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**Planning and Management of the
Surplus Ammunition Disposal Process
in the Bulgarian Armed Forces**

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June 2004**

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**PLANNING AND MANAGEMENT OF THE SURPLUS
AMMUNITION DISPOSAL PROCESS IN THE BULGARIAN ARMED
FORCES**

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PLANNING AND MANAGEMENT OF THE SURPLUS AMMUNITION DISPOSAL PROCESS IN THE BULGARIAN ARMED FORCES

Abstract

This project analyzes the surplus ammunition disposal process in the Bulgarian Armed Forces. It explains how the system works, and considers whether it could better serve national security needs. The end of the Cold War and the ensuing doctrinal changes lead to a significant reduction in most European countries' armies. This leads, in turn, to huge piles of surplus ammunition, which pose threats to national security, to the environment, and to the defense budget. While some aspects of stockpile management and security do have political implications, the disposal process as a whole needs a detailed cost-benefit analysis. This project analyzes relevant data, takes existing constraints into consideration, and recommends possible technological and cost-reducing improvements.

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LIST OF ACRONYMS

APIT	Armor-Piercing Incendiary Tracing
APT	Armor-Penetration Tracing
AT	Anti-Tank
ATGM	Anti-Tank Guided Missile
CATTR	Central Artillery Technical Test Range
EU	European Union
GDP	Gross Domestic Product
HE	High Explosive
HEIT	High-Explosive Incendiary Tracing
HF	High Frequency
IAS	Integrated Alarm Systems
MLRS	Multiple Launch Rocket Systems
MOD	Ministry of Defense
NATO	North Atlantic Treaty Organization
OSCE	Organization for Security and Cooperation in Europe
PfP	Partnership for Peace
RDX	Cyclotrimethylenetrinitromin
SALW	Small Arms and Light Weapons
SAM	Surface-to-Air Missile
SEESAC	South Eastern Europe Clearinghouse for the Control of SALW
TNT	Trinitrotoluene (Trotyl)
UN	United Nations
UN	United Nations Development Program

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EXECUTIVE SUMMARY

The purpose of this professional report is to provide recommendations for surplus ammunition disposal in the Republic of Bulgaria. The report focuses on planning and managing the disposal process in the Bulgarian Armed Forces, but it stresses that the surplus ammunition problem requires immediate action at a national level.

The problem with the surplus ammunition is typical for former Warsaw Pact countries. It stems from the new world balance of power. Changes in military doctrines lead to reducing the Armed Forces and redefining their missions. Consequently, large quantities of serviceable ammunition are identified as surplus. Some ammunition types become obsolete with respect to the new force structure. Surpluses pose threats to the national security, the environment, and the defense budget.

The solution to this problem incorporates a robust surplus ammunition disposal process involving the following phases:

- Determining the exact surplus ammunition types and quantities;
- Determining, from the entire surplus, items for sale and for disposal;
- Determining, from the items for disposal, usable items and items for destruction;
- Analyzing the disposal options from technological, economic, and environmental perspective;
- Formulating a disposal plan;
- Executing a disposal plan.

The individual phases can be adjusted to meet the current political, economic, technological, environmental, and societal constraints.

The political constraints stem from being a party to international agreements and treaties for armament control and non-proliferation. The economic constraints come from the limited national resources. It is impossible to fund the surplus ammunition disposal process from the state budget only. The

technological constraints include lack of proper methods to dispose of certain ammunition types and limited utilization capacity of the available equipment. Labor safety and environmental protection issues must be incorporated in disposal methods. Therefore, safety and environmental constraints are associated with the technological constraints. The societal constraints originate from high unemployment in some regions due to economic restructuring and the decline of the country's military industry.

There are two generic approaches to solving the surplus ammunition problem:

- Long-term storage (or “temporizing”);
- Energetic reduction of the surplus stocks by utilization and destruction.

These two approaches have been analyzed in this report from technological and financial viewpoint. Long-term storage is technologically feasible and relatively cheaper and the “tangible” part of the analysis favors it. Ten years of storage would cost 39 million euro, while the disposal would cost 47 million euro. Proper disposal requires the establishment of an integrated Utilization Center, which entails investments of about 9.85 million euro. The “intangible” part of the analysis, however, highlights the advantages of energetic reduction.

Utilizing the surplus ammunition will result in a 30 percent rate of recovery (about 16.5 million euro). The expenses for storing the surplus ammunition for ten years constitute a considerable portion of the disposal operating costs. Moreover, the hazard of explosion increases with long-term storage.

If surplus ammunition disposal is initiated and properly executed, then money will be spent for utilization instead of for storage and sales revenue from secondary products will offset a certain portion of the expenses.

Therefore, energetic reduction is recommended. Determining what products to utilize and to destroy must be based on a detailed cost-benefit analysis, considering labor safety and environmental protection issues.

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I. INTRODUCTION

The end of the Cold War reshaped the world balance of power. In Europe, both the NATO member-states and the former Warsaw Pact countries changed their national security concepts and military doctrines. Defense resources had to be reallocated due to the new challenges of the international political, economic, and social environment.

The process of resizing and restructuring the armed forces in virtually all the countries inevitably leads to weapons and ammunition becoming surplus to current needs. The Republic of Bulgaria is not an exception. These surpluses are currently being stored in the Bulgarian Armed Forces, the Ministry of Interior, the defense industry, and other institutions.

With the new *Law on Defense and Armed Forces*¹ and following the execution of the *Plan for the Organizational Development of the Bulgarian Armed Forces* (Plan 2004), many military units have been demobilized and the rest have undergone a structural reform. New regulating documents have been developed and implemented in regard to the changes of the criteria for creating and echeloning ordnance stocks. These changes affect the displacement, storage, and safeguarding of the explosive ordnance. They also determine the quantities and the status of the surplus ammunition and how they will be disposed of.

All the explosive ordnance available in the Republic of Bulgaria is subject to technical checks and maintenance in the military units and to laboratory and firing ground tests at the Central Artillery Technical Test Range (CATTR) and the firing grounds of the defense industry according to the requirements of the existing directives.

¹ Appendix A contains a list of basic documents relevant to the Bulgarian surplus ammunition disposal process and used as sources of information in this professional report.

The storage, maintenance, and safeguarding is organized in compliance with the regulations. The ammunition for the weapon systems currently in service is stored in specially designed storage depots according to the compatibility requirements. In case of insufficient storage area, the surplus ammunition is stored in open sites at the technical territories of the artillery depots. Reinforced-concrete depots equipped with Integrated Alarm Systems (IAS) accommodate the small arms cartridges and the hand grenades. Depots with temperature and humidity control accommodate the explosive ordnance that requires a special mode of storage.

The technical checks, maintenance, and repair of the stored explosive ordnance correspond to the current regulations and use the available technological equipment.

The control tests analysis has shown that a certain percentage of the ammunition does not meet the technical requirements due to a reduced reserve of the powders and pyrotechnical compositions' chemical stability and to significant deviations of the ballistic features. For some of the products, like PG-7VM, the unsatisfactory parameters are typical for lots manufactured before 1976; for PG-9V - before 1973; for PG-9VM - before 1974 and for RPG-22 - before 1987². Significant changes in the pyrotechnical compositions of some components have resulted in deteriorated parameters of the artillery rounds. Such rounds should be taken out of storage and disposed of.

The technical assessment and the analysis of the demand in terms of types and quantities suggest that all explosive ordnance manufactured before 1970 should be considered for disposal. Small arms cartridges stored in sealed package have preserved the required parameters and will stay in service. Additional tests of the small arms ammunition lots manufactured before 1970 must be conducted depending on the demand and then the lots with positive

² *National Program for Utilization and Destruction of Surplus Ammunition in the Territory of the Republic of Bulgaria*, Sofia, 2004, p. 7.

results will be offered for sale. Disposal of surplus explosive ordnance with no market demand is also slated.

Experts from the Bulgarian Ministry of Defense have analyzed the surplus ammunition technical status. Based on the results of the laboratory and firing ground tests, the explosive ordnance is divided into two groups: for sale and for disposal.

Sale is recommended for the explosive ordnance with good technical properties and reserve of the chemical stability of their powders, explosive substances, and pyrotechnical compositions securing 60% of their initially set shelf life. The aircraft-launched ammunition is offered for sale with a remaining operational resource of 20 percent of the initially designated one.

Utilization³ or destruction is recommended for the explosive ordnance with faulty technical properties and reduced chemical stability reserve of their powders, explosive substances, and pyrotechnical compositions, as well as for the types of ammunition with no market demand.

The utilization is an up-to-date process and partially solves one of the major issues in the reform of the Bulgarian Armed Forces and the defense industries as a whole — the disposal of the surplus stocks. This process is labor-intensive and technologically complex. It requires modern technologies, technological equipment, skilled personnel, and significant funding.

Preliminary calculations suggest a required surplus ammunition disposal funding of about \$40 million.⁴ Such financial resources could be provided cumulatively: by the government budget, within the scope of the military and technical assistance among the NATO countries, by the Partnership for Peace (PfP) Trust Fund, and through bilateral agreements with donor countries and institutions. The PfP Trust Fund, for example, provides a framework and practical mechanism to enact initiatives to remove surplus weapons and ammunition from government inventories on a project basis. Projects are funded by NATO

³ The term “utilization” in this report is defined as “the process of dismantling ammunition and the subsequent use of its components.”

⁴ *National Program for Utilization and Destruction of Surplus Ammunition*, p. 8.

member countries under the coordination of a lead nation and the host nation supported by voluntary financial contributions.⁵ As part of a co-operation program between Bulgaria and the U.S. State Department, 77,050 small arms, 612 light weapons, 435 tons of small arms ammunition (6,896,216 rounds) and 135 tons of artillery and anti-tank ammunition (9,370 rounds) were destroyed in 2001.⁶ The co-operation with South Eastern Europe Clearinghouse for the Control of Small Arms and Light Weapons (SEESAC) and the United Nations Development Program (UNDP) resulted in the destruction of 4,500 AK-74 assault rifles and a significant amount of small arms and anti-tank ammunition.⁷ Another project funded the destruction or demilitarization of SS-23 and SCUD missile systems and FROG rocket systems, as agreed to by the governments of Bulgaria and the United States. All SS-23 and SCUD missile systems and FROG rocket systems in Bulgaria were destroyed or demilitarized rendering each system incapable of delivering a missile. These actions were completed by October 30, 2002 prior to the November 2002 NATO Summit at which Bulgaria received an invitation to join NATO.⁸

Of course, it would be difficult to provide all the necessary funding within one or two years. Actually, it is expected that the disposal financing process may take eight to ten years, or even longer.

The above statements infer that the surplus ammunition requires the establishment of regular storage conditions, control of the explosive substances and powders' status, safeguarding and strict recordkeeping, no matter if it is earmarked for sale or for disposal. The calculations for completing the Bulgarian

⁵ NATO, *Demilitarization and Conversion*, TRIntel, May 2003, available http://www.trltd.com/trintel/nato_demilitarization_and_conversion.php, accessed 10 March 2004.

⁶ *Controlling Small Arms Proliferation: The View from Bulgaria*, Bulgarian Red Cross/Saferworld seminar report, 2002, pp. 5, 11.

⁷ Adrian Wilkinson, *Support to Republic of Bulgaria Weapons Destruction*, AR/008 SEESAC Activity Report, 27 June 2003, available <http://www.seesac.org/reports/ar008.htm>, accessed 28 April 2004.

⁸ *Elimination of Bulgaria's Missiles and Rockets*, Non-proliferation and Disarmament Fund Project # 170, FY 2002, available <http://www.ndf.org/Projects/ViewProject.jsp?ProjectId=22>, accessed 06 May 2004.

Army ordnance stocks between 2002 and 2004 show that armament will decline with the army strength reduction while the quantities of surplus explosive ordnance will increase. At present, the surplus ammunition represents about 50 percent of the total available in the Bulgarian Armed Forces.

The further storage and maintenance of the ammunition will require a significant number of depots, storage areas, and skilled personnel. None of these will be available by the end of the military reform. This problem is equally valid for the other surplus explosive ordnance in Bulgarian territory beyond the Armed Forces' jurisdiction.

The solution to this problem seems to include sale and disposal. The disposal option itself comprises utilization and destruction. The further accumulation and storage of surplus explosive ordnance is hazardous. Although the sale option is preferable, it is subject to some constraints, which include the necessity to store and maintain the ammunition safely until its removal from the depot. The disposal option also faces specific constraints.

This professional report focuses on the disposal option and answers the following questions:

- What are the main phases of the surplus ammunition disposal planning and management process?
- What are the constraints of the surplus ammunition disposal planning and management process?
- Considering the storage capacities, the available technological practices, the financial analysis, and the constraints, what improvements can help solve the surplus ammunition disposal problem?

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II. DETERMINING THE TYPES AND QUANTITIES OF SURPLUS AMMUNITION

Success in reforming the Bulgarian Armed Forces depends on a number of political and economic factors. Reform inevitably leads to a new force structure, which reflects the new external and internal environment. The final decision on new force structure is an important initial step to determine which ammunition types and quantities fall under the “surplus” category. However, some surplus items can be earmarked even before the new force structure is set in stone.

The surplus ammunition is determined on the basis of the regulating documents defining the reserve quantities of rockets, missiles, artillery rounds, explosive substances, and powders required for the Bulgarian Armed Forces. It also includes the surplus powders stored as a state reserve.

It is necessary to analyze these quantities from different perspectives: quantity, relative share of each type, overall weight, relative share of the mass of powders and explosive substances, year of manufacturing, shelf life, and storage conditions.

The surplus ammunition in the territory of the Republic of Bulgaria has been determined by type, quantity, and tonnage as of January 1, 2003.

