environmental legislation has largely spurred the development of R3 demilitarization processes to reduce the reliance on OB/OD but has also made demilitarization systems more complex and expensive to develop and operate. The environmental compliance process itself is costly. In the United States, the major demilitarization facilities must operate under Resource Conservation Recovery Act Subpart X and Clean Air Act Title V permits. Securing these permits has reportedly cost some demilitarization sites, especially incinerators, USD 2–5 million, and permits must be renewed every five to ten years (Thompson, 2007; Thompson and Holcum, 2011a, p. 28-14; El Dorado Engineering, Inc., 2012).

The conflicting priorities of environmental compliance and cost effectiveness lie at the heart of the OB/OD debate as well as the effectiveness of R3 processes.

The OB/OD debate

Demilitarization uses two main methods: OB/OD and industrial demilitarization. Most nations' demilitarization regimes involve a combination of both. Each method has its advantages and disadvantages (King and Diaz, 2011, pp. 37–42). Environmental considerations are a decisive factor and in that respect OB/OD remains controversial.

Disadvantages

In the past years, OB/OD has fallen out of favour with many demilitarization practitioners who consider it a source of uncontrolled soil, groundwater, and air pollution. The public also views OB/OD in a negative light, citing noise and vibrations, and claiming health risks as a result of the dispersion of chemicals in the surrounding air and groundwater (RTO, 2010, p. 3-18). While industrial contractors use these arguments as well, they are also aware that OB/OD competes directly with industrial dismantling.

The principal environmental impacts of OB/OD are air emissions,⁴² residual material (either energetics or toxic materials such as heavy metals), and noise. When carried out on a large scale over an extended period in one location, significant quantities of hazardous materials may accumulate on or near the site. The literature also emphasizes surface and subsurface contamination with heavy metals and unexploded explosives, which results from incomplete consumption of energetics, even during high-order detonation⁴³ (RTO, 2010, p. 3-18). This is accentuated if poor techniques are used, which may leave large quantities of unexploded materials. Similarly, incomplete detonation may occur if the



Albanian EOD soldiers preparing a mixed demolition pit of about one tonne of munitions deemed unsuited for industrial demilitarization, Bize demolition range, Albania, September 2009. © David Towndrow, NATO Support Agency (NSPA)

wrong procedure is used, with the result that energetic materials are released into the environment; this type of problem may arise during the destruction of insensitive munitions, which, by design, react less violently to thermal effects than conventional munitions.

Detractors of OB/OD also point to the dangers caused by shockwaves, projected fragments, and kick-outs⁴⁴ ejected by the explosions over a wide area. Open burning, although rarely used with ammunition today, is still used for propellants and some pyrotechnics. Even when done properly, the deflagration process is incomplete. If done incorrectly, raw propellant tends to scatter from the burn point, often leaching into the surrounding soil (RTO, 2010, p. 3-18).

Some demilitarization specialists also find the OB/OD process inefficient. OB/OD is considered wasteful of resources, since nothing can be recycled. The process is slow, labour-intensive—particularly in heavily populated regions where explosive limits are low—and its safe execution depends on daylight and good weather. Although it can be argued that OB/OD is appropriate for high-explosive rounds, it is less suitable for munitions with less energetic material content (such as countermeasure ammunition and low-vulnerability ammunition), as they are filled with insensitive high explosives that require significant preparation to ensure complete detonation. In addition, beyond a certain quantity, OB/OD may not be cost-effective. The destruction of large stockpiles of ammunition in non-conflict environments often requires the building of industrial demilitarization facilities, which, once amortized, are more effective and less costly.

Beginning in 2000, some countries progressively moved away from OB/OD. That year, the Canadian Department of National Defence instituted severe restrictions on OB/OD operations as a result of reports of environmental contamination at several Canadian Forces bases and ammunition depots (Park, Eng, and Garrard, 2011, p. 1.2). Between 2000 and 2006, it appears the United States sought to replace OB/OD methods with alternate, environmentally approved methods. The DoD's reliance on OB/OD reportedly dropped from 80 per cent in the 1980s to 32 per cent in 2010.⁴⁵ A number of countries, notably Germany, the Netherlands, and Sweden, have banned OB/OD if alternative processes are available (MSIAC, 2006).

Some countries have re-examined OB/OD and its environmental impacts.

Advantages

Although the demilitarization industry is very vocal about the need to phase out OB/OD, opinions are more nuanced among 'organic' demilitarization practitioners, or MoD representatives, and among the mine action and explosive ordnance disposal community.

One argument is cost. Many industrial demilitarization methods use complex and expensive pollution control systems. El Dorado Engineering estimated the cost of providing EU-standard nitrogen oxide control at USD 1 million in the United States, where the substance is not regulated (MSIAC, 2006). In a 2009 proposal, NSPA estimates the cost of shipping, installation, training, commissioning, and spare parts for a pollution control system at EUR 1.4 million (USD 1.9 million) (NAMS, 2009, annexe D). This has obvious repercussions on the per unit demilitarization price. One observer finds that a 750-pound bomb costs USD 225 per ton to destroy using OB/OD, but more than USD 1,000 per ton to demilitarize using R3 processes (Raftery, 2007, p. 14). Countries that have entirely banned OB/OD have no choice but to use more environmentally friendly options, regardless of how costly they are.

Due to the high costs of industrial demilitarization, some countries have re-examined OB/OD, seeking to quantify its environmental impacts more precisely. Much of this research has been carried out in the United States, where OB and OD are subject to a permit system, regulated by the Environmental Protection Agency. Studies conducted by the Naval Air Weapons Center at China Lake, California, concluded in 2004 that, if ammunition items were properly prepared prior to OD, the metal from the ammunition casing tended to fragment, rather than vaporize, and therefore did not contribute to air emissions. The resultant emission plume did not contain sufficient quantities of toxic or hazardous

pollutants to pose a significant danger to human health or the environment. The studies also concluded that the levels of dioxins from the OD of explosive waste were significantly less than the emissions typically generated by a medical waste incinerator.⁴⁶ In 2004, the South Eastern and Eastern Europe Clearinghouse for the Control of Small Arms and Light Weapons confirmed and used many of these findings (SEESAC, 2004, p. 25).

