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Lieutenant Colonel István Ember:

Challenges of Explosive Ordnance Disposal Support and Modern Methods for Identifying and Rendering Safe Military-Origin Explosive Devices in the 21st Century

author's review for Doctor of Philosophy (PhD) thesis

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INTRODUCTION

JUSTIFICATION OF TOPIC SELECTION AND FORMULATION OF THE SCIENTIFIC PROBLEM

In the task system of military engineering, numerous specialized skills and specific responsibilities can be found. Within this complex framework, explosive ordnance disposal (EOD) tasks are perhaps the most hazardous, presenting challenges that may receive relatively little attention in scientific contexts, even on a global scale. While some areas, such as improvised explosive devices (IED) related to terrorism, have generated significant research results, there are identifiable scientific problems awaiting solutions in the context of conventional military-origin explosive ordnance.

Hungary is in a particularly unique position in this regard, as the organization of public service EOD activities falls within the scope of defense duties. This task, which is relatively rare in the context of other armed forces, brings forth intriguing challenges that can be addressed through scientific methodologies.

Along the lines of the above thoughts, several questions for examination have been identified within the field, from which the following have been analysed. The first challenge is posed by the impacts of climate change, which directly influence public service EOD activities. With a wealth of data available regarding the specifics of EOD activities in the country, there exists an opportunity to collect and organize these data to identify trends that affect proactive task planning.

By conducting this procedure specifically for a river highly affected by global climate change, further concrete results can be anticipated. Previous experiences have shown that increasingly frequent low water levels significantly increase the volume of reported explosive devices, imposing a dynamic burden during task planning. Extracting information and findings from the indicated data may aid in achieving optimal work and task organization, thereby reducing this burden.

The second area where investigation is necessary and worthwhile concerns ammunition disposal as a service. This refers to ammunition disposal provided by enterprises and companies, in which the Hungarian Defence Forces (HDF) can also participate within defined legal frameworks. This fundamentally civilian activity is part of everyday life, and several companies in our country operate in this domain. Under appropriately regulated and supervised systems, this could function even more efficiently, but, in my opinion, not all the necessary conditions are currently in place. However, it is definitely important that this inherently accident-prone sector likely addresses any shortcomings through internal resources, internal regulations, and training. It could be in the interest of all parties involved to conduct these operations under more regulated frameworks and appropriate supervision. A well-established organization with a developed legal background could create the conditions for quality, safe, and effective ammunition disposal.

The third problem area relates to the identification of explosive devices encountered during public service EOD tasks. In most cases, professionals can perform definitive identification through visual methods alone during tasks. Despite the extensive knowledge gained during their training, Hungarian EOD experts are expected to perform these identifications without the support of technical tools.

Since this is a crucial aspect in the process of task execution, it is understandable that Hungary places great emphasis on ammunition recognition, a departure from the practices of other nations.[1] Moreover, this practice may not always be feasible. Despite the vast knowledge base, situations and explosive device types may arise where visual identification requires some form of technical support, particularly of a technical nature. I intend to analyse this by focusing on a specific family of explosive devices.

The fourth area concerns cumulatively shaped charges, a topic not widely addressed in Hungarian public service EOD tasks.[2] It is important to note that the Hungarian EOD practice is based on nearly eight decades of experience, and I have no intention of disputing its applicability in this discourse. It is important to acknowledge that successful neutralization activities are carried out in the thousands annually, making such doubts untenable. However, there are forward-looking possibilities that could enhance the efficiency, optimal cost distribution, and even safety of these neutralization activities.

Building on this line of thought, there is a need for cost-effective, reproducible tools that can be used by EOD personnel for specific tasks. This is worth emphasizing because modern technological solutions, such as 3D printing or additive manufacturing, enable the application of tools designed for a specific task. Therefore, there is no need to consider universally applicable cumulatively shaped charges, as their full capabilities may not be necessary for every task, and their use can sometimes even be disadvantageous.

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[1] The most prevalent practice involves the use of expensive, database-driven identification-assisting software, which necessitates the on-site application of information technology tools.

[2] Such tools are regularly deployed; however, their production is exclusively feasible under industrial conditions, and their procurement is subject to procedural requirements.

For this reason, focusing on a specific area, I find it crucial to examine these possibilities in the context of special charge artillery shells. This could yield forward-looking results, particularly for explosive devices filled with chemical agents, due to the relatively limited research conducted in this field.

DESCRIPTION OF RESEARCH OBJECTIVES AND HYPOTHESES

The research objectives have been formulated based on the presented scientific problems and the directions identified within them. As the first objective, I will thoroughly examine alerts related to domestic public service activities concerning military-origin explosive ordnance. Analyses covering various periods and locations from recent years will provide a comprehensive overview of nationwide explosive ordnance contamination, its intra-annual variations, and local distribution. Drawing from this data, I will assess the current relevance of past analyses within the field and identify emerging trends.

Regarding the Danube River, I will analyse extreme low water levels from recent periods and compare them with data on alerts received by EOD personnel. Through this, I aim to identify markers that, coupled with continuous water level monitoring, can support the work of organizers of EOD activities.