The biggest quantity is small arms cartridges, which amounts to about 400 million pieces and represents more than 98 percent of the total number of explosive ordnance, followed by the anti-aircraft ammunition, hand grenades, and anti-tank grenades.⁹

These numbers do not give a clear vision of the relative share of the different types of explosive ordnance. It is a good idea to calculate the ratios of the tonnage of each separate type of ammunition and the total tonnage of the explosive ordnance (Figure 1).

⁹ *National Program for Utilization and Destruction of Surplus Ammunition*, p. 24.

The mass of the small arms cartridges is 13.4 percent, the mass of the hand and anti-tank grenades is 7.1 percent, the mass of the anti-tank ammunition is 5.9 percent, the mass of the tank rounds is 17.7 percent, the artillery rounds have 16.7 percent, the one of the anti-aircraft rounds is 24.1 percent, etc. The tank, artillery and anti-aircraft ammunition represent the greatest volume for disposal: 58.5 percent of the total tonnage.

The Land Forces' surpluses have the greatest relative share, representing 92.3 percent of the total surplus mass. The surplus explosive ordnance in the Navy and in the Air Force amounts respectively to 0.4 percent for the naval ammunition, 0.4 percent for the aviation guided missiles, 0.6 percent for the air-launched non-guided rockets, 2.2 percent for the aviation bombs, and 0.6 percent for the aviation cartridges, fuses, and pyrocartridges. The engineering explosive ordnance represents 3.1 percent of the total mass, and the powders – 0.4 percent, respectively.

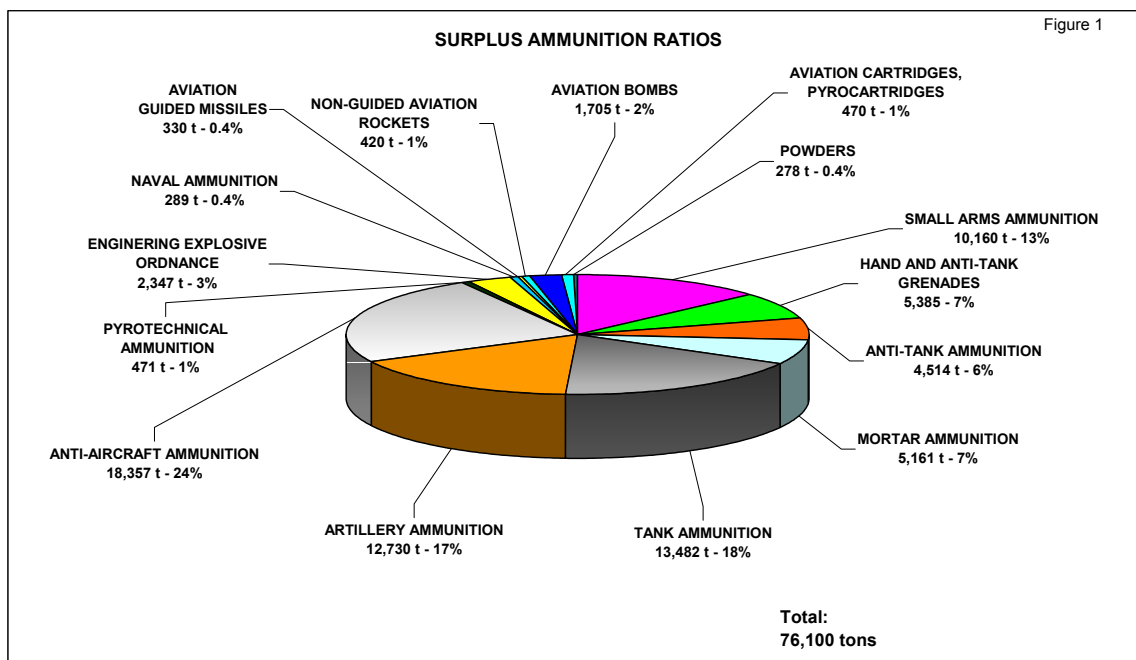


Figure 1. Surplus Ammunition Proportions (After *National Program for Utilization and Destruction of Surplus Ammunition in the Territory of the Republic of Bulgaria*)

As of January 1, 2005, the relative share of the surplus ammunition will be increased due to the downsizing of the Bulgarian Armed Forces. This increase involves mostly small arms cartridges, amounting to 1.6 percent of the total mass. The hand and anti-tank grenades will amount to 0.6 percent, the mortar rounds to 0.3 percent, and the artillery rounds to 0.6 percent.

The total mass of all types of surplus explosive ordnance for disposal is 69,684 tons as of January 1, 2003, and it will reach 76,100 tons by January 1, 2005.¹⁰

¹⁰ Ibid., p. 25.

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III. ANALYSIS OF THE TECHNICAL CONDITION OF THE SURPLUS AMMUNITION

How serviceable ammunition is mostly depends on its basic components: the explosive substances and the propellant powders.¹¹ A more detailed view on these components will clarify the classification of the surplus ammunition, based on the serviceability criterion.

A. INITIATING EXPLOSIVE SUBSTANCES (PRIMERS)

These explosive substances are often called primary, or primers, because they activate the detonation of the high-explosive fillings, called secondary ones, and ignite the propellant explosive substances.

The initiating explosive substances explode very easily with simple external influences like flame, impact, piercing, and friction. The burning of the initiating explosive substances is unstable even at atmospheric pressure and the detonation practically occurs immediately after their ignition. The basic types of initiating explosive substances include: detonating mercury, lead azide, lead trinitroresorcinol, and tetrazene.

The group of the initiating explosive substances also includes the ignition compositions whose burning speed is delayed and adjusted by special additives. The purpose of igniting compositions is to generate a flame beam that ignites the powder charges, the delayers in the remote squibs, the delayers in the fuses, and other explosive devices.

¹¹ Most of the technical data in this chapter is based on *Analysis of the Ammunition Utilization Problems* (Unpublished paper), Logistics Command – General Staff of the Bulgarian Army, Sofia, 2002.

B. HIGH-EXPLOSIVE SUBSTANCES

The substances belonging to that group normally detonate. These explosive substances do have the ability to burn. However, the burning process can become unstable and result in an explosion or detonation under certain conditions. The initiating explosive substances are used to activate the detonation of high-explosive substances. The above-mentioned simple types of external influences, which can initiate the primers, cannot cause a reliable detonation of the high-explosives. That is the reason high explosives are called *secondary explosive substances*. The high-explosive substances are used mainly for charging ammunition and other types of explosive devices.

Depending on their chemical composition, the high-explosive substances can be divided into several classes:

- Nitric-acid ethers or nitrates of the spirit or the hydrocarbon;
- Nitro-compounds. The nitro-compounds are the most important high-explosive substances and include: trinitrotoluene (trotyl, TNT), trinitroxylene (xylyl), trinitrophenol (picric acid), trinitrophenyl, methyl, nitramin (tetryl), cyclotrimethylenetrinitromin (RDX), and cyclotetramethylenetetranitromin (octogene);
- Explosive mixtures with oxidizers representing mixtures of an oxidizer with an explosive substance or a fuel.

Most ammunition types are charged generally with the following explosive substances:

- Trotyl (a basic high-explosive substance for charging many types of projectiles);
- RDX and RDX/trotyl alloys;
- Ten and tetryl (used for special small-caliber projectiles);

- Dinitrobenzene and dinitronaphthalene (used in some specific types of ammunition);
- Composite explosive substances with aluminum.

The trotyl deficiency in the past and in wartime has caused the development of substitutes: cheaper explosive substances with lower power based on the ammonium niter-ammatols. This type of explosive fillings is widely used to charge different types of artillery shells and aviation bombs. It should be noted that in wartime some explosive substances are produced according to wartime standards, which allow reduced characteristics of a certain explosive substance. A decision on the disposal option should consider this fact.

Trotyl is a product of nitrated toluene. Its chemical denomination “trinitrotoluene” (TNT) is a nitrocompound from the aromatic compounds. There are currently six TNT isomers having one common formula and differing by the different position of the nitrogroup within the benzene nucleus, resulting in their different physical and chemical properties. The alpha-isomer is used as an explosive substance for charging the explosive ordnance.

TNT has a high chemical stability. Continuous heating at temperature up to 130°C does not significantly affect its explosive properties. Visible decomposition happens only at temperatures above 150°C. TNT also has high physical stability. With proper storage, pure trotyl does not change its properties for a long period of time. Artillery ordnance charged with pure trotyl can be stored in the depots for years and even for decades.

TNT is a low-sensitive explosive substance and rarely detonates in a cast form. Pressed trotyl is more susceptible to detonation. Trotyl needs a powerful detonator to provide a reliable detonation of the charge. As a rule, the detonator is made of more powerful and sensitive explosive substances – tetryl, ten, and RDX.

TNT has a low sensitivity to mechanical impacts. If a weight with a mass of 10 kg falls over a trotyl layer from 25 cm height, it causes explosions in four to eight percent of the time. As a rule, there is no detonation when a bullet hits TNT. TNT is very useful for military purposes because of its safety in firing, i.e. due to its insensitivity to jolts and jerks during firing.

RDX (trimethylenetrinitramin) is a product of the urotropine nitration. It is included in the group of the powerful high-explosive substances. In most cases the RDX is used with a phlegmatizer, which reduces the sensitivity of RDX to external influences and improves its pressing capacity. Pure RDX is difficult to press. RDX sensitivity to mechanical influences is significantly higher than TNT sensitivity. RDX is also more susceptible to detonation. It is more powerful than TNT and actually is one of the most powerful explosive substances with a detonation speed of 8,380 m/sec.

The RDX is not hygroscopic and it is practically insoluble in water. It resists dissolving by spirit, but is easily dissolved by acetone. RDX does not interact with metals. Diluted alkali and acids do not influence RDX. However, concentrated acids generally decompose it. Concentrated nitric acid, on the other hand, dissolves it without decomposition.

Ten is a nitric-acid ether of pentaerythrite. Its detonation sensitivity is a little higher than for RDX and the other secondary explosive substances. The detonation speed is 7,900 m/sec with explosive substance density of 1,600 kg/m³. As a rule, usage of Ten requires retarding by adding some (up to 5 percent) paraffin, wax, or other substance. Thus, the shock sensitivity of Ten is reduced while its operability and detonation are preserved.

Pure Ten is used as a secondary charge of detonating primers. Phlegmatized Ten is applicable for charging detonating cords, detonators, shaped charges, and other explosive devices.

Tetryl is a powerful high-explosive substance. It is highly shock-sensitive, with a detonation speed of 7,470 m/sec. Tetryl has a significantly higher

explosive capacity as well as a higher sensitivity to detonation than TNT. Tetryl is used mainly in the manufacture of detonators and detonating primers. It is highly sensitive to mechanical influences. This is the reason it is not suitable for charging ammunition, except for the small caliber projectiles both in pure and retarded form. Some alloys of Tetryl with TNT or RDX were used during World War I for charging some projectiles, bombs, mines, and torpedoes.

Dinitrobenzene is a nitro-derivative of the benzene and belongs to the group of relatively less powerful high-explosive substances. It is a strong poisonous substance and thus it can be used only in restricted cases as an additive to other explosive substances. It was used in greater quantities as a trotyl substitute during World War I in Germany and later in Russia, and also during World War II.

Dinitrobenzene is a chemically neutral substance and does not react with metals. It has a good stability. Its sensitivity to chemical influences is about half that of TNT. Dinitrobenzene power is 10 to 15 percent smaller than the power of trotyl. Its detonation speed is 6,100 m/sec. It is impossible in practice to use a mixture of dinitrobenzene and TNT because this mixture has a low melting point.

Nitronaphthalenes are aromatic nitrocompounds and they are usually obtained as isomeric mixtures. Out of the four possible derivatives, *dinitronaphthalene* has a practical application for military purposes and was used for charging ammunition during World War II.

Dinitronaphthalene is a very weak explosive substance and has no independent application. It is widely used in mixtures with ammonium nitrate, known as dinaphthalene or dinaphtite mixtures. The most frequently used mixture contains 88 percent ammonium nitrate and 12 percent dinitronaphthalene. This mixture was used during World War II for charging artillery shells and mines with steel-cast iron cases.

The group of the *ammonium-niter* explosive substances includes the ammonites, which are mechanical mixtures of ammonium niter and another fuel or another explosive substance.

The *ammatols* are mixtures of the ammonium niter and trotyl. The ammatols are a good substitute for TNT, and their production and use in wartime is substantial.

Generally the properties of the ammatols are determined by the corresponding properties of the ammonium niter. The ammatols are hygroscopic, and they interact with metals in the presence of moisture. This results in separation of ammonia, which reacts with the trotyl and forms explosive compounds that are sensitive to heat and explosive influences. Hence, ammunition charged with ammatols cannot be stored for a long time.

The explosive composition *TA* (77.5 percent trotyl and 22.5 percent aluminum powder) is used for charging mine sweepers. The powerful explosive mixture *TGA* (60 percent trotyl, 24 percent RDX, and 16 percent aluminum powder) is used for charging torpedoes and naval mines. This composition belongs to the cast group. Therefore, charging is done by the casting method. Five compositions of the *TGA* type are widely known:

- Compositions, susceptible to casting: *TG-20* (20 percent RDX and 80 percent trotyl), *TG-30* (30 percent RDX and 70 percent TNT), *TGA* (40 percent RDX, 50 percent TNT, and 10 percent aluminum). These compositions have been used mainly for charging large-sized products, like aviation bombs or torpedoes.
- Compositions, not susceptible to casting: *A-IX-1* (80 percent retarded RDX and 20 percent aluminum powder) and *A-IX-2* (80 percent RDX and 20 percent aluminum powder). Those compositions have been used mainly for charging anti-tank projectiles and the projectiles for the tank and aviation guns.

C. PROPELLANT EXPLOSIVE SUBSTANCES OR POWDERS

The substances from that group have a specific type of explosive transformation – burning, which is not transformed into a detonation even under the high pressures resulting from the conditions of the firing. Those substances are intended to relay the motion of the bullet or the projectile in the groove of the barrel or in the body of the gun, as well as to transfer the motion of the rocket projectiles.