From 2008 onwards, some practitioners in the demilitarization community progressively reinstated OD as a sensible method for use on particular munitions in appropriate locations. Based on test results indicating that the impact on the environment due to OB and OD operations is much less severe than previously believed, the US DoD progressively requalified OB and OD methods as an indispensable, safe, efficient, and environmentally acceptable means of clearing large quantities of obsolete military munitions (Nordquist, Cramer, and Williams, 2009; DoD OB/OD Workgroup, 2008).⁴⁷ In the United Kingdom in 2008, the open burning of 170,000 barmines,⁴⁸ 20 miles outside of London, was considered the most environmentally friendly option due to the lack of industry interest in buying the RDX/TNT by-products of industrial demilitarization, and due to the cost⁴⁹ and CO₂ footprint associated with transporting the mines to Europe for industrial processing (Emerson and Towndrow, 2008; RTO, 2010, p. 3-3). More recently, the Finnish and Canadian defence forces conducted similar soil sampling studies, both of which pointed to relatively modest environmental impacts of OB and OD (Park, Eng, and Garrard, 2011, pp. 1-12-13; MSIAC, 2006). Efforts are under way to characterize and quantify air emissions from OB/OD, mostly through the creation of dispersion models and the updating of emissions factors databases (Nordquist, Cramer, and Williams, 2009; Williams, 2010).

OB/OD remains the primary destruction method for many armed forces, including within NATO.

Regardless of cost and environmental issues, field practitioners consider OB/OD indispensable in situations that involve the disposal of:

- munitions in insufficient quantity to justify setting up an industrial production line;
- munitions that are not safe to move or safe to process industrially;
- surplus propellant and explosive materials that cannot easily be recycled or reused;
- munitions in countries where logistics are poor and the shipping of large equipment is not cost-effective; and
- stockpiled munitions in-theatre following a conflict.

As a result, OB/OD remains the primary 'institutional' or 'organic' ammunition and explosives disposal method for many armed forces, including within NATO. In the UK, for example, propellants and explosives are currently destroyed by OB/OD. QinetiQ at Shoeburyness processes small items through an explosive waste incinerator, but the bulk of the propellants and explosives, as well as a large range of munitions, are burned or detonated in the open (Stalker, 2011b, p. 17-1). International organizations issuing RfPs usually acknowledge the need for MODs to retain OB/OD capacity, but will nevertheless prohibit the use of OB/OD in most demilitarization contracts to avoid litigation and to standardize tenders. For instance, NSPA endorses OB/OD where it is demonstrably safe and environmentally responsible to use—such as in most of its Pfp projects (NAMSA, 2009, annexe G).

The effectiveness of R3 processes

The R3 philosophy of recovery, recycling, and reuse is the staple of the demilitarization industry. Proceeds from the sale of recyclable munitions materials derived from demilitarization are used to offset the processing costs. Yet there are technical and commercial challenges.

Not all munitions are suited to R3. Ammunition designers have traditionally focused their product development and design on performance, not on ease of demilitarization at the end of the munitions' life cycle (Mescavage, 2010).

In particular, modern munitions containing plastic-bonded explosives (PBXs) are more difficult to recycle than conventional explosives. Conventional melt-cast explosives,⁵⁰ based on TNT, are vulnerable to unplanned stimuli, such as bullet attacks and sympathetic detonations. In order to reduce accidental initiation during storage, transportation, and handling, ammunition manufacturers increasingly use insensitive munitions that are ‘less susceptible to shock and other external stimuli’ (Temple and Hooper, 2011, p. 21.3). These munitions use PBXs instead of TNT. Most of the insensitive formulations are not recyclable or are ‘at least more difficult to demilitarize at the end of their shelf life’ (Ampleman, 2011, p. 31.3). ‘Design for demilitarization’—US DoD policy that aims to factor disposal considerations ‘that do not impact performance’ into ammunition procurement—has yet to gain comparable traction outside the United States (Mescavage, 2010; Stalker, 2011a, p. 14.2) .

Other circumstances may complicate the application of R3 processes. In some cases, the quantity to be demilitarized is insufficient to develop an economically sustainable industrial process line. The history of munitions is often unknown, and identification of chemicals, components, and materials present in munitions can be difficult to establish when no records are available.⁵¹ This makes the reuse of components or materials difficult in the military environment, which has exacting performance requirements.

Donor-funded demilitarization projects report that the recycling of scrap metal is where most of the money is made. For some lines, typically the large-calibre and mortar lines, the returns from sales of scrap are reportedly similar to the total processing costs (Towndrow, 2012, p. 8). According to NSPA, the current costs for the demilitarization (excluding



Factory workers preparing to thermally treat bulk explosives recovered during the demilitarization process at EST Energetics GmbH, Steinbach, Germany, 2011.
© NATO Support Agency (NSPA)

transport) of 120 mm mortars in Albania are almost matched by the returns on the scrap metal. For 122 mm artillery shells, the demilitarization cost of EUR 7.29 (USD 9.53) per shell is exceeded by the scrap value EUR 8.59 (USD 11.23) per shell.⁵² In general, however, the costs of processing and transport are still higher than the return from the recovered material.

The situation is different for the recycling of explosives for commercial, energetic end-use applications. This activity is largely market-driven and only viable when relevant quantities are significant. The main challenge is identifying a suitable and sustainable market for the end-use material (Van Baalen and Honey, 2011, p. 10-13). However, the explosive industry is very competitive and TNT is a fairly low-value explosive.⁵³ As far as the civil demilitarization industry is concerned, the amounts of energetic material that it can supply are trivial and the cost of recovery and conversion high with respect to the market value of recycled materials (RTO, 2010, p. 3-23; NIAG, 2010, pp. 83-88).

In most cases, R3 offsets the cost of demilitarization, but makes no profit.

