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A HISTORY OF DETECTION OF EXPLOSIVE DEVICES 1. (700-1950)

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ABSTRACT

This study presents the history of explosive devices and that of their detection. With the invention of explosive devices and their subsequent use, the methods of warfare changed significantly. New procedures emerged that were already unthinkable to implement without the use of such tools. In parallel with the emergence of explosive devices with increasing destructive power, the need to deactivate them also came to the fore. Opposing parties made increasing efforts to detect, deactivate, and destroy explosive devices. After the completion of military operations, the detection of explosive devices did not lose its importance, and developed into an essential mission, since the areas had to be cleared of devices left over from the military actions and posing a murderous danger.

KEYWORDS: explosive device, mine, minefield, detection, deactivation

1. Introduction

The history of mankind is a history of wars. This statement is especially true of the 20th century, where not a single year passed without an armed conflict (Kiadó, 2001). Throughout human history, combat tools and procedures have been continually developed. The ancient legend of Prometheus, who stole fire from the gods to pass it on to humans, is very well known. In this myth, our distant ancestors could have foreseen that the key to human growth lies in the control of fire. After all, he who is able to dominate fire, gains advantage over others. The same was thought of explosives as well.

It has been a very long time since the invention of explosives, and these "compounds" have been used in countless cases for and against humanity. Accidental explosions during their discovery or production have clearly demonstrated the "magical power" of these materials. Although they were only utilised as fireworks at religious ceremonies for a long time, it was also realized that such materials could be used for "something else" (Szabó & Tóth, 2012). The pre-planned and systemic use of the properties of explosive materials resulted in the creation of explosive devices. Explosive devices can be used both in defensive and offensive operations. Such type of their military application changed the nature of warfare.

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Parallel with their application, the need for defence against explosive devices emerged, which could result in increased survivability of friendly troops. The history of the detection of explosive devices dates back to about the same era as the history of the military use of explosive devices.

2. From the Medieval Period to the End of the Modern Period

For centuries, humankind has been using explosive materials both for military and industrial purposes. The use of explosives for military purposes resulted in the creation of explosive devices. According to current wording, an explosive device can be any object or device that contains an explosive or pyrotechnic substance (Mű/41, 2014). The earliest man-made explosive material was black or smoky gunpowder, which is commonly referred to as gunpowder, as it was used for a very long time mainly to fire projectiles from firearms. The history of black powder begins in China around 700 A.D., when it was discovered that the mix of nitric, sulphur, and charcoal in the right proportions might result in a material that can make spectacular fireworks (Lukács, 2012). However, it was not used for military purposes for another nearly 300 years. Documents suggest that in China, during the Song Dynasty in 970, Feng Y-Sheng and Yue Y-Feng used incendiary arrows, the tips of which were dipped in gunpowder, (Андреев, 1956) but black powder was also used to operate other weapons. Subsequently, gunpowder was regularly used in China for military purposes too. In 1232, in Kai-Fung-Fu, the capital of the Jong Dynasty, the city's defenders used "Ho-Pao" devices in order to break the siege by the Mongols. From the descriptions of the effects of the device, it can be concluded that it might have been the first explosive device in the world.

After its discovery, the gunpowder spread quite slowly in the world, because the Chinese, having recognised the importance of "black dust," kept it as a secret weapon. Into Europe, the black powder was brought by English monk Robert Bacon, who presented its operation and strategic importance to the Pope in 1240. In 1242, in his book "Liber de Nullitate Magiae", Bacon provides an exact "smoke powder" recipe for fireworks. According to this, black powder can be produced by mixing 40% potassium nitrate, 30% carbon and 30% sulphur.

Black powder appeared in the Middle East at about the same time when it appeared in Europe. It is not known whether it was "borrowed" from China or developed independently, but according to certain records, Muslims used the mix as early as the 13th century. The incendiary arrows coated with the flammable materials they had previously used had not been effective enough because they went out easily during flight. It was established that black powder mixed with salt compounds was significantly more stable and did not go out in flight, so that previous deficiencies could be easily eliminated. It was also found that when a mixture of such a composition was filled into a tube with one of its end left open, the gases formed during ignition left the open part and the device itself did not have to be thrown because it activated itself, got launched and airborne. In flight, it was driven by the thrust produced by the ejecting gases rearward. As a result of this process, the rocket was invented. Such rudimentary missiles were used in the wars against the Mongols and the Crusaders (Ghazal & Ismail, 2011). Although the use of black powder in an explosive device proved to be beneficial to the troops using it, its use in this field was not widespread. Presumably, this may be related to the conditions required for the

storage of gunpowder, which became wet and unusable if it was not stored in sufficiently dry conditions. The dry conditions, necessary for storage, could not always be created by the belligerents on the battlefield, since their camps were often relocated. Therefore, the creation of those conditions was limited for providing gunpowder necessary for the use of firearms.

In the 15th century, in addition to its use in firearms, black powder was introduced for use in tunnels and shaft passages dug into the ground, with the aim of destroying enemy fortifications. To this end, tunnels were dug as close as possible to the walls of fortifications. They were filled with black powder or other incendiary mixtures that were blown up in order to destroy the walls of the fortifications and to create a gap in it for access by the attacking infantry. Such a method was used by the army of Russian Tsar Ivan IV, also known as "Ivan the Terrible" during the siege of Kazan in 1552.