The propellant explosive substances can be divided into two classes according to their physical and chemical structure: (1) nitrocellulose powders and (2) solid composite rocket fuels.

The *nitrocellulose powders* with a nitrocellulose base are plastified with some type of solvent. Depending on the plastifier's volatility, the nitrocellulose powders are divided into the following categories:

- Nitrocellulose powders made with the use of a volatile solvent (plastifier), which almost completely separates itself from the powder mass during the consequent production phases. These powders are also called *pyroxyline powders*.
- Nitrocellulose powders made with the use of a hardly volatile or non-volatile solvent (plastifier), which remains completely inside the powder mass. The spirit nitrates nitroglycerine and nitrodiglycol are mainly used as non-volatile solvents (plastifiers). These powders are called *ballistite powders*. The ballistite powders are called, for example, nitroglycerine or nitrodiglycol, depending on the name of the spirit nitrate used as a non-volatile solvent. Trinitrotoluene or dinitrotoluene is used as a non-volatile solvent (plastifier).

- Nitrocellulose powders made with a mixture of solvents, volatile and non-volatile (for instance, nitroglycerine with acetone), are called *cordite powders*.

Solid composite pyrotechnical fuels are produced as mixtures of (1) oxidizers and (2) burning and bonding substances (polymers).

D. CLASSIFICATION OF THE SURPLUS AMMUNITION ACCORDING TO THE SERVICEABILITY CRITERION

All surplus explosive ordnance in Bulgarian territory is subject to scheduled technical checks and maintenance, specified by relevant regulations and directives. The laboratory and field tests at the Central Artillery Technical Testing Range (CATTR) have been performed regularly and in compliance with the schedules. All lots of tested ammunition that did not meet the requirements of the programs and the guidelines have been banned for firing, collected from the military units, and disposed of. As a result of those activities, there is presently no surplus ammunition that has been banned for firing.

Despite the above circumstances, it is reasonable to analyze the ammunition's technical status. Such an analysis will reveal the typical changes in the tactical and technical parameters.

Checking the values of these parameters for every type of surplus ammunition is performed as the first step of the disposal process. At this stage, the surplus inventory is sorted according to the manufacturing date criterion. It is expected that older explosive ordnance would have a greater deviation from the requirements and decreased chemical stability of the powders and explosive substances. These parameters are likely to reach values that categorize them as unfit for further storage, maintenance, and service. It is worth considering that a great part of the surplus ammunition is being stored in open sites, and this significantly accelerates the ageing processes. Open-storage items would sooner become unserviceable.

Laboratory and field test statistics show that most ammunition types become unserviceable after about thirty years of storage. Based on this assumption, all surplus explosive ordnance can be divided into “produced before 1975” and “produced after 1975.”

The first group includes the whole quantity of:

- 57 mm rounds with armor-penetration tracing (APT) projectile;
- 100 mm rounds with remote-fragmentation projectile;
- All types of 76.2 mm rounds;
- 106 mm agitator rounds;
- All 122 mm shaped-charge rounds for M-30;
- All special explosive ordnance for M-30;
- All types of explosive ordnance for 122 mm A-19 gun;
- 130 mm rounds HE full-charge rounds for M-46;
- 130 mm rocket projectiles for R-2;
- All hand grenades F-1 and RG-42;
- All 7.62 mm cartridges for ordinary and machine gun pistol;
- All 7.92 mm and 8 mm cartridges;
- All 7.62 mm cartridges with light and heavy bullet;
- All types of 12.7 mm cartridges, and all 40 mm illumination and agitator rockets.

Significant statistical evidence suggests that these types of ammunition have undergone enough chemical deterioration to categorize them as unserviceable.

This group also includes some of the following ammunition types produced before 1975:

- 42 percent of the 57 mm fragmentation tracer rounds, 120 mm HE mortar bombs, and the PG-9V rounds;
- 18 percent of the 100 mm rounds with HE projectile/full-charge, and 100 mm shaped-charge rounds;
- 30 percent of the 122 mm rounds with HE projectile and reduced charge for M-30, 130 mm rounds with armor-piercing (AP) projectile for M-46, 7.62 mm cartridges model 1943 with a tracer bullet, 14.5 mm cartridges with AP and AP-incendiary bullet;
- 21 percent of the 152 mm rounds with HE projectile/full-charge for D-20;
- 46 percent of the 7.62 mm cartridges model 1943 with a steel-core bullet;
- 49 percent of the 152 mm rounds with an AP projectile for ML-20;
- 55 percent of the 100 mm rounds with an armor-piercing projectile;
- 59 percent of the 122 mm rounds with HE projectile/full-charge for ML-20;
- 76 percent of the 152 mm rounds with a concrete-piercing projectile, 130 mm rounds with a reduced charge and HE projectile for M-46, and 82 mm fragmentation mortar bombs;
- 85 percent of the 100 mm rounds with a sub-caliber projectile and the PG-7V/PG-7VM rounds;
- 92 percent of the 14.5 mm cartridges with an instant incendiary bullet;
- 4 percent of the 7.62 mm cartridges model 908/30 with tracer bullet and with a steel-core bullet.

The second group includes the ammunition lots manufactured after 1975. It is considered that their technical condition classifies them as fit for combat use.

This group comprises all quantities of ATGM 9M14M, the 23-mm rounds with High-Explosive Incendiary Tracing (HEIT) and Armor-Piercing Incendiary Tracing (APIT) projectile, 100 mm rounds with HE projectile for MT-12, 122 mm shaped-charge rounds for 2S1, the OG-9VM rounds, hand grenades RGO-78, 5.45 mm cartridges with a tracer bullet and steel-core bullet, 9 mm pistol cartridges, and 116 mm illumination projectiles.

The surplus powder quantities are determined by their production year. The oldest lots have been earmarked as surplus. They have a reduced reserve of chemical stability and significant degradation in their ballistic characteristics.

The technical parameters of the ammunition currently in service also change over time. Typical examples include: ammunition with pyrotechnical components and the missiles from the tactical, anti-tank, anti-aircraft, and anti-aircraft portable systems. This process will also affect the remaining explosive ordnance at a later stage. In other words, certain quantities of ammunition must be disposed of on a regular basis in the future.

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IV. ANALYSIS OF THE METHODS AND TECHNOLOGIES FOR AMMUNITION DISPOSAL

A. DISPOSAL METHODS

As previously mentioned, this professional report focuses on two options for disposing of surplus ammunition: utilization and destruction.

Some years ago, the destruction option dominated mostly for two reasons. First, the bipolar world provided greater opportunities for sale. Today, the political constraints in the arms trade are significant. Second, surpluses were negligible in a static force structure. The Armed Forces' downsizing and restructuring nowadays leads to vast quantities of surplus ammunition.

At present, utilization tends to be the basic method for disposal. It involves dismantling the ammunition and the consequent recycling of the components.

Ammunition disposal is a high-risk activity that requires qualified experts, proper technical equipment, and facilities meeting the safety requirements.

The technological process of extracting the explosive fillings from the explosive ordnance cases is the most dangerous and complicated phase of the entire utilization process. Selecting the technology depends on the explosive fillings' properties and the stipulated safety requirements during the extraction. According to these criteria, the explosive ordnance can be divided as follows:

- Ammunition with explosive substance arranged in separate pieces, usually of cylindrical shape. This type includes, for example, the high-explosive projectiles with calibers from 57 to 130 mm and the aviation non-guided rocket projectiles of the S-5/S-8 type.
- Ammunition with TNT bursting charge, which allows melting of the explosive filling. This type includes the high-explosive projectiles and mortar rounds with caliber from 76 to 152 mm, the anti-tank mines, the

high-explosive aviation bombs, the different types of naval mines, and the missile warheads.

- Ammunition with mixed bursting charge where the composition includes a cast TNT component (greater than 20 percent). This type includes the compositions: TNT-RDX, TNT-RDX-AI, TNT-AI, TNT-dinitronaphthalene, and naval mixtures. Such explosive substances are used to charge artillery mortar bombs, missile warheads, torpedoes, naval mines and bombs, different aviation bombs, non-guided projectiles, anti-tank and anti-personnel mines.
- Ammunition with mixed bursting charge without a cast TNT component or containing a cast component with less than 20 percent TNT content. This group includes the high-explosive increased power projectiles and non-guided rocket projectiles for Multiple Launch Rocket Systems (MLRS) like BM-21.
- Ammunition with liquid, plastic, or elastic explosive fillings. They comprise, for instance, different de-mining systems and the warheads of volume detonating systems.
- Cluster shaped explosive ordnance. This group comprises the missile warheads, the cluster artillery shells, the air-launched AP bombs, and the warheads of some anti-tank guided missiles.

The above classification of the surplus ammunition serves as a basis for selecting a disposal technology.

Explosive ordnance dismantling is a basic activity within the disposal procedure. Generally, the dismantling procedure involves detaching the fuse and opening the case to access and remove the explosive filling. Dismantling the fuse itself involves opening the fuse body to access the explosive filling, removing it, and subsequently disposing of the body and the explosive components.

Presently, no universal method for dismantling ammunition exists because of the many kinds of ammunition and fuses, and the varied composition of explosive fillings in both physical design and chemical properties.

Detaching the fuse from the case can be done by unscrewing it manually or by using automated devices. Detaching the integrated fuses of the shaped charges is done by supersonic cutting, hydraulic cutting or by mechanical cutting using special attachments.

The opening of the explosive ordnance case to access the explosive filling can be performed in different ways¹²:

- Explosive cutting of the projectile body;
- Burning the bodies with pyrotechnical compositions (thermite cutting);
- Supersonic cutting;
- Cutting (milling and drilling) using machining equipment;
- Chemically dissolving the bodies or their separate parts;
- Magneto-dynamic opening of the bodies;
- Breaking the explosive ordnance bodies after an initial cutting;
- Electro-chemical dissolving;
- Laser opening;
- Melting the explosive ordnance bodies;
- Hydraulic cutting.

All these methods have advantages and drawbacks.

The basic advantage of explosive cutting is that it does not require complex equipment. Technologies employed are power-independent and are

¹² This classification of available methods is based on *National Program for Utilization and Destruction of Surplus Ammunition*, pp. 43-46.

based on low-class explosion processes; hence, environmental pollution can be reduced to an acceptable level. However, this is not a very safe way of extraction because of the possibility of uncontrolled explosion and environment pollution.

Opening the bodies by using pyrotechnical compositions is relatively inexpensive. However, it is also not completely safe, as the hot particles and the high temperatures increase the possibility that the explosive filling may ignite. Also, the burning produces toxic elements, such as lead, mercury, and chlorine.

The ultrasonic way to open the explosive ordnance bodies in order to extract the explosive fillings is applicable with any type of explosive ordnance charging. Using water avoids explosion or fire and ensures environmental safety.

High-speed mechanical cutting of the ammunition cases is considered highly dangerous. This method is effective but requires accurate positioning and intensive cooling. It is suitable for thin-wall cases and requires a cutting speed several times higher than the explosive filling combustion speed.

As a rule, chemically dissolving the bodies is used only when the other methods are not applicable – most often with extremely dangerous products or small stocks.

The magneto-dynamic method is based on the plastic deformation of cylindrical bodies in strong magnetic fields. The experimental data and preliminary assessment suggests this method is suitable for extracting the linings of shaped charges and other warheads, for example.

Explosive ordnance bodies can be broken in different media: air, water, or chemically active liquids. This method is relatively simple and highly effective. The thinner bodies are opened directly, while the thicker ones require some initial preparation. Operations under this process should be performed in a liquid medium to avoid spreading hazardous particles in the air and to decrease explosion and fire hazards. Breaking is performed in a chemically active environment when opening explosive devices containing toxic substances.

Electrochemical dissolving can be cost-effective when large quantities of ammunition with thick-wall metallic bodies must be disposed of. However, energy consumption and environmental hazards make this method unsuitable for opening the bodies of the classical ammunition types.

Laser cutting of ammunition cases to access the charged explosive filling increases productivity. It is useful for opening explosive ordnance bodies made of any material. It achieves this automatically, safely, quickly, and with a preset depth. However, cutting metals in this way requires intensive cooling and oxygen supply. There are some additional advantages: the absence of a mechanical or electrical influence on the processed metal and the high rate of productivity – the cutting speed reaches tens of centimeters per minute. The laser cutting is based on the thermal effect of the laser beam on the material. A 1 kW laser device can cut products with 14 mm-thick walls at a speed of 0.5 m/min.

Melting is useful for plastic materials with melting temperature up to 200°C. However, a considerable portion of ammunition cases features materials with melting temperature from 200 to 600°C. Thus, this method can hardly find a wide application.

Hydraulic cutting features a supersonic jet stream, which cuts the bodies of the ammunition warheads. The temperature in the cutting zone does not exceed 90°C and the width of the slot is minimal. The industrial application of the high-pressure liquid jets is safe and inexpensive. High-pressure hydraulic systems are a significant technological leap. They increase productivity, the quality of the products, and improve working conditions. This technology is considered to be most efficient and explosion-safe. Unlike laser cutting, which is precise but is still based on thermal destruction, hydraulic cutting is performed in cold conditions and thus the materials could be cut in an explosion-safe medium. This method enables the cleaning and removal of coatings with different chemical composition, as well as punching holes in hard and fragile materials using pulse liquid and abrasive liquid jets.

Based on the considerations above, the hydraulic jet-stream can be considered the most cost-effective, explosion-safe, and technologically advanced method. It can be automated when used on an industrial scale.

Given the wide range of explosive ordnance and the absence of universal dismantling methods, many alternative approaches for ammunition dismantling may yet be employed.

B. METHODS FOR EXTRACTING EXPLOSIVE SUBSTANCES

The method for extracting explosive substances from the ammunition cases depends on the type of energy consumed to destroy the bonds between the dispersion particles forming the charge. It also depends on the technological and design features of the explosive ordnance.