Within the realm of ammunition disposal, I will present the current situation and examine explosive devices as particularly hazardous assets. This is crucial, as the outcomes will substantiate the need and merit for more definitive regulatory and supervisory frameworks. Due to various processes occurring within their structure and contents, explosive devices pose increasing risks. Therefore, it is useful and practical to align their management and exploration with these deteriorating processes. Hence, my goal is to, based on international standards, outline the theoretical structure and comprehensive task system of an organization capable of supervising and overseeing national ammunition disposal. The analysis of the deeper legal questions required for this will not be conducted, as it might necessitate a separate extensive study.

Subsequently, I will delve into the intricacies of explosive device identification, focusing exclusively on military-origin explosive ordnance. To substantiate the problem, I will introduce a specific family of explosive devices – the 10.5 cm Hungarian 1983/1933 M fragmentation-destroyer and special charge artillery shells. For the four analysed devices, my objective is to demonstrate the limitations of identification solely through visual methods. I will present and validate the possibility of complete, unequivocal identification and propose details of this crucial process for the aforementioned four explosive devices.

Concerning cumulatively shaped charges, my objectives span several components. As a first step, I will examine whether additive manufacturing enables the creation of tools applicable in EOD tasks. This, of course, pertains only to the fabrication of charge components; the analysis of explosive material and initiators is not within the scope of this process. By the end of the design cycle, I aim for the development of an electronic model that can be easily and relatively inexpensively produced using additive methods, without requiring substantial financial investment in manufacturing equipment. This could lay the groundwork for professionals to independently create the necessary charge components for specific tasks.

Linked to the previous charge design, I intend to conduct an optimization study. At the end of this process, I will identify a charge variant from the examined versions, tailored for a specific task. This task involves reliably and effectively perforating the wall of a medium-sized fragmentation-destroyer or special charge artillery shell. The investigated charge will be filled with explosive material and assembled with an initiator under on-site conditions.

Hypotheses:

1. Global climate change directly impacts domestic public service EOD activities, primarily in the context of low water levels in the Danube River. Identifiable markers and data can assist in proactive planning of neutralization tasks, thereby optimizing the utilization of resources.
2. It is necessary and feasible to establish a regulatory and supervisory body within the structure of Hungarian administration that exercises appropriate professional oversight in the field of ammunition disposal. This body should be capable of shaping the regulatory and standardization framework for ammunition disposal and participating in its development.
3. I assume that in the Hungarian EOD practice, the visual method may not always suffice for unequivocal identification, but with technical support, a methodology can be developed to enhance the efficiency and safety of handling certain special charge explosive devices.
4. It is possible to design, size, and model a shaped charge that can be widely produced using additive manufacturing methods and does not require significant computer-aided design or 3D printing expertise for reproduction.

5. With low-density materials and additive manufacturing solutions, it is possible to create components of shaped charges capable of perforating the case of specific medium-sized artillery shells. This demonstrates the significance of optimizing for the designated task.

DESCRIPTION OF RESEARCH METHODS

In the dissertation, I intend to apply the research methodology of István Gőcze.[3] The presented problems will be addressed through fundamental and applied research. In this context, the first set of questions, which pertains to the impacts of climate change on the planning of EOD tasks during low water levels of the Danube, constitutes fundamental research. This is primarily justified by the absence of prior experiences in this domain, and the potential influence of the results on the functioning and organization of military entities. In addition to these reasons, the results and methods can be extrapolated to clarify other similar questions.

Concerning the field of EOD, we can categorize it rather as applied research. To achieve the defined objective, I will solve the outlined problem by adopting established practices from elsewhere and harmonizing them locally.

The practical problem-solving in the identification of specialized explosive devices and sizing of cumulative charges holds ground for both applied research domains. Hence, these aspects will also fall under the category of applied research.

The first set of questions examines a concrete effect of climate change on EOD forces. I will analyse this area using various research methods, primarily grounded in theoretical logical research solutions. The data will be organized using mathematical statistical methods to compare them and discern commonalities and trends. Following this, I will employ induction to draw general conclusions regarding the processes.

When analysing the research problems in the field of EOD, I will also utilize theoretical and logical methods. Initially, I will present the current situation and compare it with international guidelines. Subsequently, I will analyse and synthesize the circumstances to develop the structure and tasks of a supervisory body applicable to our country.

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[3] GŐCZE István (2011): A tudományos kutatás módszerei [Methods of scientific research]. *Hadtudományi Szemle*, 4(3), 157–166. Online: https://tudasportal.uni-nke.hu/xmlui/static/pdfjs/web/viewer.html?file=https://tudasportal.uni-nke.hu/xmlui/bitstream/handle/20.500.12944/13609/2011_3_alt_gocze_istvan_157_166.pdf?sequence=1&isAllowed=y

In relation to the identification of specialized explosive devices, a theoretical and logical approach will be used to compare various explosive devices. The identified differences will represent aspects that aid EOD personnel. To develop a finalized procedure, I will also employ empirical methods. The necessity of using X-ray equipment will be substantiated through a military-technical experiment, constituting a demonstrative form of investigation.