Some examples illustrate the problem. In 2003 the US Army Aviation and Missile Research, Development, and Engineering Center established a Missile Recycling Capability at the Anniston Defense Munitions Center to recycle up to 15,000 TOW missiles annually. It was initially estimated that '98 percent of the missile hardware, warhead explosives and propellant ingredients could be reused or recycled into various industrial applications' (Gustafson, 2003). Yet the reuse and recycling of the TOW's energetic materials into commercial explosives, such as booster charges for the mining industry, yielded limited results because the US economic downturn severely limited market demand for reuse of this material. Currently, the disassembled TOW launch and flight motors are being disposed of through OB/OD. Similar concerns affect the demilitarization of the MLRS. While the US Army reuses components and recycles scrap metal, energetics are processed by closed disposal thermal treatment processes (Wright, Lee, and Gunter, 2011, pp. 6.4, 6.5).

The potential for recovery and reuse of military explosives for military applications is unclear. In the United States a programme was initiated in 2001 to requalify TNT recovered from demilitarization operations and reuse it to load munitions and bombs. Since TNT production capabilities in the United States and Canada were scarce or nonexistent, it was estimated that the process would be cost-effective (Anderson, 2001). Yet a recent report indicates that recovered TNT is not normally suitable for military applications (RTO, 2010, p. 3-28).

Although practitioners often disagree on the extent to which R3 revenues can offset operational costs, there is general agreement that in most cases R3 will partially offset the cost of demilitarization rather than produce an overall profit. In other words, demilitarization will not generate revenue overall, but the use of R3 can help reduce costs considerably (RTO, 2010, p. 3-28).

CONCLUSION

Most Western countries have 'organic'—that is, state-owned, MoD-operated—demilitarization facilities to process ammunition that has been declared unsafe for operational use by security forces. The routine disposal can amount to a significant volume over a year, and can comprise many different types of munitions. These categories are typically destroyed by the military using simple dismantling techniques or by OB/OD.

The end of the cold war created vast surplus ammunition stockpiles, which this 'organic' demilitarization capacity could not address. Because of the large tonnages involved and given time pressure—as ammunition tends to become unsafe with age—industrial dismantling became a cost-effective and efficient option. These complex processes require

specialized, automated machinery, flexible lines, and high production rates that only industry can provide. The large, post-cold war ammunition stockpiles in the United States and Europe provided the necessary economies of scale for this industry to thrive.

Predominantly headquartered in the United States and Western Europe, a limited number of industrial demilitarization contractors transport, store, and demilitarize significant amounts of ordnance on behalf of client governments under normal competitive tendering rules. Importantly, they are also prime actors, stakeholders, and potential facilitators of international donor-funded arms control and ammunition demilitarization programmes.

Industrial demilitarization contractors operate under a complex regulatory framework, blending classified military ammunition standards with general civilian legislation aimed at controlling large continuous processing operations. Among other factors, compliance with international, regional, and national environmental legislation has influenced the development of industrial demilitarization technologies for disassembly, incineration, and contained detonation of conventional ammunition. Increasingly strict environmental emission limits—especially in the EU—have mandated the inclusion of complex pollution control systems at the end of the demilitarization lines, as well as the recovery, recycling, and reuse of ammunition components. This remains an important requirement in the industry.

Yet the requirements of environmental compliance are often at odds with the international community's push for speedy surplus destruction at reasonable cost. For example, multiple licensing requirements slow demilitarization programmes, while the need to comply with environmental legislation increases the costs of demilitarization for client governments. The current debates surrounding the environmental impact of OB/OD and the extent to which R3 revenues can offset overall demilitarization costs reflect the underlying struggle between environmental imperatives and the need for cost-effectiveness in industrial ammunition demilitarization.

At this writing, significant surplus stockpiles remained in the United States, Europe, and elsewhere. In Europe, many of the surplus cluster munitions and MLRS are already on contract for disposal over the next few years but, once this backlog has been dealt with, it seems likely that these countries' demand for industrial demilitarization services will drop. It is generally believed that manufacturers currently produce significantly less ammunition for current weapon systems than they did during the cold war, and therefore that MoDs are generally procuring much smaller quantities of ammunition. In the short and medium term, the quantities that will require demilitarization are thus likely to be far lower, yet the complexity of the dismantling process may increase (Van Baalen and Honey, 2011, p. 10-8; NIAG, 2010, p. 160). If these predictions are accurate and demilitarization needs fall, the commercial market is likely to consolidate around an even smaller number of operators. ■

LIST OF ABBREVIATIONS

AMCOM	United States Army Aviation and Missile Life Cycle Management Command
APE	Ammunition Peculiar Equipment
CCM	Convention on Cluster Munitions
DAC	Defense Ammunition Center (United States Army)
DoD	Department of Defense
EU	European Union
MLRS	Multiple-launch rocket system
MoD	Ministry of defence
NATO	North Atlantic Treaty Organization

NSPA	North Atlantic Treaty Organization Support Agency
OB/OD	Open burning/open detonation
PBX	Plastic-bonded explosive
PfP	Partnership for Peace
R3	Recover, recycle, and reuse
RASR	Regional Approach to Stockpile Reduction
RfP	Request for proposal
SDC	Static detonation chamber
WP	White phosphorus