Different methods of extraction exist and have been used worldwide. However, many of them are not environmentally appropriate and have numerous disadvantages. It is important to extract the explosive substance and process it to a finished product in a complete technological cycle.

Experts in the field divide the available technological methods for extracting the explosive substances in two groups: physical and chemical methods.

Certain technological features define these methods. For instance, the physical methods are subdivided into thermal and mechanical, depending on the type of influence. The thermal methods are also subdivided in two types: cryogenic and melting.

The *cryogenic* method requires cooling of the product in a freezing chamber. Thus, extracting is performed by cooling at temperature of -196°C for three hours. Liquid nitrogen is normally used as a cooling agent. Then vibrations with a frequency of 30 to 50 Hz and an oscillation amplitude of $(2.5\div 3.0)\cdot 10^{-3}\text{m}$ are applied to the ammunition.

The *melting* sub-methods use different heat carriers, for example steam, silicone oil, paraffin, HF current, electromagnetic field, or ultrasonic pulses to extract the explosive substance.

The technological processes for mechanical extraction of the explosive substances comprise two basic groups. The *contact* group requires direct mechanical impact: drilling, crushing, hydrodynamic influence, centrifugal processing, or ejection. The *contactless* methods involve supersonic, magneto-dynamic, and pulse extraction.

The chemical methods of explosive extraction involve solvents and reactants.

These methods are based on the selection of an appropriate solvent or reagent for each explosive filling. The solvents and reagents interact with the explosive filling and form chemical products that do not explode. For instance, TNT, which is not hygroscopic and is practically insoluble in water, can be well dissolved in organic solutions, especially in acetone, benzene, toluene, and even in alcohol. TNT is also well dissolved in sulphuric and nitric acids. Under normal temperature, the acids do not oxidize the TNT, but only dissolve it and when this solution is diluted, the TNT crystallizes in its unchanged composition. However, the heated acids react with the TNT and this can cause an explosion. Similarly, TNT reacts with the alkali metals.

The RDX and octogene are also non-hygroscopic, practically insoluble in water and very well dissolved in acetone. They do not dissolve well in the ordinary solvents. The sulphuric acid dissolves RDX. The nitric acid dissolves RDX under normal temperature and decomposes it under increased temperature. Water also decomposes RDX.

The general disadvantages of the chemical methods may be connected with the changes in the chemical properties of the extracted explosive fillings, which cause additional difficulties when the extracted compositions are used again. Moreover, the chemical methods for extracting explosives represent the greatest hazard for the environment.

C. DESTRUCTION METHODS

Some types of explosive ordnance are not generally suitable for recycling and must be destroyed. The destruction normally involves demolition or burning.

Demolition by explosion should be performed at special sites (firing grounds, test ranges) with sufficient area, meeting the following requirements:

- The environmental pollution must not exceed the permissible limits.
- Labor safety norms must be observed.
- Distance from the storage facilities to the explosion sites should meet the safety requirements and, at the same time, minimize the transportation costs.

Explosion is recommended as a demolition method for ordnance with expired shelf life, for ammunition that cannot be dismantled, and for ammunition with negligible salvage value. However, it is worth considering that demolition of out-of-service explosive ordnance is regarded as a loss for two reasons. First, the fixed costs, the variable costs, and the overhead are considerable. They include the labor of scientists, engineers, workers, testers; materials (some of which are very precious), and the consumed power resources. Second, the demolition of the dismantled out-of-service explosive ordnance pollutes the soil, water, plants and air, and inevitably affects the health of people and animals. Based on these reasons, the mass demolition of the dismantled out-of-service explosive ordnance in open sites is inadmissible.

Explosive extraction accumulates explosive substances and waste products, which cannot be used and are subject to destruction by burning in open sites. The TNT equivalent of the explosive substance being burnt should not exceed 30 kg. All the burning conditions are specified in the relevant regulations. The basic requirement for destroying explosive substances by burning is to spread them on the ground in the form of a path, less than 0.5 m wide, while the layer thickness must not exceed 0.15 m.

The dry wastes of flaky TNT collected in polyethylene or paper bags have to be spread on the ground in one layer up to five times the width of the bag. These conditions provide safe burning that will not detonate TNT.

In order to increase productivity, burning the explosive substances is allowed if they are arranged in several paths separated from each other at a safe distance to avoid a chain detonation.

A great quantity of charges from blended rocket fuels are destroyed not only by explosion but also by burning in open sites. This contaminates the environment because burning one ton of such a fuel, composed of 70 percent ammonium perchlorate, 10 percent burning bonding substance, and 20 percent aluminum, emits 180 kg hydrochlorate and 400 kg dialuminum trioxide into the atmosphere. These compounds adversely affect people, plants, and wildlife. Therefore, reducing the harmful influence of the burning products represents an important environmental task.

D. CONTEMPORARY DISPOSAL TECHNOLOGIES

About 150 non-military applications of recycled explosive ordnance are used worldwide. Almost one half of them involve employing explosive substances. Many explosive materials are useful in the mining industry, petroleum and natural gas industry, stone-pits, etc. The salvaged metal from the cartridges and the projectile bodies can be used in tubes, roof covering elements, and other products.

The development of technologies for ammunition disposal differs from similar activities in other areas. Some specific features must be taken into consideration. The first specific feature is that the explosive ordnance contains substances, which represent a great potential hazard. The second feature refers to the integrated composition of the explosive ordnance. The initial ammunition design does not anticipate dismantling. The third feature is that the ammunition

contains significant quantities of explosive substances and powders, besides the metal parts that are easy to dispose of.

Therefore, the process of developing technologies for explosive ordnance disposal is accompanied by various additional problems.

Some types of explosive ordnance, especially those with high-explosive action, can be directly used for engineering activities in non-military industries. The analyses of the ammunition design, the explosive substances, their efficiency, and their safety characteristics show that explosives have many potential applications such as elongated de-mining charges, blasting charges, anti-tank mines, etc.

The technologies for destructing and crushing large objects by booster and shaped charges are quite common nowadays. These technologies are used for: separating misshaped casts in the metallurgical plants; crushing rock or ore massifs; crushing cold metal, frozen soil, reinforced concrete foundations; making trenches, canals, or petrol tank holders. They are also applicable for dismantling tanks and armored vehicles, submarines and ships, aircraft, ferroconcrete constructions, supports and bridges, pipes and pipelines, metal containers, or buildings. The basic advantages of this application include a significant reduction of labor costs and power consumption, relative simplicity and accessibility. Environmental and safety issues remain problematic, but they can be solved considering the contemporary level of technology.

New technologies have emerged worldwide to control the influence of explosions on different materials. They are designed to solve special tasks in the mining industry, the metallurgical and petroleum processing industries, construction, and machine engineering. Dual-purpose explosion technologies exist to process non-metal material blocks (like granite or marble); clean the surfaces of containers from ice or cold metal; apply coatings to the inner surfaces of complex configuration parts; and press different dust-like materials.

However, it must be noted that the industrial usage of the energetic materials, obtained through ammunition utilization needs a detailed safety analysis. Safety of industrial explosives is not comparable to the safety of military explosives. The latter are always used within a strong body protecting them from mechanical and other influences. Moreover, the level of quality control in the production of military explosive substances is higher and the purification methods are more precisely applied. Therefore, the industrial use of salvaged explosive substances requires additional protection from mechanical and heat influences. Water phlegmatization is the most frequently used technology for such protection. Gas bubbles, micro-spheres, and pigmented aluminum provide the detonation capacity of such jellied or emulsified explosive compositions. Therefore, obtaining reliable industrial explosives from conversion products is not an easy task. Introducing high-explosive fillings or powders in industrial explosives does not guarantee fully effective results. In fact, hazards ultimately increase.

The explosion synthesis of super-dispersed materials is another potential application of recycled explosive substances. The explosive synthesis of ultra-solid substances by detonation of salvaged explosives and powders is an efficient technology for obtaining rare materials with a wide industrial application.

Polishing systems have been developed on the basis of super-dispersed diamonds. They are used in the extremely fine processing of precise surfaces in electronics and optics. Super-disperse diamonds have a medical application through their capacity to transport antibodies to human cancer cells.

Super-dispersed diamonds represent an efficient anti-friction additive to motor and transmission oil. They also find application as active filler of composite polymer materials, facilitating the formation of perfect three-dimensional configurations and significantly increasing the strength and durability, as well as the thermal, radiation, and chemical stability of the materials. A new radiation-absorbing material has been created with super-disperse diamonds.

There are other possible applications for explosive substances. For instance, they can be used to obtain nitrogen oxides through burning with further oxidizing in nitric acid, which can interact with ammonia and turn into ammonium niter. The waste products based on TNT and other explosive substances can be used to obtain materials for the production of varnish and paint.

The scrap metal from the ammunition cartridges and cases represents an important portion of the salvage value. These high quality materials should be used in the national economy after processing. For instance, the bodies of the projectiles and the cartridges can be turned into pipes using screw rolling iron mills. The cartridges with cylindrical shape and variable wall thickness are especially suitable for the production of various commodities.

The cartridges can also be used in pyrometallurgical processes, which comprise melting and subsequent liquid phase restoration. Plastic deformation is another method for recycling artillery cartridges.

Some countries have developed a dry-run experimental technology for granulated TNT production. There is also a technology for emulsion granulating of utilized TNT and pyropowder. Experimental samples of charges with different TNT and pyroxyline content have been obtained.

Another possible application refers to the development of explosion seismic sources. For instance, the 100 mm and 300 mm naval rounds are used to create seismic shaped charges. The seismic charge is a cylindrical cardboard cartridge filled with powder elements obtained after dismantling the rounds, weighing 1 kg each.

New designs of bursting charges with different applications have been developed. The following designs of bursting charges are widely known:

- Elongated shaped charges for dismantling armored equipment and cutting large metal objects from 20 to 150 mm thick;

- Charges for making holes in harsh environmental conditions using explosive substance tubes;
- Auxiliary ring-shaped charges used for mass demolition activities;
- Remote action charges for demolishing stone covers over mountain roads and for inducing avalanches;
- Multi-purpose mass application initiating charges acting as intermediate detonators or independent charges.

Scientific and technological advances will probably generate other new technologies for ammunition disposal, which should successfully cope with the safety problems while increasing productivity.

E. TECHNOLOGICAL ISSUES AND CONSTRAINTS

Disposing of explosive ordnance and their components creates various technological problems. Detonating primers are an example. First, the timely disposal of the detonating primers is a difficult task due to the enormous scale of their production (millions of pieces). Second, handling primers is not explosion-safe. Third, the detonating primers themselves contain toxic substances.

Presently, the primers are either destroyed in special cabins, or they are used for initiating industrial explosive substances.

Extracting explosive substances from ammunition with expired shelf life and their further use presents potential safety hazards. Ageing explosive ordnance decomposes, interacts with the anti-corrosion coatings, and alters the initial design. The extent of such changes depends on the storage conditions and on the explosive ordnance design. Extracting the explosive fillings from the ammunition cases by melting or dispersion may lead to additional changes of the fillings due to the mixing with the anti-corrosion coatings. Destabilizing insoluble particles of the anti-corrosion coating and solid inclusions like chips or flakes may also pollute the extracted products. Thus, the extracted product may significantly

differ in its physical, chemical, and explosive properties from the product that has been initially used for charging. This may lead to an uncontrollable decomposition during the different processing stages, like the dismantling of the products, extraction of the charge and its further processing into an industrial product, the transportation, and the industrial use of the new explosive product.

The existing problems regarding the mechanical methods for dismantling ammunition require a detailed examination.

As stated above, the basic problem of the mechanical discharging methods is technological. The solution involves developing of physically reasonable methods and procedures to determine which technologies to apply. The procedures should consider the fundamental characteristics of the explosive substances and should be based on how the explosives interact with the knife, drill, liquid jet, or other operational tools.

The second problem is the operational cost incurred in the dismantling.

Third, the problem of future use of the ammunition components is worth considering. These components must have their initial status preserved. The dismantling technologies based on high-pressure liquid jets are recommended, because they meet that requirement. This process is chip-free and also avoids an intensive impact of the solid operational tool on the extremely sensitive explosive charge.

Solving the problems of ammunition utilization is determined to a great extent by the technological ability to provide safe working conditions. Technically, the task of dismantling explosive ordnance to its initial composite elements is comparable in complexity to their production and assembly. However, dismantling is significantly more dangerous and unpredictable than charging.

Ammunition design reflects charging technologies. However, performing the reverse task – extracting the charge out of the body – has not been foreseen in explosive ordnance design. Consequently, dismantling can involve mainly

unconventional methods based on intensive thermal, mechanical, pulse, electrochemical, or other impacts. All the above listed processes feature the presence of a relatively high risk factor.

The age of the explosive ordnance is another reason for high risk-levels in the dismantling. Long-term storage leads to irreversible changes both in the design elements and the explosive charges. Over time, decomposition occurs in the powders and the explosive substances under the influence of multiple changes in temperature and oxygen levels. The autocatalysis phenomenon is accompanied by the emission of nitrogen oxides and other gaseous products, which in their turn decompose the powders and the explosive substances. As a result of the chemical changes, the charges become more sensitive to external impact, so they also become more dangerous in terms of fire and explosion.

During storage, some explosive substances undergo physical alterations. Separation of trotyl oil is frequently observed in the less pure TNT. (Such low-quality TNT is used for charging ammunition in wartime.) This process causes changes in the substance's structure. The above listed chemical and physical phenomena destroy charge integrity and reduce the strength of cohesion to the internal surface of the projectile.

In the case of dismantling ammunition charged with ammonium niter explosive fillings, mixing the charge with a primer composition containing potassium chlorate is possible. This results in a very dangerous compound (chlorine-ammonium salt) that is sensitive to friction and impact. The improper handling of such ammunition can cause a fire or an explosion. This chemical compound has the property of self-ignition, even at moderate summer temperatures. Chlorine-acid ammonia decomposes easily and the residual products are easy to detect by the yellow color and specific smell of the separated chlorine. Explosive ordnance that has shown such signs should not be used; it should be demolished as soon as possible.