In the context of sizing cumulative charges, I will also utilize a combination of possible methods. The preparation of the design and sizing process will commence by collecting existing procedures. From this data, I will select appropriate methods or elements that adhere to the sizing criteria. Following design and production, I will conduct military-technical experiments. These demonstrative experimental detonations will aid the optimization process. Due to the uniqueness and hazards of the field, initial experiments will be partially artificial, evolving into a more neutral form at a later stage. It should be noted that while this approach is relatively neutral from a penetration standpoint, it is partially modelled, with the test conducted on a metallic projectile body possessing similar parameters yet void of any dangerous substances.

The successful execution of the planned investigation thus necessitates the utilization of multiple research methods. These possibilities will predominantly stem from the realm of specific (partial) methods.

CHAPTER 1
CURRENT CHALLENGES IN PUBLIC SERVICE EOD TASKS

The subject of my investigation in this chapter is to analyse the statistical data of EOD activities spanning several years, comparing the trends in reported explosive device incidents. I will emphasize on the intra-year fluctuations to gain a clear understanding of the monthly distribution of reported incidents.

Subsequently, I will examine the distribution on a county level to analyse the alarm data in relation to areas or regions considered contaminated based on historical military events. Following this, I will investigate the distribution of discovered explosive devices, also broken down by year.

An area of significant importance in recent times is the exploration of organizational challenges arising from changing weather patterns. To achieve this, I will analyse the increasing occurrence of low water levels in the Danube River, aiming to identify indicators for managing the challenges of organizational tasks.

I will exclusively focus on the EOD tasks related to the activities of the HDF. The EOD units and activities under the Ministry of Interior (MoI) will not be subject to any form of examination. Concerning explosive devices, only conventional military-originated ones will be included in the study; improvised explosive devices are excluded from the scope as this falls within the jurisdiction of the MoI in our country.

Regarding the investigation of public service EOD activities, the formulated hypothesis is as follows:

> *Global climate change directly impacts domestic public service EOD activities, primarily in the context of low water levels in the Danube River. Identifiable markers and data can assist in proactive planning of neutralization tasks, thereby optimizing the utilization of resources.*

PARTIAL CONCLUSIONS

In this chapter, I have provided a detailed overview of several aspects within the military branch of public service EOD activities in Hungary. The historical overview and legal framework clarification were essential introductions to the examined field, establishing a solid foundation for discussing a well-established and independently regulated activity with a rich tradition.

Armed with this knowledge, many of the subsequently explored results became more comprehensible, especially regarding contaminated areas and the types of discovered and neutralized hazardous devices.

I conducted a thorough analysis of EOD statistical data spanning three years, yielding insightful findings that, at times, were unexpected. My primary focus was on the annual variation in reported incidents, aiming to create a data table that would aid in organizing EOD tasks. It was evident from the data that, with minor fluctuations, the reported incidents to the HDF EOD Duty Desk remained consistent in intensity over the observed period. It is noteworthy that the most significant burden in this regard is observed during the spring season when a substantial increase in alerts begins in March, escalating continuously until April and often reaching several times the February figures. While this pattern is dynamic, it repeats annually, providing ample opportunity for preparation. The seasonal rise is attributed to the commencement of spring agricultural activities and the improving weather conditions that drive increased construction industry operations.

Regarding the nation's contamination, I conducted analyses for the same period as above, projected onto a county-level breakdown. The county-level data did not yield major surprises, as historically war-affected regions were the most contaminated, aligning with the noted historical facts. Notably, Budapest, Pest County, and Fejér County stood out, accounting for nearly half of the annual alerts during the studied three years. It is fortunate that the HDF 1st Engineer and Riverine Guard Regiment (HDF 1st ERGR) base is located in this region. This alignment with historical trends and the location of specialized units underlines the strategic consideration given to historical factors, trends, and current challenges in the course of organizational restructuring over recent decades.

However, Győr-Moson-Sopron County proved to be surprising in terms of contamination. The available information would have predicted a region with significantly higher alert numbers, yet the data consistently fell below average, contrary to expectations. While this presents an unexpected outcome, I have not delved deeper into this aspect, as it deviates from my research objectives.

Conversely, the least contaminated regions yielded expected results. Békés County continued to report the fewest alerts, and Tolna, Nógrád, and Zala Counties consistently appeared with below-average figures on the lists.

As part of the analysis related to public service EOD tasks, I examined a significant impact of climate change: the increasing occurrence of low water levels (below 100 cm) in the Danube River near Budapest, known as "low water phase". This dynamic factor imposes a challenge for EOD activities. Through analysis, I demonstrated that the number of annual reports from the Danube may significantly increase, even up to 19 times, during a 30-day "low water phase" period. Rapid response is often required for these incidents to prevent a substantial increase in neutralization costs due to rising water levels. I analysed "low water phase" data for the year 2018 and contrasted it with the preceding two years to establish annual patterns.

To reinforce these findings, I extended the analysis to the period of August–September 2022, using daily data. This period validated the assumptions and confirmed that dry conditions can indeed lead to dynamic pressure on EOD units.