ENDNOTES

- 1 This chapter does not discuss: (i) the demilitarization of chemical or nuclear weapons; or (ii) the removal of unexploded ordnance or explosive remnants of war by commercial companies or NGOs (a distinct market with its own regulatory framework).
- 2 Artillery and mortar rounds, which often make up the bulk of a nation's surplus conventional ammunition tonnage, are procured in such large quantities that disposing of them exclusively through increased training would exceed barrel wear limitations. Author correspondence with Adrian Wilkinson, ammunition specialist, December 2012.
- 3 Many companies did not fill out the Survey's industry questionnaire, invoking such reasons as proprietary procedures, pricing, and individual market share. The following companies did reply: Dynasafe Demil Systems; DynCorp International; El Dorado Engineering; EST Energetics/Spreewerk; EXPAL; Nammo; NIRAS/DEMEX; SAB (Sonderanlagenbau) Nord GmbH; and TRZ Kragujevac.
- 4 The annual turnover of a company like Spreewerk Lübben GmbH, for instance, is approximately EUR 12 million (USD 16 million) (Spreewerk Lübben GmbH, 2012, p. 3).
- 5 Author correspondence with Sissel Solum, senior vice president of communications, Nammo Raufoss, 10 December 2012.
- 6 Dynasafe Demil Systems AB (2012); El Dorado Engineering, Inc. (2012); Follin (2012); DynCorp International (2012); author correspondence with Karsten Wohler, managing director, Sonderanlagenbau Nord GmbH, 6 December 2012.
- 7 This agency replaced the Federal Office of Defense Technology and Procurement as of 2 October 2012.
- 8 For public supply and service contracts, the threshold is currently set at EUR 400,000 (USD 525,000) (European Commission, 2012).
- 9 At the NATO Lisbon Summit on 19–20 November 2010, heads of state and government agreed to merge three agencies—the NATO Maintenance and Supply Agency, the NATO Airlift Management Agency, and the Central Europe Pipeline Management Agency—into a single body, the new NATO Support Agency, or NSPA, which became operational on 1 July 2012.
- 10 A well-documented PfP Trust Fund case study is Albania (Gobinet, 2012, p. 37).
- 11 To sponsor weapons and ammunition disposal programmes, the United Nations Development Programme, the Organization for Security and Co-operation in Europe, the EU, and the European Community also coordinate the procurement of high-value items such as explosive waste incinerators.
- 12 Author correspondence with a demilitarization contractor, July 2012.
- 13 Demilitarization figures can reflect short tons (US), tons (UK), or metric tonnes, for either the gross weight of the ammunition or the gross weight of the ammunition including packaging (which is referred to as tonnes all-up weight). This ambiguity makes accurate estimation of capacities and capabilities difficult. Logistics planning for demilitarization, for example, traditionally uses tonnes all-up weight. This chapter reflects, for each figure, the unit of measurement used in the corresponding source.
- 14 US figures from the 2010 Demilitarization Symposium in Tulsa indicate an average cost of USD 1,570 per tonne. Author correspondence with the US Army Defense Ammunition Center (DAC), 20 November 2012.
- 15 The short ton is a unit of mass equal to 2,000 pounds (about 907 kg). In the United States it is often called simply 'ton' and is not distinguished from the metric ton (or tonne, 1,000 kg, roughly 2,205 pounds) or the long ton (2,240 pounds or roughly 1,016 kg).
- 16 US figures from the 2010 Demilitarization Symposium in Tulsa indicate a demilitarization stockpile of 587,000 tons, with annual funding of approximately USD 146 million. Author correspondence with DAC, 20 November 2012.
- 17 NSPA recently participated in high-level staff talks with deputy director-level representatives of the Russian demilitarization industry. These talks may result in a cooperative effort between NATO and the Russian Federation in the area of ammunition demilitarization, initially as an exchange of technical information (author correspondence with NSPA, October 2012).
- 18 The four plants are state enterprise Ukroboronservice (demilitarization capacity of 12,000 tonnes of ammunition per year, including use of domestically produced explosive waste incinerator); state enterprise Ukroboronleasing (demilitarization capacity of 33,000 small arms and light weapons per month); Shostka State Research Institute for Chemical Products (demilitarization capacity of 20,000 tonnes of ammunition per year);

- Donetsk governmental plant of chemical products (demilitarization capacity of an explosive waste incinerator procured by NSPA from El Dorado Engineering, Inc., 22,000 7.62 mm rounds per hour, plus 440 fuses per 8-hour shift). Author correspondence with NSPA, October 2012.
- 19 The Ukraine State Demilitarization Programme foresees the demilitarization of 474,000 tonnes of ammunition by the end of 2017. Author correspondence with NSPA Project Office, Ukraine, 13 November 2012.
- 20 The Geneva International Centre for Humanitarian Demining defines cluster munitions as ‘conventional munitions each of which is designed to disperse or release multiple submunitions (in some cases called “bomblets”) over an area that may extend to several hundred square metres. The general definition of this weapon describes both the container (also called a dispenser or “parent munition”) and the submunitions it holds’ (GICHD, 2009, p. 8).
- 21 An MLRS artillery rocket such as the M26 contains a warhead that delivers 644 M77 sub-munitions. The disposal of MLRS warheads poses challenges in terms of the massive number of bomblets that must be handled.
- 22 In contrast, the destruction of a BL755 cluster bomb reportedly costs anywhere from EUR 250 to EUR 400 (USD 350–550), depending on the degree of material recycling (Towndrow, 2010; Bohle, 2010, p. 18).
- 23 Author correspondence with NSPA and Brian Jeffers, director, marketing division, Nammo, December 2012.
- 24 Dual-purpose improved conventional munitions are dispensed in large numbers using projectiles or artillery rockets, such as MLRS (GICHD, 2009, p. 13).
- 25 For a preliminary overview of these techniques, see Wilkinson (2006, annexe 1).
- 26 One launch pod contains six standard MLRS rockets.
- 27 The measurement is sometimes referred to as net explosive content, net explosive mass, or net explosive weight (in US pounds). Net explosive quantity, expressed in kilograms, is ‘the total explosive content present in a container, ammunition, building etc, unless it has been determined that the effective quantity is significantly different from the actual quantity. It does not include such substances as white phosphorous, smoke or incendiary compositions unless these substances contribute significantly to the dominant hazard of the hazard division concerned’ (UNODA, 2011a, p. 20).
- 28 Author correspondence with DAC, 20 November 2012.
- 29 Aside from the biannual US DoD Global Demilitarization Symposium, there is no international trade body to give voice to or represent the demilitarization industry.
- 30 The Act gives the Environmental Protection Agency the authority to control the generation, transportation, treatment, storage, and disposal of hazardous waste (USEPA, n.d.).
- 31 Concerning waste management, an EU directive specifically excludes decommissioned explosives from its scope, but the text does not define what ‘decommissioned’ means (EU, 2008). Industry representatives report that they consider decommissioned explosives to be those ‘destined for demilitarization’. The exclusion provides significant advantages for those involved in demilitarization, as much of the legislation relating to waste and stemming from the directive no longer applies. However, the products of disposal, packaging waste, and other by-products are not exempted from EU environmental requirements (Honey, 2011, p. 11.3; Stalker, 2011b, p. 17.4).
- 32 OHSAS 18000 is an international series of occupational health and safety management system standards.
- 33 AQAP stands for Allied Quality Assurance Publications; AQAP 2130 is the NATO quality assurance requirement for inspections and tests.
- 34 In 2000 an operator died during the start-up of a 155 mm improved conventional munition projectile demilitarization process in the Lindesberg facility; in 2006 an operator died during the demilitarization process utilizing a detonation chamber; and an explosion occurred during the fully automatic disassembly of MLRS M26—the plant reported only material damage (Nammo, 2012).
- 35 Author correspondence with NSPA, 3 January 2012.
- 36 Author correspondence with an EXPAL product manager for demilitarization, January 2012.
- 37 Survey researchers’ notes taken during the 3rd RASR workshop, 2–4 November 2010, Sarajevo.
- 38 Explosions that occur during industrial demilitarization do not qualify as unplanned explosions at munitions sites. However, the database definition covers explosions of ammunition that is being stockpiled in a plant’s depot prior to demilitarization.
- 39 Ammonium perchlorate is the oxidizer and primary ingredient in solid propellant for most large rocket motors, including MLRS. White phosphorus is used in ammunition such as mortar projectiles, artillery shells, and grenades as an obscurant and incendiary to screen, shield, or protect troops, to blind or isolate the enemy, or to mark their targets (Voie, 2011; Karsrud, Voie, and Longva, 2011; Walsh, Walsh, and Collins, 2011).
- 40 Air pollutants include volatile organic compounds, acidic gases (such as nitrogen oxides and sulphur dioxide), particulate matter, heavy metals, and dioxins. Pink water refers to water contaminated with TNT, RDX, HMX, or the by-products of these explosives (MSIAC, 2006).
- 41 Author interview with David Towndrow, NSPA, 23 July 2012.
- 42 Notably, one of the products of burning TNT is nitric oxide, a major air pollutant.
- 43 High-order detonations occur when a round fully functions as designed. Specialists define a high-order detonation as ‘the consumption of a minimum of 99.99% of the explosive load during detonation’ and low-order detonation as ‘a detonation that propagates incorrectly, fragmenting most of the ordnance and consuming around 75% to 99.99% of the [high-explosive] load’ (Walsh et al., 2011).