Some elements of the explosive ordnance corrode and become unserviceable over time due to atmospheric humidity, in spite of the sealed body and the anti-corrosion coating. The sealing of the inter-connection disintegrates and humidity enters the artillery round. Corrosion penetrates the whole volume of the round. The fuses that have deteriorated due to long-term storage represent a significant danger because they can be armed by insignificant mechanical impacts.

The environmental problems of the surplus ammunition disposal deserve special attention and will be discussed separately.

F. ENVIRONMENTAL PROTECTION

The surplus ammunition disposal process requires the development and application of diverse dismantling and recycling methods. It involves different types of explosive ordnance and its individual components and poses threats to the population and the environment. After applying proper risk analysis, adequate measures must be taken to minimize those threats.

Assessing environmental dangers in disposing of explosive ordnance is required both due to the specific nature of the ammunition as products and due to the natural, geographic, and structural specifics of the country. Some of the more important considerations in this aspect follow:

- The greater part of the explosive ordnance to be disposed of contains hazardous substances and components with specific hazardous features in terms of fire, explosion, and toxicity.
- In most cases, the explosive ordnance is arranged in large quantities of one type or similar types of products that are stored in a relatively small number of depots. This fact presupposes a “concentration” of the environmental risk.

- Bulgaria lacks installations and specialized enterprises to process hazardous waste, while the municipal depots for household and industrial waste have insufficient capacity and generally do not comply with the existing environmental requirements.
- Bulgaria is densely populated. In general, there are no regions sufficiently far away from inhabited places where the disposal could be executed without obeying the environmental protection requirements.

The negative consequences of explosive ordnance utilization, demolition, and burning of some components can be assessed by the costs required to restore the environment to its normal status or at least to its admissible parameters. We must note, however, that while the costs for the restoration of the soil, the water, and the fauna can be estimated to a certain extent, the cleaning of air cannot be evaluated. Explosive ordnance disposal in open sites inevitably pollutes the air. Therefore, the problem of environmental and atmospheric pollution is extremely important when large quantities of explosive ordnance are being demolished or burnt. Improving the oxidation processes cannot solve this problem; “complete” combustion also forms carbon monoxides, nitrogen oxides, hard carbon particles, etc.

From an environmental point of view, explosive substances can be divided into two groups; those containing heavy metals, and those not containing heavy metals.

The biosphere can protect itself actively from the second group (high-explosive substances), as there are microorganisms that “eat” TNT, for instance. However, it is necessary to protect the biosphere from the substances containing heavy metals through neutralizing the toxic properties of lead (Pb), for example, by substances that form anions or complex chemical compounds.

Lead dispersion at long distances from open-site explosions restricts the use of that method. The explosive ordnance demolition should be performed in

sealed premises to provide environmental safety while taking appropriate measures to neutralize the toxic gases and heavy metals.

Also, explosive substances undergo transformation during burning and the resulting poly-dispersed particles pollute the environment. In the case of burning, the quantity of particles emitted into the environment is 10 to 100 times higher than during an explosion. The environmental harm due to those methods is indisputable. Moreover, a lot of resources are irreversibly lost.

Filters are most commonly used to purify the gases during the disposal of the classical explosive ordnance. Their type, design, and productivity depend on the chemical composition and the quantities of the separated gaseous products. Neutralizing the separated hydro-chlorate and collecting the particles of the dialuminum trioxide is necessary in order to reduce the quantity of the atmospheric pollutants during the burning of blended rocket fuels. For that purpose, a water solution of alkali or carbonates of some metals (like sodium alkali, potassium alkali, sodium carbonate or potassium carbonate) is injected in the jet of the burning products. The water absorbs the hydro-chlorate forming sodium or potassium chloride, and the aluminum oxides are in the form of a water suspension. Thus, the gaseous products of the burning are cleaned from the hydro-chlorate. The aluminum oxides are separated from the suspension by the sedimentation method. During the burning of blended rocket fuels in the rocket motors or in constant pressure chambers the aluminum oxides assume a spherical shape and can be used to produce adsorbents, catalysts and super-solid, fire-proof and corrosion-resistant materials. Such an approach to the destruction of blended rocket fuels ensures environmentally clean operations.

Generally, water purification involves purifying appliances with mechanical, chemical, and biological sections. A serious problem in the purification of the drainage waters concerns the separation of compounds that are difficult to oxidize. Such toxic components (like TNT and RDX) accumulate in the water during the disposal.

For simplicity, the factories purify the nitrate containing wastewaters along with the other drainage waters in the conventional purification appliances. However, in practice the purification process of the wastewaters containing explosive substances by the classical scheme is ineffective. Therefore, associated wastewaters should be directed to on-site purification systems before they enter the public purification network.

Special regulations define methods for re-cultivating contaminated soil, but contemporary disposal methods and technologies make these methods irrelevant as no soil is contaminated.

Throughout the world, the regulation of the surplus ammunition disposal process requires a detailed risk assessment of human health and environmental protection. Any newly developed technology for disposing of specific types of explosive ordnance must comply with the parameters of the risk analysis.

The requirements of the Environmental Protection Law must serve as a foundation for protecting the water, soil, biodiversity, the atmosphere, and for processing of the waste products. The Bulgarian and European environmental legislation must be used as criteria for objective control. The basic documents in this field are as follows:

- The *Environmental Protection Law*, promulgated by the State Gazette, issue 91/2002;
- The *Law for Restriction of the Waste's Harmful Influence on the Environment*, promulgated by the State Gazette, issue 86/September 30, 1997, amended and supplemented in issue 91/September 25, 2002;
- The *Water Law*, promulgated by the State Gazette, issue 67/July 27, 1999, amended and supplemented in issue 42/May 9, 2003;

- The *Law for Atmospheric Purity*, promulgated by the State Gazette, issue 45/May 28, 1996, amended and supplemented in issue 102/November 27, 2001;
- The *Law for Protection against the Harmful Influence of the Chemical Substances, Detergents, and Products*, promulgated by the State Gazette, issue 10/February 4, 2000, amended and supplemented in issue 91/September 25, 2002;
- Order #2/1998 concerning the standards of admissible emissions (concentration of combustion gases) of harmful substances emitted in the atmosphere by stationary sources;
- Order #2/1990 concerning the protection in case of emergency during activities with hazardous chemical substances, promulgated by the State Gazette, issue 51/June 6, 1998, supplemented in issue 73/August 17, 1999;
- Order #6/2000 for the emission standards of admissible content of harmful and hazardous substances in the waste waters in water collectors, promulgated by the State Gazette, issue 97/November 28, 2000;
- Order #9/1999 for the limits of sulphuric dioxide, nitrogen dioxide, fine dust particles, and lead in the atmospheric air, promulgated by the State Gazette, issue 46/May 18, 1999;
- Order #14/1997 for the limits of the admissible concentrations of harmful substances in the atmosphere in inhabited places, promulgated by the State Gazette, issue 88/October 3, 1999;
- Council of Ministers' Provision #153/1999 for processing and transporting industrial and hazardous waste;
- 96/61/EEC *Pollution Complex Prevention and Control Directive*;

- 78/319/EEC *Toxic and Hazardous Wastes Directive*.

Independent experts licensed by the Ministry of Environment and Water Resources according to the appropriate legal procedures will perform the ecological assessment. International expertise must be used to determine the most suitable methods for environmental assessment.

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V. ANALYSIS OF UTILIZATION OPPORTUNITIES

A. ASSESSMENT OF THE METHODS, TECHNOLOGIES, AND TECHNOLOGICAL EQUIPMENT FOR AMMUNITION DISPOSAL

The Bulgarian defense industry specializes in the manufacturing of the following products: small arms ammunition; signal, flare, and illumination pyrotechnical means; hand grenades; anti-aircraft artillery rounds; high-explosive, shaped, and other types of anti-tank rounds; non-guided air-launched rockets of the types S-5 and S-8; aviation bombs up to 500 kg; shaped and high-explosive artillery rounds up to 152 mm; mines and mortar rounds up to 120 mm; 122 mm high-explosive rocket projectiles; fuses with mechanical, piezo, and proximity action; anti-tank guided missiles (ATGM); portable surface-to-air missiles (SAM); engineering explosive ordnance, including different types of anti-tank mines, their fuses, elongated, cord, shaped, and concentrated charges; detonators; powders and live charges for mortar, artillery, tank, and other rounds.¹³

The defense industry companies have the capacity to solve specific tasks related to the manufacturing of explosive ordnance and processing of explosive materials. They have expertise in the processing of powders, TNT, RDX, explosive mixtures, tetryl, ten, ammonium niter explosive substances, pyrotechnical mixtures, composite solid rocket fuel, and other products. The firms employ technologies for grinding and blending explosive substances and manufacture engineering explosives (including hot-blended ones), detonation means (cast and pressed intermediate detonators, a wide range of detonating cords), and special purpose explosives like shaped charges, punchers for the petroleum output industry, and mixtures based on TNT and RDX.

¹³ *National Program for Utilization and Destruction of Surplus Ammunition*, pp. 93-94.

The companies can assemble explosive ordnance at different production sites, meeting all the requirements for labor safety, environmental protection, fire and explosion protection, and confidentiality.

Casting, pressing, or screw-pressing methods are normally used for charging the ammunition cases with explosive substances. The charging of the boosters, rocket motors, and the final assembly is performed on conveyor lines.

Qualified experts and operators are available to solve complex tasks including explosive ordnance disposal. Business contacts have been established with leading companies and research institutes in the field of ammunition disposal. Some of the Bulgarian companies have developed their own technologies for explosive ordnance disposal. Projects for customized machinery involved in the technological processes are also under development.

The following findings are offered:

- The companies have the required production capacities and technologies, which could be successfully used for explosive ordnance disposal, but only after considerable improvements. Basically, the available production sites meet all safety requirements but they do not meet the requirements for environmental protection.
- The companies have the necessary facilities to store large quantities of ammunition and associated components.
- The companies have qualified personnel to work with explosive substances, weapons, and ammunition.
- A certain level of expertise has already been acquired during the disposal of anti-personnel mines and other types of explosive ordnance.

However, a very wide range of explosive ordnance types will have to be disposed of. It is impossible to create an integrated method, an integrated technology, and universal technological equipment to execute the related

activities. The selection of a method, technology, and the corresponding technological equipment depends on the physical, chemical, and explosive properties of the substance used in the ammunition, as well as on the geometrical design and the design-specific features.

Disposing of explosive ordnance elements, like fuses and capsule sleeves, results in environmental pollution. They should be accumulated until reliable and environmentally safe equipment is acquired for their processing. At the same time, such an accumulation would inevitably increase the risk of uncontrolled explosion with severe consequences for the infrastructure and the environment. Clearly, at this stage the disposal of those components needs a very cautious and differentiated approach.

Presently, a number of hazardous substances are emitted in violation of environmental protection and labor safety requirements. Moreover, some types of ammunition emit toxic and carcinogenic substances that are extremely dangerous to humans. All those facts impose special requirements for the technological equipment of the relevant disposal sites.

Surplus ammunition disposal entails explosion hazard. So the design of the equipment should consider the alteration of the physical and chemical properties of the explosive substances, as well as the possibilities of explosion. The working tools must impact the explosive material or the ammunition case in such a way that accidents are avoided.

Several other important requirements concern the equipment for ammunition disposal. The first and most important requirement is that the equipment should include automated means for explosion and fire protection without being considerably complicated or it should be designed in such a way, that the possibility of an explosion or fire is reduced to an acceptable level.

The second requirement relates to selecting a technology that keeps the processed materials in an explosion-safe condition. The disposal equipment should be small. It should have the capacity to process a minimum quantity of

explosive substances during extracting, to be reliable, and to operate automatically.

Static and dynamic design solutions should prevent explosions or detonations. The equipment should also allow for adequate clearance between the operating tools and the ammunition body. No overheating of the explosive substance should occur. Special devices must be available to enable the disassembly of the equipment in explosion- and fire-hazardous places.

A proper design of the equipment would certainly help to ensure labor safety. However, because much is unknown about the chemical properties of these materials, fires or explosions cannot be completely avoided. Therefore, ammunition disposal requires special regulations to protect operating personnel, equipment, and facilities.

The disposal sites and equipment should be safely separated from the temporary storage sites.

Many of the operations required for the explosive ordnance disposal cannot be completely automated. Yet, certain dismantling operations should use mechanization and remote-control processes.

Safety during the explosive ordnance disposal is a basic requirement for the equipment. This requirement must be mandatory, unconditional, and independent of any temporary constraints – timing or technological.

The process should not allow rolling of the projectiles, charges, and cartridges, if they are not arranged in parallel to each other. Also, the fuses and capsule sleeves must never be struck. Accumulation of explosive ordnance on the work premises is also highly unacceptable. The batch quantity will be determined by the operations management principle of minimizing inventory.

The operations with the explosive ordnance must avoid the possibility of dropping. If a product accidentally falls from a height more than 1 m, the fuse must be unscrewed in a specially designed chamber.

Considering the general safety of the disposal processes, the following is explicitly forbidden:

- To dig the explosive ordnance in the ground or to dip it in water collectors of any kind;
- To turn the explosive ordnance over or to drag and throw wooden cases filled with explosive ordnance;
- To transport rounds and their components if they are not arranged in compliance with the regulations;
- To carry explosive ordnance in faulty packing or in wooden cases turned upside down;
- To store unpacked explosive ordnance.

In case of railway transport, the explosive ordnance should be arranged so that their longitudinal axes are perpendicular to the wagon's longitudinal axis. After the loading, specific measures must be taken to exclude falling, displacement, and vibration during transportation.

In case of truck convoys, transporting explosive ordnance together with inflammable liquids is forbidden. Convoys should not stop in inhabited places.