Based on the available data, I developed indicators related to the Danube's water levels to manage the dynamic burdens arising from "low water phase" situations. As the HDF 1st ERGR is involved in riverine military activities on the Danube, daily water level data are accessible, enabling continuous monitoring without imposing a significant burden on the designated organizational unit. However, timely preparation is crucial. For instance, special attention should be given to the Budapest water level at 200 cm, while below 150 cm, reserve forces need to be mobilized to manage the situation. Below 100 cm, it is highly likely that the number of reports from the Danube will significantly increase, potentially leading to an elevated deployment of EOD patrols.

With these considerations in mind, I established a categorization system regarding the burdens imposed on EOD tasks, proportional to the quantity of reported presumed explosive device incidents. These normal, dynamic, and exceptional burdens shape the alert data and, at times, cause sudden spikes, posing challenges to the HDF 1st ERGR's organizational unit responsible for planning EOD tasks. This categorization serves as the foundation for a guide that contains valuable information specifically tailored to the aforementioned organizational unit, although I emphasize that it exclusively includes data related to the areas investigated in my research. This guide can evolve and expand in the future, accommodating new factors as needed to facilitate comprehensive organizational tasks.

CHAPTER 2
CHALLENGES OF DOMESTIC AMMUNITION DISPOSAL

The aspects of ammunition disposal in Hungary are highly diverse. It is worth examining the field and its potential shortcomings and risks from various perspectives. Building on this line of thought, I aim to illuminate the primary hazards that loom over deminers and ammunition disposal experts.

In the pursuit of this investigation, I will review the categories and most significant types of explosive devices, as well as the inherent risks they pose. While it is impossible to completely eliminate these hazards, the goal is to minimize them as much as possible. I will identify the causes of explosion hazards that arise during the render safe procedure of the most common explosive devices found in our country. I will provide examples of processes that present particularly high risk, thus substantiating my findings.

I will also analyse the connection between civil ammunition disposal and the construction industry, and I will examine the state of regulations and standards applicable to companies operating in this field.

Subsequently, I will thoroughly review international recommendations for the direction, organization, and supervision of EOD activities. Based on these, I will formulate my concept for an authority that can be applied in Hungary and integrated into the existing system, capable of improving the current situation.

Regarding the content of the chapter, my formulated hypothesis is as follows:

> *It is necessary and feasible to establish a regulatory and supervisory body within the structure of Hungarian administration that exercises appropriate professional oversight in the field of ammunition disposal. This body should be capable of shaping the regulatory and standardization framework for ammunition disposal and participating in its development.*

PARTIAL CONCLUSIONS

In this chapter, I have summarized explosive devices and provided a comprehensive overview of their categorization and primary types. This was necessary to establish the foundation for further analysis, which examines the dangers faced by explosives experts and professionals involved in ammunition disposal. Grouping these hazardous factors, I have identified potential risks arising from fuses, explosive materials, and pyrotechnic substances.

I have presented specific examples of some of these risks, in order to provide a relevant understanding for those involved in professional work.

In my opinion, the summary of risks has demonstrated that professionals engaged in detection and disposal must contend with increasingly growing hazards. This should influence existing procedural guidelines, as problems may arise, possibly in the medium term, leading to unintended detonations due to factors not previously experienced. Of course, established practices and safety regulations mitigate these risks, but in the civilian sector, a uniform system is no longer applicable.

A key driver in ammunition disposal is the construction industry, which is also supported by my earlier findings. I have examined the possibilities for ammunition disposal within the context of such projects. I presented three potential scenarios and proposed recommendations for appropriate selection. In each case, I consider it reasonable to order some form of instrumental inspection process before embarking on such projects, as this significantly reduces the existing risks. Neglecting ammunition disposal entails hazards that further escalate due to the deteriorating physical and chemical conditions of explosive devices.

Continuing the preceding line of thought, I investigated the regulations pertaining to ammunition disposal companies and their operational possibilities. The relevant stipulations, in most cases, are exclusively general or linked to quality assurance requirements. The activity itself is not included in the Hungarian Classification of Economic Activities (HCEA) list; rather, it can only be compiled from various combinations of other activities.

Specific standards, regulations, and control requirements for the actual work cannot be clearly identified in Hungary. Nevertheless, due to the former explosives experts and established best practices, accidents are not common. However, one cannot rely on this for a potentially life-threatening activity, especially in the case of deteriorating physical and chemical conditions of explosive devices.

I attempted to address the identified issues or shortcomings. I examined the standards and guidelines issued by the United Nations Mine Action Service (UNMAS), which could be considered. Generally, these mainly regulate mine-clearance tasks, and the ones related to explosives have significant differences from national procedures. However, the recommendations often suggest introducing and applying existing national entities, standards, and regulations in certain cases. Therefore, I conducted a detailed examination of the organizational forms proposed for directing, controlling, and establishing the regulatory background of the activity.

While the processed documents contained the necessary information in detail, selecting or adapting those that align with national specificities posed difficulties.