- 44 Kick-out is the ejection of undetonated devices and can be minimized by the proper placement of multiple charges.
- 45 R3 processes account for the other 68 per cent. Author correspondence with DAC, 20 November 2012.
- 46 MSIAC (2006); Nordquist, Cramer, and Williams (2009); Park, Eng, and Garrard (2011); Thompson and Holcum (2011a, p. 28.14).
- 47 As many of the alternative (and high-tech) methods proved economically unsustainable in the United States, the country adopted the existing, simpler methods of mechanical cutting and melt-out that had served Europe so well (see Table 9.3).
- 48 A barmine is a long, rectangular anti-tank landmine.
- 49 The United Kingdom estimated that the open burning of 170,000 barmines would cost GBP 1 (USD 1.60) per barmine, as opposed to GBP 13 (USD 20) per barmine by industrial processing in Europe (RTO, 2010, p. 3-23). Extensive work was reportedly carried out to determine and monitor the environmental impact, and to inform regulators and local populations.
- 50 Trinitrotoluene (TNT) is a crystal that melts at around 81°C. In the melt-cast process, explosive mixtures based on TNT are liquefied by raising the temperature above 81°C, then cast inside of shells. The temperature is subsequently lowered to let the explosives solidify (Ampleman, 2011).
- 51 In order to characterize the chemicals, components, and materials present in munitions, some nations have established databases. The largest of these is the Munition Items Disposition Action System (MIDAS) database managed by the US Army Defense Ammunition Center. Originally established in the early 1990s to identify alternatives to OB/OD, the system now encompasses virtually the entire US inventory of munitions (Thompson and Holcum, 2011a; 2011b).
- 52 Author interview with David Towndrow, NSPA, 23 July 2012.
- 53 TNT yields approximately EUR 400 (USD 520) per tonne. Author correspondence with Adrian Wilkinson, ammunition specialist, December 2012.