Research on methods and technological equipment currently available in the Bulgarian defense industry reveal that the above requirements are not completely met. State-of-the-art technologies have not been implemented yet. The basic technological equipment does not comply with the requirements for disposal. The utilization is performed using the technological equipment for the regular production of explosive ordnance. Different companies own the equipment depending on their specialization. The equipment is old and it is generally not susceptible to upgrading. Its designs are obsolete and the funding for upgrading to an up-to-date level would exceed the funding required to purchase new equipment. Moreover, the technological equipment of the

Bulgarian companies does not meet the contemporary European environmental protection standards.

The basic disadvantage of the current practices stems from the lack of technologies and equipment for processing the obtained explosive substances, powders, and other materials into semi-finished or finished products. Furthermore, there is no equipment to use the energy released during the burning of explosive substances and powders that cannot be recycled.

Another great disadvantage is the lack of equipment for disposing of extremely explosion-hazardous and sensitive elements like fuses, capsule sleeves, detonating primers, and tracers. Furthermore, no specialized equipment is available to recycle body elements and artillery shells or wooden and plastic packing materials.

It is an important fact that the Bulgarian ammunition storage depots are located at distances no farther than 300 km from the defense industry companies. Unlike in huge countries where the transportation costs represent 20 to 30 percent of the total disposal costs, in Bulgaria those costs will not influence the option of an integrated disposal center negatively.

Based on the considerations above, it is reasonable to perform the surplus ammunition disposal in an integrated Utilization Center, specially designed for that purpose. The center should apply contemporary methods and technologies. The equipment in this center should provide for high levels of productivity, safety, and environmental protection.

This center should be embedded, if possible, into an already existing base that is far enough from populated area and is located in a region with a relatively high unemployment rate. The base should have a suitable infrastructure: a railway station, easy access roads, electric power and water supply sources, and proper communication facilities. Moreover, the center should have a sufficient number of safe storage depots, administration and public buildings, specialized fire-protection system, and a robust alarm/safeguarding system.

The experience of the leading countries shows that establishing such a center requires a closed cycle of disposal. In other words, the center should not only disarm and dismantle the explosive ordnance, but transform the obtained materials into secondary products as well.

The center should handle all types of ammunition ranging from small arms cartridges to missiles. The center should have the capacity to dispose of explosive ordnance from the Balkan countries, thus becoming a regional center for surplus ammunition disposal.

Considering the analyses of the types, quantities and technical condition of the surplus ammunition, the contemporary disposal methods and technologies, the condition of the technological equipment available in the Bulgarian defense industry, the safety and environmental protection requirements, as well as the experience of the leading countries in this field, the following basic technical capabilities are required:

- Disposal of small-arms ammunition, hand grenades and anti-tank grenades;
- Disposal of artillery, mortar, anti-tank, tank, and anti-aircraft ammunition with caliber from 23 mm to 152 mm;
- Disposal of large-caliber explosive ordnance like missiles, aviation bombs, torpedoes and marine bombs, and some types of engineering explosive ordnance;
- Disposal of extremely dangerous explosion-hazardous elements and pyrotechnical means like fuses and fusing devices, capsule sleeves, detonating primers, squibs, tracers, and pyrotechnical compositions;
- Demolition of explosive ordnance that is not to be utilized for safety, technological, or economic (cost > benefit) reasons;
- Processing the explosive substances and powders into semi-finished and ready-made products;

- Burning explosive substances, powders, and other elements that are not to be utilized for safety, technological, or economic (cost > benefit) reasons;
- Processing bodies (cases), cartridges, and other metal elements; wooden, plastic and other packing materials for further use.

The establishment of the disposal center requires the development of a project comprising the following basic stages:

- Technical and cost-benefit analyses (determine the region and location to establish the center; analyze the existing infrastructure; determine the structure of the center and the allocation of its elements; calculate the required technological equipment; determine the technological equipment to be imported and purchased locally; assess the existing facilities and estimate the repair and construction costs; calculate the mounting of the technological equipment; calculate the transportation costs related to the establishment of the center; evaluate the costs for training of personnel; calculate financial and economical activities of the center; prepare a ten-year business plan to realize the project and its resource management) – 6 months.
- Repair, reconstruct, and construct buildings, infrastructure, and communication facilities – 18 months.
- Transferring know-how, technologies, and equipment, to include local acquisition of certain equipment – 12 months.
- Mounting of the technological equipment, training of personnel, and making the center operational – 6 months.

The project starts with the technical and cost-benefit analyses. The execution of the other stages starts immediately after these steps have been

completed. Some of the stages may coincide in time. Thus, the disposal center should be established within two years.¹⁴

The disposal of the surplus ammunition will result in large quantities of secondary materials of different types and properties. Considering their further realization, priority is given to the powders, explosive substances, bodies, cartridges, fusing devices, and packing materials. Some of those ammunition elements (such as the powders, explosive substances, and fusing devices) are hazardous both during the dismantling and during the recycling process. Moreover, the many years of storage have resulted in alterations in their physical and chemical properties, which pose even higher risks during the disposal process.

Therefore, for each explosive ordnance type, it is mandatory to perform a cost-benefit analysis and a risk analysis before making a decision about the disposal option – utilization or destruction.

B. POWDERS

The surplus powders of the propellant charges can be divided into the following basic groups¹⁵:

- Pyroxyline powders;
- Nitroglycerine and diglycol powders;
- Rocket ballistite powders;
- Igniters (black powders);
- Flare extinguishers.

The pyroxyline powders are obtained mainly during the dismantling and disposal of the small arms ammunition, the artillery, mortar, tank, and anti-aircraft

¹⁴ This scheduling is based on *National Program for Utilization and Destruction of Surplus Ammunition*, p. 108.

¹⁵ The technical data in this chapter is based on *Analysis of the Ammunition Utilization Problems*, pp. 29-45.

ammunition, the aviation cartridges, pyrotechnical means, and the reserves of the national economy – 3,855 tons in total. The share of the anti-aircraft ammunition is the largest – 30 percent, followed by the small arms ammunition – 25 percent, the tank ammunition with 20 percent, and the artillery ammunition with 13 percent.

The powders of the small arms ammunition consist of eight types, and the greater share is given to the rifle powder for cartridges (VT) – 34 percent, then the rifle retarded powder for cartridges (VUFL) – 24 percent, and the grain seven-groove powders (5/7) – 21 percent. Only one type of powder is obtained from the mortar rounds – viscose tube graphite powder (VTM).

The relative share of the pyroxyline powders from the aviation cartridges is 0.02 percent, from the pyrotechnical means – 0.0002 percent, and from the reserve of the national economy – 0.07 percent.

Ten types of powders are obtained from the artillery, tank and anti-aircraft ammunition. The fresh pyroxyline powder (11/7) has the greatest relative share – 38 percent, followed by the mixed powder with tube powder from fresh pyroxyline (14/7 + 18/1 TR) – 29 percent.

The nitroglycerine and diglycol powders are obtained mainly from the anti-tank grenades, the artillery, mortar, tank and anti-aircraft ammunition, and from the motors of the anti-aircraft missile system *Dvina* – 3,135 tons in total. The greatest share is for the anti-aircraft – 35 percent, followed by the tank ammunition – 29 percent, and the artillery explosive ordnance – 17 percent.

The anti-tank grenades contain two powder types. The share of the nitroglycerine powder NVL-38 is insignificant. The main quantity comes from the strip nitroglycerine ballistite type powder NBL-42.

The nitroglycerine powders obtained from the artillery, tank and anti-aircraft explosive ordnance comprise four types, and there is one type of diglycol powder. The main share falls to the nitroglycerine powder without

dibutylphthalate NDT-3 (18/1) – 79 percent, for 16/1 – 14 percent, and the nitroglycerine powder with dinitrotoluene NDT-3 (23/1) share is 5 percent.

Two powder types can be obtained from the main charges of the mortar rounds and one powder type from the auxiliary charges. The main quantity comes from the round nitroglycerine ballistite type powder (NBK-32 / 65-14) – 19 percent, and from the strip nitroglycerine ballistite type powder (NBL-35) – 10 percent.

Only one type of nitroglycerine powder is obtained from the powder rocket motors of the anti-aircraft missile system *Dvina* – NMF-2.

The rocket ballistite powders are obtained mainly from the anti-tank grenades, the anti-tank guided missiles, and the air-launched guided and non-guided rockets. Their total quantity is more than 480 tons. The nitroglycerine powder with an additional layer and fixative of nitrodiglycol chalk and lead oxides (RNDSI-5K) has the greatest share – 60 percent.

The total quantity of the igniters and flame extinguishers is about 100 tons. They are obtained mainly from the anti-tank grenades, the artillery, tank and anti-aircraft explosive ordnance.

The total quantity of powders amounts to 7,585 tons and the greatest share is given to the pyroxyline powders – 51 percent, followed by the nitroglycerine and diglycol powders – 41 percent, and the rocket ballistite powders – 6 percent. The quantity of the igniters and flame extinguishers is insignificant, less than 2 percent (Figure 2).

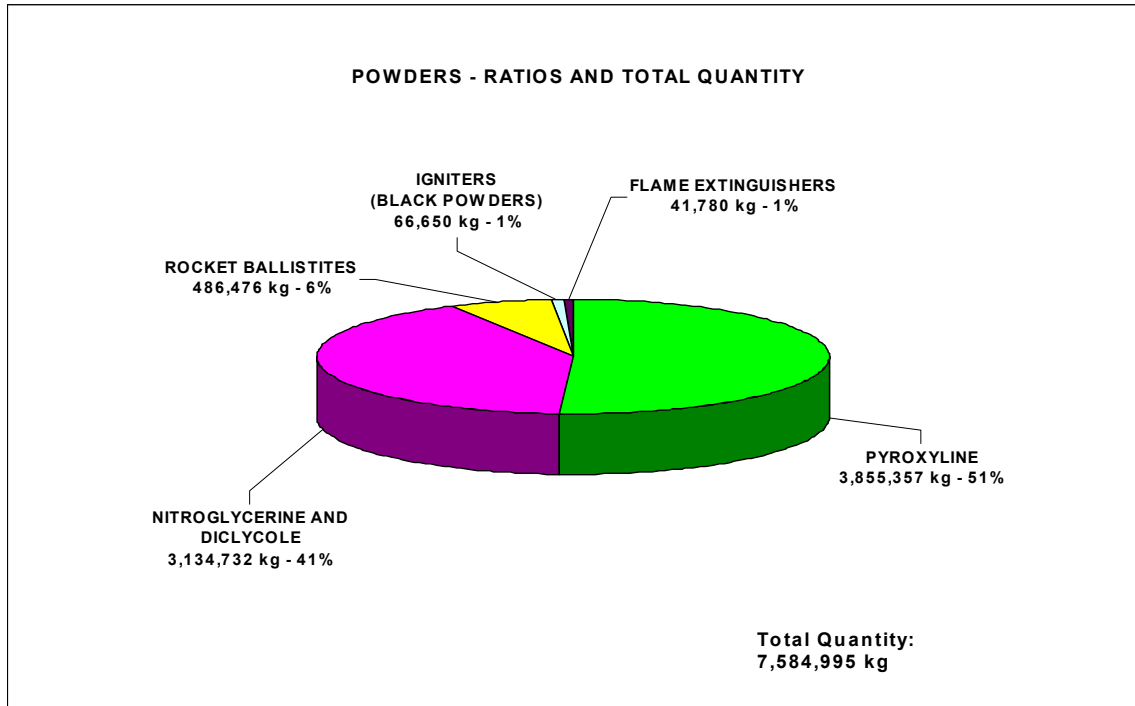


Figure 2. Surplus Powders (After *National Program for Utilization and Destruction of Surplus Ammunition*)¹⁶

The analysis leads to the conclusion that the powders obtained through the utilization of surplus ammunition can have important industrial applications.

The water-proof and water emulsion explosive substances can have a wide application in the mining industry, in quarries, and for some other commercial purposes: fuels for the anti-hail rockets; manufacturing of hunting, training, and other non-military types of cartridges; non-military pyrotechnical materials; briquets, and so on.

C. EXPLOSIVE SUBSTANCES

Explosive substances (obtained through ammunition utilization plus the surplus quantities in state reserve) can be divided into the following basic groups:

¹⁶ The *National Program for Utilization and Destruction of Surplus Ammunition* also provides similar graphs for other types of ammunition components.

- TNT;
- RDX (A-IX-1 and A-IX-2);
- TNT with smoke and flare-intensifying elements (TDU);
- TNT with RDX, aluminum powder, retarded (TG, TGA, TGAG-5);
- Plastite;
- Ammonite.

TNT can be obtained from almost all types of explosive ordnance, except for the small arms ammunition and the aviation guided and non-guided rockets. Its total quantity is about 2,300 tons. The greatest share of TNT can be obtained from the artillery explosive ordnance – 33 percent, from the mortar rounds – 25 percent, and from the aviation bombs – 17 percent.

There are two types of RDX: retarded RDX (A-IX-1) and retarded RDX with aluminum powder (A-IX-2). RDX can be obtained from most of the explosive ordnance types, except for the small-arms cartridges, the mortar ammunition, the aviation bombs, the naval ammunition, and the engineering explosive ordnance. Its total quantity is about 670 tons. The greatest share of the RDX will be obtained from the anti-aircraft ammunition – 23 percent, from the anti-tank grenades – 20 percent, from the artillery ammunition – 17 percent, and from the anti-tank ammunition – 16 percent.

TNT with smoke and flare-intensifying elements (TDU) is obtained mainly from anti-aircraft and artillery ammunition. Its total quantity is about 300 tons and 90 percent of that quantity will be extracted from anti-aircraft ammunition.