To address the issues of regulation and control in the field, I devised two concepts based on the aforementioned UNMAS documents. The first version aligns better with international standards and operates at two managerial levels. The National EOD Authority (NEA) as an organizational unit provides legislative support, regulation, and accreditation. The EOD Operations Centre (EOC) functions as a separate organization, operating under the NEA, predominantly responsible for inspection and record-keeping.

In the second version, I merged the organizations of the first version. The resulting National EOD Authority and Operations Centre (NEAOC) would also be capable of performing the entire task system, yet with reduced costs and a smaller apparatus.

Despite the fact that the first version better conforms to international standards, due to local practice and moderated expenses, I recommend its implementation.

The devised concept could provide a partial solution to reducing the aforementioned risks, as we must not forget that explosives experts engage in life-threatening activities. For those involved in detecting explosive devices, the uniform and safer organizational framework could offer a secure backdrop during tasks, and continuous inspection could ensure quality execution for investors and clients. Regarding risks, the complete eradication is a mirage; only reduction and optimization are attainable. This might sound peculiar to those active in other fields, but it is an accepted part of the life of explosives experts.

CHAPTER 3

CHALLENGES IN IDENTIFYING SPECIAL AMMUNITION FOR ARTILLERY WITH UNIQUE PAYLOADS

The challenges of public service EOD tasks carry numerous complexities for professionals in the field. Peril to life is practically present in every neutralization procedure. Nonetheless, there is a particular domain that we might deem even more hazardous - the realm of Chemical, Biological, Radiological and Nuclear EOD (CBRN EOD).

In the context of CBRN EOD, my dissertation does not encompass atomic and biological weapons. Among specialized explosive devices, I will solely delve into those loaded with smoke agents, sulfur mustard, and toxic KLARK agents. These hazardous substances will be analysed exclusively within the scope of militarily originated explosive devices, focusing on a specific group of explosive devices that were part of Hungary's armed forces during World War II.

Regarding the chapter's theme, my formulated hypothesis is as follows:

I assume that in the Hungarian EOD practice, the visual method may not always suffice for unequivocal identification, but with technical support, a methodology can be developed to enhance the efficiency and safety of handling certain special charge explosive devices.

PARTIAL CONCLUSIONS

The examined field necessitates considering that specialized and even more hazardous chemically loaded explosive devices are rarely found in Hungary. However, historical facts indicate that a significant amount of chemically armed explosive devices was stored in our country. Since a single such device has the potential to cause the death of many people and severe illnesses, I investigated the unequivocal identification possibilities of a specific type of special artillery grenade.

Through research, it has been confirmed that if an explosive device falling within the scope of investigation is unearthed, its identification can pose difficulties. Determining the manufacturing country alone can be problematic due to the many similar types, and even within that, several grenades with matching dimensions exist. In this complex task, explosives experts need to find the appropriate tool. Visual identification is aided by several factors, but in some cases, the 10.5 cm Hungarian 1938/1933 M artillery grenades can only be divided into two groups: those with fragmentation-destructive and KLARK charges, and those with smoke and sulfur mustard charges. Further refinement through visual methods is no longer possible.

In such cases, visual identification must be supplemented with methods that facilitate safe neutralization. X-ray examination offers the opportunity to obtain an evaluative image of the internal structure of the explosive devices, which is highly necessary in our case. The image of the internal structure solves difficulties that cannot be handled through visual methods. Based on the X-ray image, the specific type of explosive device can be determined, which is essential for selecting further neutralization procedures.

To achieve this, I developed identification processes specific to such explosive devices. In addition, I outlined the key steps in handling such explosive devices, which should be applied appropriately by professionals, in alignment with procedures defined in national regulations and established practices.

It's important to note that this process is not only possible and necessary for the artillery grenades under investigation. Similar difficulties may arise for other explosive devices filled with hazardous materials listed above, which is why I recommend considering the application of X-ray methods for those cases as well. This might be particularly relevant for the 10.5 cm 1933 M artillery grenades, although I have not extensively examined this aspect.

CHAPTER 4
DESIGNING A CUMULATIVE CHARGE FOR SPECIFIC EOD TASKS USING A 3D PRINTER

In the field of blasting technology, it is essential to continuously monitor modern technical solutions and review existing procedures for the purpose of their improvement. As there is often a convergence between military and civilian explosive tasks, with minimal differences in tools and significant variation in end goals and motivations, the above statement applies to military applications as well.

Explosive ordnance disposal soldiers engage in daily activities that involve performing explosive tasks, as the final step in rendering safe discovered explosive devices. While other professional tasks such as dismantling fuzes or removing components can precede destruction, ultimately, the process culminates in an explosion, the act of destruction.

I consider it necessary to incorporate this inherently life-threatening activity among the continually evolving research directions. Each advancement, new tool, and procedure can aid explosive ordnance disposal soldiers in performing their duties more safely and efficiently.

The application of 3D printers in explosives technology represents an innovative research area. While this method is excellently suited for creating component prototypes for various charges, it must be acknowledged that the process now offers much broader possibilities. For small production runs, establishing manufacturing lines for individual products may not be cost-effective. In such cases, 3D printing serves as an excellent alternative as a production method for components and devices.