BIBLIOGRAPHY

- Ampleman, Guy. 2011. 'Development of New Insensitive and Greener Explosives and Gun Propellants.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Anderson, Curtis. 2001. 'Qualification of Recycled TNT for Use in the Production of HE Loaded Projectiles and Bombs.' *JOCG Demil Express*, Vol. 9. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol09.pdf>>
- Bohle, Vera. 2010. 'Implementation Aspects of Stockpile Destruction.' *Disarmament Forum*, Vol. 1, pp. 13–24. Geneva: United Nations Institute for Disarmament Research. <<http://www.unidir.org/pdf/articles/pdf-art2928.pdf>>
- Boyer, Travis. 2012. 'US Mobile Demilitarization Investment Study Overview for NATO Maintenance and Supply Agency (NAMSA).' Presentation made at the NAMSA conference on Mobile Equipment for Ammunition Demilitarization, Capellen, Luxembourg, 31 May.
- Carlson, Kathryn Blaze. 2012. 'DND's \$23M cluster bomb stockpile will cost \$2M to junk.' *National Post*. 19 July. <<http://news.nationalpost.com/2012/07/19/dnds-23m-cluster-bomb-stockpile-will-cost-2m-to-junk/>>
- Courtney-Green, Peter. 2005. 'Effective Disposal of Surplus Munitions Stockpiles.' Presentation made at Defence Logistics 2005, London, 8 February. <http://www.namsa.nato.int/Demil/docs/Defence_Logistics_2005.pdf>
- . 2007. 'Demilitarization Developments in NATO.' Paper presented at the 15th Annual Global Demilitarization Symposium and Exhibition, Reno, Nevada, 15 May. <http://www.dtic.mil/ndia/2007global_demil/GeneralSessionTuesday/T1420CourtneyGreen.pdf>
- Dillard, David. 2010. 'MLRS Recycling Facility Coming to Anniston.' *JOCG Demil Express*, Vol. 27. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol27.pdf>>
- DoD OB/OD Workgroup. 2008. 'Development of Emission Factors to Sustain Conventional OB and OD Operations at DOD Facilities.' *JOCG Demil Express*, Vol. 24. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol24.pdf>>
- Dynasafe Demil Systems AB. 2012. 'Small Arms Survey Questionnaire for Industrial Demilitarization Contractors.' Unpublished questionnaire.
- DynCorp International. 2012. 'Small Arms Survey Questionnaire for Industrial Demilitarization Contractors.' Unpublished questionnaire.
- El Dorado Engineering, Inc. 2012. *Capabilities and Experience*. Brochure.
- Emerson, Steve and David Towndrow. 2008. 'Barmine Disposal.' Presentation made at the 16th Annual Global Demilitarization Symposium, Salt Lake City, Utah, 5–8 May.
- EU (European Union). 2000. Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste. <<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:332:0091:0111:EN:PDF>>
- . 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. <<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF>>
- . 2010. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (Integrated Pollution Prevention and Control). <<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010L0075:EN:NOT>>
- European Commission. 2012. 'Current Rules, Thresholds, and Guidelines.' <http://ec.europa.eu/internal_market/publicprocurement/rules/current/index_en.htm>

- Follin, John. 2012. 'Transportable Cryofracture Process for the Destruction of Munitions.' Presentation made at the NAMSA conference on Mobile Equipment for Ammunition Demilitarization, Capellen, Luxembourg, 31 May.
- France. 2008. *Synbèse du rapport sur le démantèlement des matériels d'armement*. Paris: Ministry of Defence. <http://www.relec.es/RECICLADO_ELECTRONICO/GestionRAEEs/Franciaresiduosmilitares.pdf>
- Genov, Borislav Georgiev, Hristo Ivanov Hristov, and Hristo Petrov Hristov. 2011. 'Bulgarian Defence Institute Future Environmental Initiatives.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Gibbs, Larry. 2010. 'My Perspective on Enterprise Challenges.' *JOCG Demil Express*, Vol. 28. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol28.pdf>>
- GICHD (Geneva International Centre for Humanitarian Demining). 2009. *A Guide to Cluster Munitions*, 2nd edn. <<http://www.gichd.org/publications/subject/cluster-munitions>>
- Gobinet, Pierre. 2012. *Capabilities and Capacities: A Survey of South-east Europe's Demilitarization Infrastructure*. Special Report No. 15. Geneva: Small Arms Survey. April. <<http://www.smallarmssurvey.org/fileadmin/docs/C-Special-reports/SAS-SR15-South-East-Europe-Demilitarization.pdf>>
- . 2013. 'Dynamic Disposal: An Introduction to Mobile and Transportable Industrial Ammunition Demilitarization Equipment.' RASR Issue Brief No. 3. Geneva: Small Arms Survey.
- and Claudio Gramizzi. 2011. 'Scraping the Barrel: The Trade in Surplus Ammunition.' Issue Brief No. 2. Geneva: Small Arms Survey. April. <<http://www.smallarmssurvey.org/fileadmin/docs/G-Issue-briefs/SAS-IB2-Scraping-the-barrel.pdf>>
- Gonzalez, Jose. 2010. *Office of the Secretary of Defense (OSD) Perspective*. Presentation for the 18th Annual Global Demilitarization Symposium and Exhibition, Tulsa, 11 May. <https://midas.dac.army.mil/Symposium/2010/10_Proceedings/A2_Gonzalez.pdf>
- Gustafson, Joan. 2003. 'Missile Recycling Center (MRC) Now a Reality.' *JOCG Demil Express*, Vol. 13. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol13.pdf>>
- Herbst, Eduard. 2007. 'Nammo Contract.' *JOCG Demil Express*, Vol. 22. Fall.
- Honey, Peter. 2011. 'NIAG Study Group 139 Report on Regulatory Aspects Relating to Demilitarisation and Disposal of Munitions.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Hsu, Peter, César Prunedá, and Solim Kwak. 2000. 'The Integrated Molten Salt Oxidation Plant.' *JOCG Demil Express*, Vol. 8. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol08.pdf>>
- IANS (Indo Asian News Service) and Ria Novosti. 2012. 'Russia to Scrap 3 mn tonnes of Ammunition.' 2 February. <http://www.thaindian.com/newsportal/world-news/russia-to-scrap-3-mn-tonnes-of-ammunition_100594885.html>
- Johnsen, Arnt, et al. 2011. 'Contamination of Energetic Materials in the Norwegian Firing Ranges.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Karsrud, Tove Engen, Øyvind Voie, and Kjetil Sager Longva. 2011. 'Environmentally Responsible Smoke Munitions.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- King, Benjamin and F. David Diaz. 2011. 'Preparing PSSM Programmes: Avoiding the Inevitable Problems?' In Benjamin King, ed. *Safer Stockpiles: Practitioners' Experiences with Physical Security and Stockpile Management (PSSM) Assistance Programmes*. Geneva: Small Arms Survey, pp. 8–47. <<http://www.smallarmssurvey.org/fileadmin/docs/B-Occasional-papers/SAS-OP27-Safer-Stockpiles.pdf>>
- Lazarevic, Jasna. 2012. *Costs and Consequences: Unplanned Explosions and Demilitarization in South-east Europe*. Special Report No. 18. Geneva: Small Arms Survey.
- Lucas, Sébastien. 2012. 'MBDA is Building a Munitions Demilitarization Capability in France.' Proceedings from the Military Green 2012 conference, 19–20 June, Brussels.
- MBDA. 2011. 'MBDA to Set Up Industrial Capability for the Demilitarization of Complex Munitions.' Press release. 25 November. <http://www.mbda-systems.com/mediagallery/news-files/PR_2011-11-25_EN-1-650.pdf>
- Mescavage, Gary. 2010. 'Implementation of Design for Demil (DFD) in the Joint Services.' Presentation made at the 18th Annual Global Demilitarization Symposium and Exhibition, Tulsa, 17 May. <https://tpm.dac.army.mil/events/Docs/2011GDS/GS-A_10.pdf>
- Meyer, Wilfried and Frank Winkler. 2012. 'GD-OTS/SAB Mobile Demil Equipment.' Presentation made at the NATO Maintenance and Supply Agency conference on Mobile Equipment for Ammunition Demilitarization, Capellen, Luxembourg, 31 May.
- MSIAC (Munitions Safety Information Analysis Center). 2006. Review of Demilitarization and Disposal Techniques for Munitions and Related Materials. Brussels: North Atlantic Treaty Organization. <<http://www.rasrinitiative.org/pdfs/MSIAC-2006.pdf>>
- Nammo. 2012. 'Small Arms Survey Questionnaire for Industrial Demilitarization Contractors.' Unpublished questionnaire.
- NAMSA (North Atlantic Treaty Organization Maintenance and Supply Agency). 2009. *Proposal to Albania and United States Department of State Bureau of Political Affairs Office of Weapons Removal and Abatement for the Destruction of Surplus Ammunition Stocks in Albania*. December. Capellen, Luxembourg: NAMSA.
- NATO (North Atlantic Treaty Organization). 2010. *Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives (AASTP-1: Edition 1, Change 3)*. Brussels: NATO.