The mixtures of TNT with RDX, aluminum powder, and phlegmatizers are obtained mainly from engineering explosive ordnance, aviation bombs, the warheads of the anti-aircraft missile system *Dvina*, and naval ammunition. Their total quantity is about 1,400 tons. The greatest share of that quantity belongs to the engineering explosive ordnance – 88 percent, followed by the aviation bombs

– 6 percent, the warheads of the anti-aircraft missile system *Dvina* – 4 percent, and the naval ammunition – 2 percent.

The plastite and the ammonite are explosive substances that are obtained only from the engineering explosive ordnance. They represent separate products and need not be extracted. Their total quantity is about 260 tons (160 tons of plastite and 100 tons of ammonite).

The total quantity of explosive substances amounts to about 4,900 tons and the greatest share belongs to the TNT – 47 percent, followed by the TNT mixtures with RDX, aluminum powder and phlegmatizers – 28 percent, the RDX – 14 percent, and the TNT with smoke and flare-intensifying additives – 6 percent. The plastite and the ammonite have a smaller share – 3 and 2 percent, respectively.

There are significant industrial applications of the explosive substances obtained during the utilization process. The contemporary methods for processing, industrial granulation, and implementation of additives and catalysts can be used to obtain waterproof, emulsion, jellied, dry, and other semi-finished and finished products from the explosive substances.

These products can be most useful in the mining industry, in the quarries, in the oil industry, for engineering construction, geologic research, fire extinguishing, and so on. A part of the obtained explosive substances can be used to produce artificial diamonds and super-hard materials.

D. FUSING DEVICES

These devices include, for example, the fuses, squibs, capsule sleeves, and pyrocartridges. The *fuses* can be divided into four general groups:

- Nose fuses;
- Piezoelectric fuses;

- Base fuses;
- Proximity fuses.

The nose fuses are used in almost all types of explosive ordnance, except for the hand and anti-tank grenades, anti-tank guided missiles, aviation guided rockets, and the aviation pyrocartridges. Their total number exceeds 5.8 mln. The greatest share of that quantity belongs to the nose fuses obtained from the anti-aircraft explosive ordnance – 60 percent, from the aviation cartridges – 17 percent, from the mortar rounds – 7 percent, and from the tank ammunition – 5 percent.

There are more than 20 different types of nose fuses. The largest surplus quantities come from the fuses for 23 mm rounds HE-IT (MG-25 and V19UK), followed by the fuses for the 57 mm rounds for S-60 gun (MG-57 and MGZ-57), the fuses for the aviation cartridges A-23, B-23, A-30 and B-30, the fuses for the tank ammunition and part of the fuses for the artillery shells (V429, RGM2, and RGM6), and the fuses for the 82 mm fragmentation mortar bombs (M5, M-5A, and M-6).

The piezoelectric fuses are obtained from the anti-tank grenades, the anti-tank guided missiles, and the aviation unguided rockets. The fuses VP-7 are dismantled from the anti-tank grenades PG-7V and PG-7VM, the fuses VP-9 are dismantled from the PG-9 rounds, the fuses 9E212 - from the anti-tank guided missiles 9M14M, and V-5K, V-5M1, V-24A and VB-5 - from the aviation non-guided rockets. Their total number is 858,772. The largest share of that quantity belongs to VP-7 – 49 percent, followed by VP-9 – 40 percent, and V-5K – 9 percent.

The base impact fuses are dismantled from the artillery, tank, and anti-aircraft explosive ordnance. Their total number is more than 68,000. The largest share of that quantity belongs to the base fuses from the tank ammunition – 67 percent, followed by the fuses from the artillery ammunition – 19 percent, and from the anti-aircraft ammunition – 14 percent.

The base fuses comprise six types and most are for DBR-2 for the tank APT rounds – 38 percent, followed by MD-8 for the same rounds – 29 percent, MD-10 for anti-aircraft rounds – 13 percent, DBR for the artillery ammunition – 9 percent, MD-7 for some of the artillery ammunition – 7 percent, and DBT and KTD for the concrete-piercing projectiles for the 152 mm ML-20 howitzer – 4 percent.

The proximity fuses are dismantled from artillery and anti-aircraft explosive ordnance, the aviation guided rockets, and the aviation cartridges. There are more than 13 proximity fuse types and their total number exceeds 250,000. Most belong to the fuses from anti-aircraft ammunition – 76 percent. The fuses from artillery ammunition are 22 percent and the fuses from aviation guided rockets – less than 1 percent.

The *squibs* are dismantled from hand grenades and engineering explosive ordnance. Their total number exceeds six million pieces. The squibs from hand grenades amount to 56 percent of that quantity and the share of the squibs from the engineering explosive ordnance is 44 percent.

Hand grenade squibs (more than 3.4 mln pieces) consist of two types – UZRGM and DVM. The ratio UZRGM:DVM is 66:34. Squibs from engineering explosive ordnance have frictional and mechanical igniters.

The *pyrocartridges* are dismantled only from aviation ammunition and total about 9,000 pcs, less than 1 percent of the total quantity of fuses and squibs. The total quantity of fuses, squibs, and pyrocartridges exceeds 13,300,000. The share of fuses in that quantity is almost 54 percent, the squibs comprise almost 46 percent, and the pyrocartridges – less than 1 percent.

Capsule sleeves are dismantled from artillery, tank, and anti-aircraft ammunition. Their total number exceeds 1,560,000 pieces. The greatest share of that quantity comes from the anti-aircraft ammunition – 62 percent, followed by the tank ammunition – 21 percent, and the artillery ammunition – 17 percent. There are three types of capsule sleeves: KV-4, KV-5(U), and KV-13(U). Their

relative share is: 50 percent for KV-5(U), 33 percent for KV-13(U), and 17 percent for KV-4.

Dismantling and recycling fusing devices is not recommended. Dismantling them is a very difficult and hazardous process, while the extracted materials are quantitatively insignificant and unsafe for further processing.

The most efficient method of disposal is to burn them in a special armored furnace, followed by sorting out and recycling the scrap metal. This is expected to obtain a scrap mass of about 600 tons.

E. METALS

The disposal of the explosive ordnance results in significant quantities from different types of metals. Metals can be grouped into ferrous and non-ferrous. *Ferrous* metals are steel, cast iron, alloyed steels, etc. *Non-ferrous* metals are brass, pure copper, aluminum, aluminum alloys, etc. The total expected quantity of metal scrap is about 35,000 tons: 78 percent ferrous and 22 percent non-ferrous metals.

Ferrous metals are obtained from almost all types of explosive ordnance, except for the anti-tank guided missiles and the aviation guided and non-guided rockets. The cartridges and the bodies of the explosive ordnance represent the basic source of metal scrap. Their total quantity exceeds 27,000 tons with 21 percent being cartridges and 79 percent ammunition cases.

Non-ferrous metals can also be obtained from almost all types of ammunition except for mortar, engineering, and naval explosive ordnance. The total weight exceeds 7,600 tons: brass – 68 percent, copper – 7 percent, and aluminum and its alloys – 25 percent.

Brass is obtained mainly from the shells of the artillery rounds (72 percent). The relative share of the small arms ammunition cartridge cases is 18 percent. The total brass quantity is about 5,300 tons.

Copper is obtained from the conducting belts of the artillery, tank, and anti-aircraft ammunition, and from the copper cones of the shaped rounds. Its composition is close to that of the pure electrolyte copper. The total copper quantity is about 570 tons.

Aluminum and aluminum alloys are obtained mainly from the anti-tank rounds and grenades and from the aviation guided and non-guided rockets. Their total quantity exceeds 1,700 tons. It is difficult to determine the purity of the aluminum, the type of the alloys, and their additional components at that stage. This should be performed during the disposal process.

The analysis shows that surplus ammunition incorporates a wide range of metals and alloys. The utilization requires detailed dismantling the explosive ordnance and sorting the obtained materials according to the type and the composition of the material. Obviously, this is a complicated and sometimes a very expensive operation.

Sorting by chemical composition is the most important step during the sorting of the dismantled parts. The nature of this task is determined by the difference in the processing technologies. Some metals and alloys can be scrapped together and do not require a detailed dismantling. Sometimes, the ammunition design itself does not allow for a detailed dismantling of all the elements. However, some metals and alloys cannot be processed together and they must be separated before recycling because their mixing deteriorates the quality of the obtained product and frequently results in damaging the metallurgical devices. Sometimes, the degree of separation of the metal components is simply limited by cost-efficient reasons like high dismantling costs or high investments for specialized equipment.

Most often the bullets consist of a steel casing, steel core, and a lead armoring. The further processing of the steel parts together with the lead armoring is not recommended. The separation of the steel parts and the lead armoring can be performed in a mechanical or in a pyrometallurgical way. The

second one is preferable, though it seems more difficult and more expensive in most cases. The lead (Pb) has a low melting temperature and liquid lead does not make the steel wet. This fact provides for a high-quality lead separation in simple heating units. The lead can also be separated immediately after its extraction in a standard molding, suitable for direct sale on the market. The steel parts have a low volumetric weight and it is advisable to press them prior to their market realization. During the pyrometallurgical extraction the lead should be cast in standard moldings. It will be sold in this form mostly.

The disposal of pure metals like copper and aluminum requires strict separation of the parts and sorting by type.

The non-ferrous metals and alloys are considerably more expensive than the steel, and it will be most efficient to realize them as semi-finished products with a strictly determined composition as specified in the Bulgarian State Standard. Relatively small metallurgical devices to melt such products are readily available.

The waste from the design chrome and high-alloyed steels should be salvaged as scrap after pressing and packing. This type of scrap is relatively more expensive. So these products should be strictly processed by type, and then pressed and packed immediately after dismantling the ammunition. This would avoid mixing them with waste of other steel types, which may reduce the price and threaten the further recycling.

The simplest use of the obtained metal waste is to use it as scrap in composing the pit for obtaining ordinary steel types. Such processing should be used for the carbon steel parts. The parts made of low- and high-alloyed steels can be used more efficiently in two basic ways:

- To include them in the pit for producing alloyed steel to economize the expensive ferroalloys needed for this production. Such a method usually achieves partial use of the precious metals contained in the components.

- To use the wastes as a pit for production of similar steel types by the “melting method.” This approach has the highest degree of use of the precious metals in the dismantled ammunition components.

Both methods have their advantages and drawbacks, no matter what the degree of utilization of the useful components is. The first way is simpler, widely applied in the practice, and it has lower costs to prepare the parts for recycling. The second way is not so widely used. Its practical realization strongly depends on the market demand for such types of steel.

F. PACKING

It is expected that different materials will be obtained from the packing during the surplus ammunition disposal process. Their total quantity exceeds 23,000 tons. Most of it is wooden material, which can find several applications:

- Recycling by purpose: the packing that is intact and fits ammunition that is still in service can be offered to the manufacturing companies after some minimum repair, re-painting, and re-marking.
- Recycling by processing: this involves practically intact packing that can be processed depending on the overall dimensions of the products for which it will be used.
- Semi-finished elements for public commodities: making boards, bars, blocks, and other elements from the intact parts of the packing.
- Transforming the wooden material into components (shavings, saw-dust, etc.) and using them for the production of flat plates and other elements for the furniture industry.

The weight of the packing paper and the metal, plastic, and rubber elements is insignificant when compared to that of the wooden material. Nevertheless, it is reasonable to recycle those materials. For instance, the thermosetting materials (polyethylene, polyamide) can be used to obtain a

ground-mass that can be used directly to make products by screw-pressing or extruding. It is preferable to use an extruder-granulator, which allows for adding fresh material, stabilizers, and coloring agents. The thermo-reactive materials (phenol-formaldehyde, etc.) can be used to obtain products suitable for briquetting or as components of asphalt mixtures.

The metal components (angular profiles, locks, hinges, etc.) can be used directly and the defected ones can be scrapped. The paper waste can be recycled in the paper mills. The rubber elements can be recycled or used in the rubber industry.

G. FINISHED PRODUCTS

The disposal of the explosive ordnance results in dismantling of mechanisms, units, and elements that can find the following applications:

- Making models and active dummies for training purposes;
- Making training cross-sections;
- Integrating ready mechanisms, units, and parts in simulators;
- Manufacturing practice ammunition;
- Developing and constructing active targets;
- Use of the serviceable elements with preserved physical and chemical properties in the production of new ammunition;
- Use of the finished products for research and development (R&D).

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VI. FINANCIAL ANALYSIS OF THE SURPLUS AMMUNITION DISPOSAL PROCESS

This chapter focuses on the financial aspects of tackling the surplus ammunition problem.¹⁷ Different approaches will need corresponding resources. One option is to keep on storing the surpluses (temporize). The alternative is to start the disposal as soon as possible. The latter option involves establishing a center for surplus ammunition utilization and the center's operation until all the accumulated surplus quantities are disposed of. Subsequently, that center would be disposing of current surpluses. As the current Bulgarian surpluses in the future will be relatively small, the center may be used to dispose of explosive ordnance coming from other countries on a contractual basis.

First, we look at the “quick disposal” option from a financial perspective. Then the calculations for the “storage” option are presented. Finally, this chapter compares the tangible aspects of the two options and analyzes the intangible aspects.

A. INVESTMENT PROGRAM

The basic stages of establishing the Utilization Center have been discussed in the previous chapter. The following investments are required to fulfill those stages:

- Technical and cost-benefit analysis: €950,000;
- Repair, reconstruction, and construction of buildings, infrastructure, and communication facilities: €1,200,000;

¹⁷ The financial data in this chapter is based on *National Program for Utilization and Destruction of Surplus Ammunition*, pp. 150-158.

- Transferring know-how, technologies, and technological equipment, to include local acquisition of certain equipment and transportation expenses: €5,700,000;
- Mounting of the technological equipment, training of personnel, and making the center operational: €1,400,000;
- Other expenses: €600,000.

The future value of the total investment costs to set up the disposal center is €9,850,000. The present value of the investment costs (basic interest rate at the time of the evaluation $r = 2.96\%$; $n = 2$ years) amounts to €9,292,000.