Regarding research on cumulative charges, my formulated hypotheses are as follows:

- *It is possible to design, size, and model a shaped charge that can be widely produced using additive manufacturing methods and does not require significant computer-aided design or 3D printing expertise for reproduction.*
- *Using low-density materials and additive manufacturing solutions, it is possible to create components of shaped charges capable of perforating the walls of specific medium-sized artillery shells. This demonstrates the significance of optimizing for the designated task.*

PARTIAL CONCLUSIONS

In the chapter, I provided an overview of the historical details related to cumulative charges and presented the most significant sizing variations. By considering the results of ongoing research at the current technological level, I managed to define the key parameters of cumulative charges that align with the expected performance requirements.

During the examination of various 3D printing methods, I successfully identified the technology that best suits the goals, parameters, and materials used. In the case of filament-based printing, there was no question that polylactic acid (PLA) was the suitable choice, as this material is virtually inseparable from this environmentally friendly process.

I illustrated the process of computer-aided design, which enables the reproduction of electronic models without significant investment in design resources.

The details of 3D printing electronic models were presented using the "CraftBot3" printer, including the essential configuration settings.

As a result of the printing process, I was able to investigate cone and hemispherical-lined cumulative charges through practical tests. These tests were conducted in two configurations and three sizes, which narrowed down the possible variations. In the second test series, I assessed the effectiveness of printed charges in two smaller sizes. The third series of tests validated the performance of the final configurations in a realistic environment and using authentic methods. Additionally, I managed to demonstrate that the cumulative jet's diameter, following full penetration, is highly unlikely to cause significant damage to the fuze well of artillery shells.

Both charge variations are capable of accommodating the smallest cone-shaped liner with a 20 mm internal diameter. The applied focal lengths for these cases are 20 mm and 40 mm, respectively.

The results confirmed that both charges can penetrate 15 mm thick homogeneous steel and two differently manufactured medium-sized artillery shells. The validated charges are designated as 20-1D-K and 20-2D-K. Both can achieve the desired penetration, but considering manufacturing time and resource optimization, I recommend the use of the first variation with a 20 mm standoff distance for explosive ordnance disposal tasks.

I not only managed to produce the charges but also precisely determined the assembly steps, intending to provide guidance for professionals during on-site assembly.

This charge is not exclusively suitable for military applications. In civilian explosives technology, tasks may arise where experts can utilize cumulative charges with such low-density liners for controlled detonations. This will require further testing in the future, such as for de-icing frozen water structures, loosening compacted materials, and fracturing rock formations.

The explosions shed light on several additional research directions. It would be interesting and useful to investigate the effectiveness of liners made with polyamide, as simulations suggest significant potential. Additionally, a combination of copper and PLA might be explored for similar reasons. Concerning the charges, it is evident that there are other components that can be further developed. This includes designing a bayonet or threaded locking mechanism for the charge housing and cap. Consideration should be given to employing an inert lens within the charge, although this requires careful handling during on-site assembly. Furthermore, in line with the application on various explosive devices, I plan to enhance the charge with an auxiliary component designed to assist attachment. This element will be attachable to standoff elements and will allow precise alignment of a single charge onto the surface of various artillery shells.

SUMMARY

In the first chapter, the statistical analyses revealed that the spring season bears the greatest burden in terms of alerts. The March-April periods are worth preparing for and necessitate efficient task organization due to their high alert frequency. The reasons are likely attributed to simultaneous increases in agriculture and construction activities.

Regarding national alert data, the alarms over the examined three-year period did not deviate significantly from the expected values. The tasks for bomb disposal experts are concentrated around Budapest, Pest County, and Fejér County, which is not surprising considering the events of World War II, but it is nonetheless an important finding. However, in the case of Győr-Moson-Sopron County, the anticipated significant contamination did not materialize, contrary to a previous study. Békés, Tolna, Nógrád, and Zala Counties, on the other hand, aligned with the predictions, with very few alerts about explosive devices from these areas.

Examining the low-water situations of the Danube River based on data from 2018 and 2022, statistics indicate that reports can increase significantly, even up to 19 times, during these periods from the river and its vicinity. These results were useful in identifying indicators necessary for forecasting such dynamic situations.

This implies that in the case of a Budapest water level of 200 cm, one should prepare for an increase in alerts, generate reserve resources below 150 cm, and anticipate a sudden rise in the quantity of tasks below 100 cm.

By categorizing the factors influencing bomb disposal task planning into groups, I have successfully created a planning guide that can support organizational activities, enabling more effective and economical resource utilization. Naturally, the data related to the Danube have been integrated into this guide.

From the perspective of this chapter, it can be stated that my hypothesis has been confirmed. Climate change affects bomb disposal task organization due to the conditions of the Danube's low-water state, and I have managed to determine the water level data that can function as markers for more effective work organization.

During public service tasks, after presenting the groups of explosive devices to be neutralized, I summarized the risks inherent in them. This was a comprehensive analysis, taking into account both chemical and mechanical possibilities. These risks emphasize the importance and necessity of carrying out activities under strict rules and continuous supervision, which is unquestionable in the case of military and law enforcement organizations. Despite significant limitations for the civilian sector in conducting search and ammunition disposal activities, these rules and controls are only modestly present.