- NIAG (North Atlantic Treaty Organization Industrial Advisory Group). 2010. *Final Report of NIAG SG.139 Study on NATO Industrial Capability for Demilitarization and Disposal of Munitions*. 13 November. Unpublished document.
- Nordquist, Tyrone, Randall Cramer, and Ryan Williams. 2009. 'Teamwork Is the Key to Better Understanding of OB/OD Emissions.' *JOCG Demil Express*, Vol. 26. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol26.pdf>>
- Park, Jason, John Eng, and George Garrard. 2011. 'An Update of Policy and Legislation as it Pertains to the Disposal/Demilitarization of Ammunition & Explosives in the DND/CF.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Perala, Reijo. 2001. 'NAMMO BUCK GmbH, Germany Awarded 3-Year Contract for Demil of BL-755 Cluster Bombs'. *JOCG Demil Express*, Vol. 11. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol10.pdf>>
- . 2002. 'Nammo Creates Demil Division.' *JOCG Demil Express*, Vol. 10. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol10.pdf>>
- Peske, Tom. 2010. 'Crane Army Disposes of White Phosphorus Ammunition.' *JOCG Demil Express*, Vol. 27. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol27.pdf>>
- Peugeot, Frédéric. 2009. 'The Conventional Ammunition Stockpile Reduction & Destruction Problematic.' Presentation made at the First RASR Workshop, Zagreb, Croatia, 5–7 May. <<http://www.rasrinitiative.org/pdfs/workshop-1/RASR-Stockpile-Reduction.pdf>>
- Raferty, Brian. 2007. *Innovative Approaches for Recycling Munitions*. Presentation made at the 15th Annual Global Demilitarization Symposium and Exhibition, Reno, Nevada, 15 May. <http://www.dtic.mil/ndia/2007global_demil/GeneralSessionTuesday/T0850Raferty.pdf>
- . 2008. *Conventional Ammunition Demilitarization (Demil): A Growing Challenge*. January–March. <http://asc.army.mil/docs/pubs/alt/2008/1_JanFebMar/articles/38_Conventional_Ammunition_Demilitarization_%28Demil%29_-_A_Growing_Challenge_200801.pdf>
- RTO (Research and Technology Organization). 2010. *Environmental Impact of Munition and Propellant Disposal: Final Report of Task Group AVT-115*. AC/323 (AVT-115) TP/274. Neuilly-sur-Seine: RTO, North Atlantic Treaty Organization. <[http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-AVT-115//\\$\\$TR-AVT-115-ALL.pdf](http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-AVT-115//$$TR-AVT-115-ALL.pdf)>
- Schmit, Steven. 2009. 'Commercial Demilitarization of Explosive D Projectiles: A Demil R&D Success Story.' *JOCG Demil Express*, Vol. 25. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol25.pdf>>
- SEESAC (South Eastern and Eastern Europe Clearinghouse for the Control of Small Arms and Light Weapons). 2004. *SALW Ammunition Destruction: Environmental Releases from Open Burning (OB) and Open Detonation (OD) Events*. Belgrade: SEESAC. <<http://www.seesac.org/uploads/studyrep/Environmental.pdf>>
- Sina, Shkëlqim. 2011. 'Financial Support to Destruction of Surplus Weapons and Munitions.' Presentation made at the Centre for Security Cooperation (RACVIAC)–Pula Conference, May.
- Small Arms Survey. 2012. 'Unplanned Explosions at Munitions Sites.' 19 October. <<http://www.smallarmssurvey.org/weapons-and-markets/stockpiles/unplanned-explosions-at-munitions-sites.html>>
- Spreewerk Lübben GmbH. 2012. 'Small Arms Survey Questionnaire for Industrial Demilitarization Contractors.' Unpublished questionnaire.
- Stalker, David. 2011a. 'Design for Demilitarization (Including an Introduction to Design for the Environment).' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- . 2011b. 'Future Options for Disposal of Energetics.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Temple, Tracey and Geoff Hooper. 2011. 'Managing the Environmental Effects of Insensitive Munitions Compositions: Air, Land and Water.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Thompson, George. 2007. 'Web-Based MACS Emissions and Health Risk Assessment Modules.' *JOCG Demil Express*, Vol. 22. Fall. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol23.pdf>>
- and Jacqueline Holcum. 2011a. 'An Overview of the U.S. Demil, Range, "Green" and Other Munition Management Capabilities.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- and Jacqueline Holcum. 2011b. 'Automated and Web-based Munition Analytical Compliance Suite (MACS).' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- , George Kevin Kennedy, and Tyrone Nordquist. 2004. 'Integrated Munitions Analytical Compliance Suite (MACS).' *JOCG Demil Express*, Vol. 16. Fall.
- Towndrow, David. 2010. 'NAMSA's Involvement in the Demilitarization of Cluster Munitions 1996–2010.' Presentation made at the 18th Annual Global Demilitarization Symposium and Exhibition, Tulsa, 12 May. <https://midas.dac.army.mil/Symposium/2010/10_Proceedings/B2_Towndrow.pdf>
- . 2011a. 'Demilitarization Developments in NATO.' Presentation made at the 19th Global Demilitarization Symposium and Exhibition, Sparks, Nevada, 18 May.
- . 2011b. 'NAMSA and Its Role in Demilitarization.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- . 2012. 'Third NATO Trust Fund Project in Albania: Fourth Periodic Report, October–December 2011.' Albania Surplus Ammunition Demilitarization Trust Fund Project. Unpublished report.
- TRZK (Tehnički remontni zavod Kragujevac). 2012. 'Small Arms Survey Questionnaire for Industrial Demilitarization Contractors.' Unpublished questionnaire.