The necessary funding, required to establish the Disposal Center will be provided from:

- The state budget of the Republic of Bulgaria;
- International institutions and funds, including environmental protection funds.

B. UTILIZATION PROGRAM

The Utilization Center's production program has been calculated at eight to ten years average, based on the surplus explosive ordnance quantities, the production capacities of the center, and the procurement of the funds for performing the disposal. Its annual anticipated production rate is as follows:

- Small arms ammunition – about 50,000,000 pieces;
- Hand and anti-tank grenades – about 450,000 pieces;
- Anti-tank rounds and ATGM – about 60,000 pieces;
- Mortar explosive ordnance – about 45,000 pieces;
- Tank ammunition – about 40,000 pieces;
- Artillery ammunition – about 35,000 pieces;

- Anti-aircraft ammunition – about 500,000 pieces;
- Pyrotechnical ammunition – about 300,000 pieces;
- Engineering explosive ordnance – about 300,000 pieces;
- Naval ammunition – about 250,000 pieces;
- Aviation rockets – about 10,000 pieces;
- Aviation bombs – about 1,500 pieces;
- Aviation cartridges, pyrocartridges, and fuses – about 150,000 pieces.

The total quantity of the explosive ordnance disposed of within a single year will amount to about 10,000 tons.

The above quantities are tentative. Depending on the specific circumstances, certain ammunition types may be disposed of with priority.

C. UTILIZATION EXPENSES

The calculation for each type of explosive ordnance is based on the current expertise in ammunition disposal in Bulgaria and the expertise of other countries.

The total amount of money necessary to dispose of the whole available quantity of surplus ammunition (VAT included) is close to €47,300,000. The distribution by product type follows (the numbers are approximated):

- Air force ammunition – 3,089,000 (7%);
- Naval ammunition – 108,000 (0.0023%);
- Engineering explosive ordnance – 1,489,000 (3%);
- Anti-aircraft ammunition – 11,809,000 (26%);
- Tank ammunition – 5,254,000 (11%);
- Artillery and mortar ammunition – 6,336,000 (13%);

- Hand grenades, AT grenades and rounds – 8,959,000 (19%);
- Small-arms ammunition and pyrotechnical means – 6,337,000 (13%);
- Materials processing – 3,912,000 (8%).

D. INCOME FROM THE UTILIZED MATERIALS

Various materials will be obtained through the disposal process, based on the technologies for utilizing the different types of ammunition. A more detailed analysis of the quantities, the market prices, and the opportunities for sale of semi-finished and final products results in anticipated revenue from the sale of those products. Table 1 incorporates the material types, quantities, prices, and expected revenue.

Material Type	Quantity [Tons]	Price per Ton [Euro]	Revenue [Euro]
Ferrous metals	30,000	70	2,100,000
Brass	5,400	850	4,590,000
Pure copper	560	1,300	728,000
Aluminum and aluminum alloys	1,700	800	1,360,000
Powders	5,250	600	3,150,000
Explosive substances	3,500	900	3,150,000
Wooden material	16,100	90	1,449,000
Total:	62,510		16,527,000

Table 1. Sales Revenue

E. ANNUAL STORAGE EXPENSES

The calculation of the storage expenses is based on the total quantity of the surplus ammunition (about 80,000 tons) and its notional allocation in four storage regions (20,000 tons of explosive ordnance per region). Considering the regulations for safe storage of explosive ordnance, each region requires an average number of 40 depots. The tentative annual expenses for the storage of the surplus explosive ordnance are given in Table 2.

Type of Expenses	Amount [Euro]
Maintenance and current repair of the explosive ordnance	550,000
Provision of the required storage conditions	400,000
Maintenance and repair of the storage regions, depots, premises, fences, roads, railway stations, platforms, etc.	1,750,000
Safeguarding	700,000
Total:	3,400,000

Table 2. Storage Expenses

The expenses for ten years of storage of the surplus ammunition constitute a significant portion of the costs for its disposal (€47,300,000). Moreover, the explosion hazard increases with long-term storage.

More detailed information is presented in Table 3. All numbers are in millions of Euro.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total:
OPTION 1											
Storage	3.4	3.50	3.60	3.71	3.82	3.93	4.05	4.17	4.29	4.42	38.91
OPTION 2											
Storage	3.2	3.0	2.5	1.8	1.6	1.1	0.8	0.5	0.3	0.1	14.90
Investment	6.5	3.35	0	0	0	0	0	0	0	0	9.85
Operations	4.51	4.62	4.86	4.86	4.75	4.75	4.74	4.74	4.73	4.73	47.29
Recovery	-1.55	-1.61	-1.75	-1.75	-1.65	-1.65	-1.65	-1.64	-1.64	-1.64	-16.53
Total:	12.66	9.36	5.61	4.91	4.70	4.20	3.89	3.60	3.39	3.19	55.51
Difference:	-9.26	-9.36	-2.01	-1.20	-0.88	-0.27	0.16	0.57	0.90	1.23	-16.60

Table 3. Comparison of Available Options

We assume a ten-year time period ($n=10$) and an annual interest rate of 2.96 percent ($r=2.96\%$) to compare the “storage” option #1 and the “disposal” option #2. The values under option #2 are based on further assumptions about the disposal schedule throughout the ten-year period.

Here are some considerations about the “tangible” and “intangible” aspects of the available options:

- The “storage” option is cheaper in a ten-year period. In a period of fifteen or more years, however, the “disposal” option becomes cheaper.
- The annual expenditure for option #1 will start exceeding the annual expenditure for option #2 after six years.
- Option #2 will free a substantial number of storage facilities, which can be used for other purposes. This opportunity cost, although not included in Table 3, favors the “disposal” option.
- Option #2 solves the surplus ammunition problem, while option #1 only temporizes it.
- Environmental and labor safety issues affect both options. However, ammunition ageing during long-term storage makes option #1 more dangerous.
- Option #2 is more viable for political and national security implications.

Considering both the tangible and intangible aspects, it seems reasonable to spend an extra €16,600,000 on option #2 in the course of ten years. If the surplus ammunition disposal process is initiated and properly executed, then:

- Money will be spent for disposal instead of for storage.
- Sales revenue will offset a certain portion of the disposal expenses.
- The surplus ammunition problem will be solved, not just postponed.

VII. CONCLUSIONS AND RECOMMENDATIONS

The problem with the surplus explosive ordnance in the territory of the Republic of Bulgaria necessitates some action at a national level. The Council of Ministers' Decision #842/December 20, 2001 mandates the development of a "National Program for Destruction and Utilization of Surplus Ammunition in the Territory of the Republic of Bulgaria."

The solution to this problem incorporates a robust surplus ammunition disposal process involving the following phases:

- Determining the exact surplus ammunition types and quantities;
- Determining, from the entire surplus, items for sale and for disposal;
- Determining, from the items for disposal, usable items and items for destruction;
- Analyzing the disposal options from technological, economic, and environmental perspective;
- Formulating a disposal plan;
- Executing a disposal plan.

The individual phases can be adjusted to meet the current political, economic, technological, environmental, and societal constraints. Furthermore, these phases may overlap in time.

The surplus ammunition disposal planning and management process does have some political, economic, technological, and societal constraints.

The political constraints stem from the fact that the Republic of Bulgaria is a party to international agreements and treaties for armament control and non-proliferation, such as the *Stability Pact Regional Implementation Plan*, the *UN Program of Action*, the *UN Firearms Protocol*, the *OSCE Document on Small Arms*, the *OSCE Document on Stockpiles of Conventional Ammunition*, the *EU Code of Conduct*, the *EU Joint Action on SALW*, and the *Wassenaar*

Agreement.¹⁸ The sale of surplus ammunition is severely restricted to a relatively short list of non-embargo countries. Furthermore, some international agreements require a prioritized disposal of some ammunition types, while other ammunition types have to be disposed of with priority according to technological, economic, or safety criteria.

The economic constraints basically come from the limited national resources. Bulgaria's transitional economy achieved a steady GDP growth rate recently. However, it is still impossible to fund the surplus ammunition disposal process from the state budget only. A certain share of international funding is required. In this respect, some economic constraints are linked with the political constraints. Donors would normally sponsor projects to dispose of ammunition types that are currently at the international agenda: nuclear weapons, anti-personnel mines, small arms and light weapons (SALW), to name a few. Bulgaria does not have nuclear weapons, and other ammunition types are heading its priority list.

The technological constraints have been largely discussed in the previous chapters. They include the lack of proper technologies to dispose of certain ammunition types and the limited utilization capacity of the available technological equipment. Labor safety and environmental protection issues must be incorporated in the disposal technologies, so we can identify *safety* and *environmental* constraints within the scope of the technological constraints.

The societal constraints originate from the high unemployment rate in some regions due to the restructuring of the Bulgarian economy. During the Cold War, the Bulgarian military industry was flourishing. It produced weapons and ammunition for a much larger standing army and for export. In some regions of the country more than 40 percent of the population worked in military plants. With the downsizing of the military industry after the end of the Cold War, those

¹⁸ Chrissie Hirst and Bernardo Mariani, *South Eastern Europe Small Arms and Light Weapons Monitor*, SEESAC, Belgrade, 2004, p. 68, available http://www.seesac.org/target/salw_monitor.htm, accessed 01 May 2004.

regions suffer from high unemployment. Most of the military plants have been privatized and have restructured their production. The ammunition disposal process would create jobs for the laid-off workers.

This professional report analyzes the available technological practices, the financial aspects, and the constraints of the surplus ammunition planning and management process. Some improvements can be recommended to find an optimal solution to the surplus ammunition disposal problem and they are summarized in the following paragraphs.

Military planners determine the explosive ordnance reserves required for the Bulgarian Armed Forces and thus provide the basis for identifying the surplus ammunition types and quantities. These quantities also include the surplus powders stored as a state reserve. The analysis of the surplus explosive ordnance (totally about 76,000 tons) has been performed concerning the types, quantities, relative share of their components, years of production, and shelf life. Moreover, a separate assessment of the technical condition of the explosive substances and powders has been performed. The results from the analysis show that some ammunition types are obsolete and irreversible physical and chemical changes have occurred with their elements. Those changes alter the main tactical, technical, and ballistic features. In general, the surplus explosive ordnance has become a real threat both for the service personnel and the environment. Therefore, it must be disposed of.

The analyses focus on contemporary methods and technologies for the utilization and destruction of explosive ordnance and the technological and environmental problems related to the disposal processes. Dismantling the explosive ordnance and the subsequent use of the explosive substances and other ammunition elements is the most cost-effective method. This must be the main disposal method unless technological constraints (especially pertaining to labor and environmental safety) dictate a different approach. Several technologies can be applied in the execution phase of explosive ordnance utilization. The problems of labor safety, technical and economic efficiency, and

the environmental issues must have priority in choosing the proper technology to dispose of a particular ammunition type.

The analysis of the Bulgarian defense industry with respect to ammunition disposal states that the existing capacities and technologies (after some improvements) could be used for partial disposal, but they do not meet the requirements for labor safety and environmental protection. This leads to the imperative to establish a Utilization Center, which will employ contemporary disposal methods, technologies, know-how, and equipment that provide for high productivity, safety, and environmental protection. It is reasonable to establish the Utilization Center on an existing military base or in an industrial park, which has the proper infrastructure and is located far enough from largely populated cities.

The center will be a commercial enterprise and this fact has beneficial social effects. First, it will create jobs in a region with a high unemployment rate. Second, there will be jobs both for qualified experts dismissed from the shrinking military industry and for officers dismissed from the downsizing Armed Forces.

The Republic of Bulgaria will not be able to provide the necessary funding for the overall surplus ammunition disposal process. Expertise, technology, and equipment should be transferred from countries that have acquired experience and knowledge in the field of explosive ordnance disposal.

The establishment of the Utilization Center needs a detailed technical and cost-benefit analysis, investment project, and business plan. It is expected that the center will be functioning for eight to ten years until the current surplus ammunition in Bulgaria is exhausted. During that period it may become a Regional Disposal Center and commence explosive ordnance disposal for the Balkan region countries.

The surplus ammunition utilization will result in great quantities of secondary materials of different types and properties. Considering their further potential use, the most important are the powders, explosive substances, bodies, cartridge cases, fusing devices, and packing. An analysis of the opportunities for

their processing and further use has been performed in the “National Program for Utilization and Destruction of Surplus Ammunition in the Territory of the Republic of Bulgaria. “

The surplus ammunition disposal process, as outlined in the “National Program” will require about €57,100,000: €9,800,000 for the establishment of the Utilization Center and €47,300,000 for the execution phase itself. It is expected that the realization of the salvaged materials will result in an income of about €16,500,000, which means there will be about 30 percent rate of recovery of the funds invested in the disposal process. Similar rates have been achieved in other countries with expertise in the explosive ordnance disposal.

We must also take into account the fact that if the disposal is not executed, then the storage expenses for a ten-year period will exceed €30,000,000. Therefore, if the disposal process does not start now, then the money required for utilization will be spent for storage and the surplus ammunition problem will persist. The problem will pose even greater threats, especially considering the environmental and safety issues.

All the above-mentioned statements lead to one general conclusion: the disposal of the surplus ammunition is the only solution to the problem, and it must start as soon as possible. The “National Program for Destruction and Utilization of Surplus Ammunition in the Territory of the Republic of Bulgaria” serves as a foundation and a guiding document for the organization of the surplus explosive ordnance disposal process. The process itself will consider the various constraints and should involve a cost-benefit analysis to find an optimal solution to the surplus ammunition problem within the limits of these constraints.

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APPENDIX: LIST OF BASIC DOCUMENTS RELEVANT TO THE BULGARIAN SURPLUS AMMUNITION PROBLEM AND USED AS SOURCES OF INFORMATION

Armaments Policy Directorate. *Armed Forces Modernization Plan 2002-2015*.

Sofia, May 2002. Available from <http://www.md.government.bg>, accessed 28 March 2004.

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