The construction industry, as the primary source of revenue for the aforementioned explosive ordnance disposal companies, exerts a significant influence on bomb disposal tasks. Pre-investment inspections can also have a profound impact on the entire construction process. In the case of bomb disposal, there are three options available to all involved parties, which I examined in detail and proposed suitable options for selection. Technically, any solution involving preliminary inspections could be viable, provided its practical implementation is feasible.

Following this, I reviewed the domestic legal circumstances concerning companies engaged in explosive ordnance disposal. This field is modestly regulated, and due to the deteriorating state of explosive devices mentioned above and the need for high-level quality assurance, it requires revision and improvement.

To address this issue, I examined the standards and guidelines issued by the UNMAS, which may be relevant to this field. While these standards primarily deal with mine clearance, there are some that apply directly to the work of bomb disposal experts.

After reviewing the organizations and structures proposed by the UN standards, I developed two versions of the structure and tasks of the domestic regulatory and supervisory authority. I suggested adopting the version that combines the two-tiered leadership level, which is the NEAOC. This may align better with Hungarian specifics and the established practice of disarmament and exploration. This version places more moderate demands on the administrative staff, and therefore also in terms of expenses.

The results unequivocally confirmed my assumptions regarding both necessity and feasibility.

In the following chapter, I summarized the details of certain Hungarian special warheads and gas warfare employed during World War II. The investigation proved that the visual identification method is not suitable for the accurate differentiation of the four types of 10.5 cm Hungarian 1938/1933 M artillery grenades. Throughout the process, it is only possible to narrow down the possible artillery grenades to two variations each.

To address this issue, I proposed the use of a mobile X-ray device, which proved successful during practical tests. This should be applied and tailored to the unique capabilities of each different device. Based on the experience, I outlined the possible identification process for the aforementioned grenades, which could assist bomb disposal experts in safer and more efficient work. My hypothesis concerning this topic was confirmed; it is necessary to supplement visual methods with technical tools in certain cases, and I also managed to present a concrete process.

In the final chapter, I provided an overview of the history and mechanism of action of cumulative charges. I collected various sizing methods and research results that offer the latest data. Based on these, I determined the key parameters necessary for a charge to confidently penetrate a medium-sized artillery shell.

This corresponds to approximately 15 mm steel penetration, making it applicable to other civilian explosive tasks as well under such performance conditions.

While reviewing the important methods of 3D printing or additive manufacturing, I successfully selected a technology that aligns with the objectives, parameters, and materials used. This involves the use of filament-based printing and PLA as the base material.

I elaborated on the computer-aided design process and the specifics of 3D printing using the available Craftbot 3 printer. This detailed description can assist professionals in the design process. However, the manufacturing parameters are only indicative; variations may occur in quality, production speed, and overall success rates across different types.

During practical tests, I examined both conical and hemispherical liner cases. The hemispherical design proved ineffective along the design parameters, prompting me to focus on optimizing the conical shape to achieve the set objectives. As a result of this process, among the five tested diameters, the smallest 20 mm type (20-1D-K and 20-2D-K) met the requirements for both standoff distances (20 mm and 40 mm). I validated their performance on actual fragmentation-destroying grenade casings and conducted further tests regarding the impact on the cumulative charge's detonator holder. The latter tests yielded particularly favourable results under experimental conditions for chemical explosive charges, theoretically preventing damage to the detonator holder.

I also developed assembly steps for the designed charges to facilitate the work of professionals in case they begin disarmament activities involving such tools within a demolition operation.

It can be concluded that the application of these charges is not exclusive to military tasks. They can potentially meet requirements for certain civilian explosive activities, although this requires further investigation.

I thus confirmed my hypothesis that it is possible to create an efficient cumulative charge through additive manufacturing, and its replication does not demand significant expertise. Furthermore, I validated the hypothesis that such an additive process is capable of producing a charge suitable for penetrating medium-sized artillery shells.

NOVEL SCIENTIFIC FINDINGS

1. Based on analyses, I determined the key data regarding the low-water conditions of the Danube and their impact on EOD task planning, thereby identifying one of the effects of climate change on domestic public service EOD tasks. Subsequently, I compiled a guide for EOD work organization, enhancing its efficiency.
2. I developed the structure of an administrative authority to oversee and regulate civilian EOD in Hungary. I defined its most important tasks, thereby creating the possibility of at least partial reduction of risks.
3. I formulated an unequivocal EOD identification process for Hungarian 10.5 cm 1938/1933 M special and fragmentation-destroyer artillery shells, enhancing the safety of disarmament activities.
4. I determined the parameters and utilized computer-aided design to create designs for shaped charges that can be easily produced through additive manufacturing, requiring no significant expertise in design and 3D printing for their reproduction.
5. Through additive manufacturing, I created and optimized a shaped charge made exclusively from low-density materials, capable of penetrating medium-sized artillery shells during EOD tasks.