- UNDP (United Nations Development Programme) and Threat Resolution Ltd. 2004. *Bosnia and Herzegovina Small Arms and Light Weapons Ammunition Demilitarization Feasibility Study*. September. Sarajevo: UNDP. <<http://www.undp.ba/upload/publications/SALW%20Feasibility%20Study.pdf>>
- UNECE (United Nations Economic Commission for Europe). 2009. European Agreement concerning the International Carriage of Dangerous Goods by Road ('ADR'). As applicable from 1 January 2011. ECE/TRANS/215, Vols. I–II. Geneva: UNECE.
- . 2011a. 'Globally Harmonized System of Classification and Labelling of Chemicals (GHS).' 4th edn. <http://www.unece.org/trans/danger/publi/ghs/ghs_rev04/04files_e.html>
- . 2011b. 'UN Recommendations on the Transport of Dangerous Goods: Model Regulations.' 17th edn. <http://www.unece.org/trans/danger/publi/unrec/rev17/17files_e.html>
- UNEP (United Nations Environment Programme). 1989. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Châtelaine, Switzerland: UNEP. 22 March. <<http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf>>
- United States. 2004. National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors. US Code of Federal Regulations, Title 40, Part 63, Subpart EEE. 40CFR63.1200. July.
- UNODA (United Nations Office for Disarmament Affairs). 2011a. *International Ammunition Technical Guideline: Glossary of Terms, Definitions and Abbreviations*. IATG 01.40. <http://www.un.org/disarmament/convarms/Ammunition/IATG/docs/IATG01.40-Glossary_and_Definitions%28V.1%29.pdf>
- . 2011b. *International Ammunition Technical Guideline: Demilitarization and Destruction of Conventional Ammunition*. IATG 10.10. <http://www.un.org/disarmament/convarms/Ammunition/IATG/docs/IATG10.10-Demilitarization_and_Destruction%28V.1%29.pdf>
- . 2011c. *International Ammunition Technical Guideline: Quantity and Separation Distances*. IATG 02.20, 1st edn. <[http://www.un.org/disarmament/convarms/Ammunition/IATG/docs/IATG02.20-Quantity_and_Separation_Distances\(V.1\).pdf](http://www.un.org/disarmament/convarms/Ammunition/IATG/docs/IATG02.20-Quantity_and_Separation_Distances(V.1).pdf)>
- USDA (United States Department of the Army). 2011. 'Ammunition and Explosives Safety Standards.' Washington, DC: USDA.
- USEPA (United States Environmental Protection Agency). n.d. 'Summary of the Resource Conservation and Recovery Act.' <<http://www.epa.gov/regulations/laws/rcra.html>>
- Van Baalen, Mark and Peter Honey. 2011. *Final Report of NIAG SG.139 Study on NATO Industrial Capability for Demilitarization and Disposal of Munitions*. Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Voice of Russia. 2012. 'Russia to Upgrade Its Munitions Storage Facilities.' 2 February. <<http://english.ruvr.ru/2012/02/02/65200403.html>>
- Voie, Øyvind. 2011. 'Risk Assessment Tools for Management of Contaminated Sites—Source Characterization, Fate and Transport (AVT-197).' *Final Report of NIAG SG.139 Study on NATO Industrial Capability for Demilitarization and Disposal of Munitions*. Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Walsh, Marianne, Michael Walsh, and Charles Collins. 2011. 'Remediation of a Military Training Range Contaminated by White Phosphorus Ordnance.' Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Walsh, Michael, et al. 2011. 'Explosives Residues on Military Training Ranges.' *Final Report of NIAG SG.139 Study on NATO Industrial Capability for Demilitarization and Disposal of Munitions*. Presentation made at the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Wilkinson, Adrian. 2006. 'The Three Ds: Disposal, Demilitarization, and Destruction of Ammunition.' In Stéphanie Pézard and Holger Anders, eds. *Targeting Ammunition: A Primer*. Geneva: Small Arms Survey.
- Williams, Ryan. 2010. 'JOCG OB/OD Emissions Factor Review Protocol.' *JOCG Demil Express*, Vol. 27. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol27.pdf>>
- Wright, Jeff, Jeff Lee, and Larry Gunter. 2011. 'US Army Missile Recycling Overview.' Unpublished presentation for the RTO-MP-AVT-177 Symposium on Munition and Propellant Disposal and Its Impact on the Environment, 17–20 October, Edinburgh.
- Zaugg, Mark, et al. 2007. 'GD-OTS and EBV EEC Unveils New CBU Demil Line.' *JOCG Demil Express*, Vol. 21. Spring. <<https://tpm.dac.army.mil/events/Docs/DemilExpress/Vol21.pdf>>

ACKNOWLEDGEMENTS

Principal author

Pierre Gobinet