RECOMMENDATIONS AND APPLICATION OPPORTUNITIES OF RESEARCH FINDINGS

The guide developed for bomb disposal task planning can be effectively utilized within the designated organizational unit of the HDF 1st ERGR. The provided data and timeframes can contribute to efficient work organization, but continuous monitoring of water levels is necessary.

The establishment of an administrative authority for overseeing and regulating civilian explosive ordnance disposal in Hungary will greatly assist in shaping and improving the regulation of the field, as well as in monitoring ongoing tasks and preparations.

I recommend implementing the unequivocal identification process for Hungarian 10.5 cm 1938/1933 M special warhead and fragmentation-destroying artillery shells into bomb disposal practices. This can aid professionals in their work, reduce the time and energy devoted to tasks.

The developed cumulative charges can be employed by bomb disposal experts once the procedure is standardized, whether for the neutralization of chemical or other specialized explosive devices. In the case of medium-sized artillery shells, the charge is capable of reliably penetrating their walls. Nevertheless, it could also prove effective for similar devices with similar wall thicknesses and payloads. Through the use of a relatively simple and inexpensive 3D printer and the presented process, these charges can be easily reproduced, making it sufficient to create the necessary number of charge components before a given task.

SUGGESTIONS FOR FURTHER RESEARCH DIRECTIONS

I consider it a valuable research direction to examine the impact of other environmental effects stemming from climate change on bomb disposal tasks or to replicate the presented process in relation to other significant surface waters. Expanding the developed guide with these results will provide further guidance to professionals in work organization.

In the context of explosive ordnance disposal, an important research task could involve the legal analysis of the presented subject matter, which could establish the background for the outlined professional tasks. Implementing the specific regulations, standards, and procedures of the UNMAS into domestic practice also presents a challenging opportunity.

Supporting the visual identification of explosive devices through the application of mobile X-ray technology in public bomb disposal tasks also presents unexplored areas. In my opinion, there may be other special devices with explosive payloads that could surface within our country and fall into the same problem domain. Exploring these and extending the process to newly identified explosive devices could also be considered as an additional avenue.

Regarding cumulative charges, investigating the efficiency of other materials, optimizing the size and liner of charges for other explosive devices, designing and testing auxiliary components for integration – these are all further opportunities for ongoing research. The potential civilian explosive application should not be overlooked either, as the tool fundamentally possesses dual usability. Substantial results could be achieved in this field as well, further confirming the effectiveness of the charges.

In conclusion, there are several promising avenues for further research, ranging from legal analyses to the optimization of materials and components, and extending the application to different scenarios. These efforts have the potential to enhance the field of bomb disposal and contribute to more effective and efficient practices.

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THE AUTHOR'S PROFESSIONAL AND SCIENTIFIC BIOGRAPHY

Lieutenant Colonel István Ember was born on October 13, 1982, in Balassagyarmat, and he grew up in Magyarnándor, a village in Nógrád County. He is married and lives in Budapest with his wife and their son.

He developed an early commitment to a military career, and after completing his local primary school, he gained admission to Lenkey János Military High School in Eger. Following successful completion of his high school studies, he continued his education at Bolyai János Military Technical College of Zrínyi Miklós National Defence University, majoring in civil engineering. On August 20, 2005, he was commissioned as a Second Lieutenant and received his first officer assignment at the HDF 1st EOD and Warship Regiment. He began his officer career as a platoon commander, later serving as deputy company commander and company commander. Within the unit, he also held positions in reconnaissance, training, and operations, and following a meritorious promotion, he assumed the role of head of explosive ordnance disposal operations, concurrently performing duties as a chief explosive ordnance disposal officer for a year.

In 2013, he achieved the level of first-class EOD operator, which he has maintained annually since. He has completed multiple national and NATO courses. As a patrol commander, he has been dispatched for 456 live ordnance incidents within the country and has successfully executed numerous blasting tasks. In addition to his military skills, he holds civilian licenses as an explosives supervisor in three areas and is authorized to conduct pyrotechnic activities.

In 2016, after completing a two-year program, he earned a degree in industrial explosive engineering from the Faculty of Engineering at University of Pannonia. In 2019, he graduated from the military leadership master’s degree program at the Faculty of Military Sciences and Officer Training of the University of Public Service. Following this, he was admitted to the Doctoral School of Military Sciences and commenced research related to his thesis.

Upon starting his doctoral studies, he assumed a new position at the Department of Operations and Support. As an assistant lecturer, he contributes to the institution's undergraduate and master's programs, with his students achieving success in both institutional and national scientific conferences. He has also been an important figure in research. In three consecutive academic years, his research received support from the New National Excellence Program. He participated in the Field-Specific Excellence Program in 2019, and in 2022, he undertook applied research tasks in a different subprogram. Currently, he serves as an institutional thesis supervisor in the Cooperative Technologies National Laboratory's Additive Manufacturing and Materials Science program, carrying out tasks as a leader in priority research areas.

He is proficient in English at an advanced level and has a basic proficiency in French.

As a result of his scholarly work, he has contributed 58 items to the Hungarian Scientific Works Repository, with 39 of them being original written works that have received 42 independent citations. His Hirsch index stands at 5.