Parallel with such type of use of explosive materials, the need to detect them emerged for the defenders. There are many stories about how demining activities actually began. In the Medieval Times, given the contemporary procedures according to which mines were explosives hidden in tunnels, tunnels were also dug as a possible way to defend against attackers' mines. With digging the probing tunnels, the intention was to find the tunnel made by the enemy and the explosives hidden in it before it was put into action. This was an extremely tedious task that failed to meet the expectations in many cases. An improved version of the method was to dig "counter-tunnels" in which explosives and incendiary materials were placed. Those, when initiated in good time, collapsed the tunnel excavated by the attacking enemy, thus preventing planting a mine. This type of demining procedure was used for force protection right until World War I. Later, simultaneously with the development of mines, new and more sophisticated detection and clearance procedures were developed. Attempts were made to flood the tunnels with water, thereby neutralizing the explosive device containing mainly gunpowder, but the applied techniques also included destruction with explosive charge adjacent to the main charge.

Some records from the mid-16th century also mention the use of black powder for criminal purposes. One such case was the assassination at Kirk O. Field in 1567, which ended with the death of Lord Darnley. As these cases were unique and the acts specifically targeted one particular person, the use of explosive devices for such purposes cannot be considered widespread. Nor did the contemporary authorities identify this type of crime as a common source of danger, therefore no attempt was made for investigation. The first use of black powder as an industrial explosive in the world took place in Selmecbánya, present day Banská Štiavnica, in 1627, where it was used by master miner Gáspár Weindl to crack the mine wall.

In the 16th century, new types of combat firearms appeared on the battlefield, while the typical use of black powder in explosive devices was limited to mines hidden below ground level. The first controlled-effect shrapnel mine on the battlefield was used by Francois de Fleury, an engineer of George Washington, on the banks of the Delaware River in New Jersey in October 1777. The mine consisted of explosive material dug into the ground, and stones placed onto or next to the charge, to act as shrapnel.

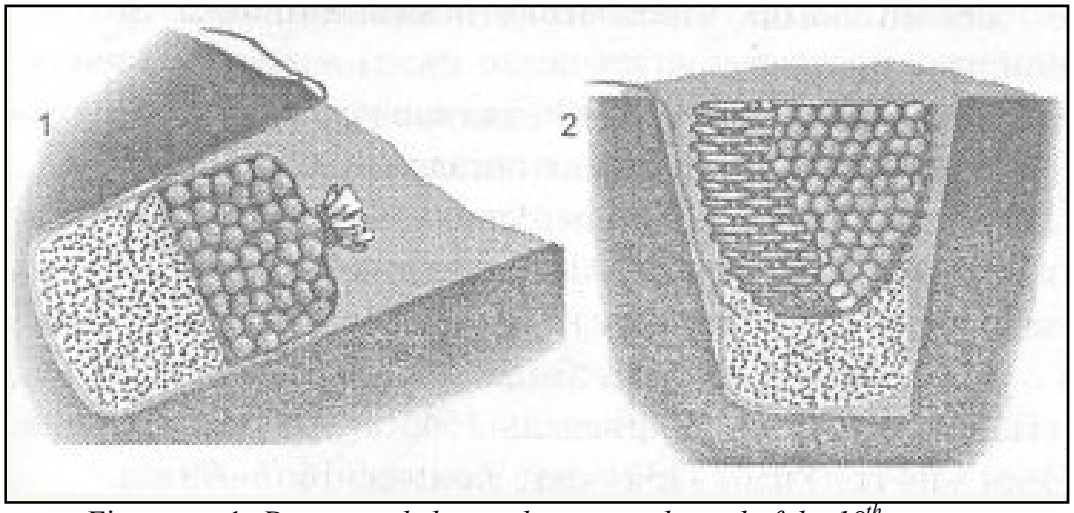


Figure no. 1: *Directional shrapnel mines at the end of the 18th century*
(Source: Veremeev, 2014)

Later, the method was further developed and used to defend permanent fortifications by halting the attacking enemy. Its operation resembled a cannon dug into the ground. The barrel was dug horizontally into the ground on the hillside, typically in the vicinity of the entrance to fortifications or near vulnerable points. The tube was filled with gunpowder and fragmentation material (pieces of stone, iron and tiles). It was used as a remote controlled mine and detonated with a fuse. In this way, an effect similar to that of today's Claymore mines was achieved. These devices were later used as victim-actuated mines. To operate them, generally friction igniters were used, actuated by either pressure or pull. Shrapnel mines improvised in this way with the use of materials at hand were later favoured by paramilitary forces that did not have huge resources, such as Viet Cong, Central American guerrillas, or Bosnian insurgents in the Yugoslav War (Croll, 1998).

The limitations of the use of black powder as a charge in explosive devices and as an industrial explosive became apparent towards the end of the modern age. The need for a more effective explosive material emerged.

In 1847, Italian Ascanio Sobrero conducted experiments with glycerine, which he added to a mixture of concentrated nitric acid and sulphuric acid. As a result, he discovered nitro-glycerine, which had significantly superior properties to those of pyroxene, which was mainly used as a propellant for projectiles. Nitro-glycerine was initially used in mining, but its use was later suspended due to its excessive sensitivity. Its military use was not possible for the same reasons. It was Alfred Nobel, who continued to study the properties of nitro-glycerine and its safe production. Through experiments, he managed to prove that the properties of nitro-glycerine mixed with diatomite did not change at all, while its sensitivity decreased significantly. As a result of the tests, he made a new, handling-proof material and in 1866 created dynamite. The second half of the 19th century brought about a significant change in the development of explosive materials for military use as well. 1885 saw the invention of picric acid, and blast experiments were performed with trinitrotoluene, which resulted in the patenting of TNT at the turn of the century. The use of new materials as charges for explosive devices revolutionized ammunition manufacturing, they were used mainly in large-calibre artillery grenades. However, the focus of the methodology of detecting explosive devices continued to be on detecting mines planted below ground level.

3. From the late 19th Century until the End of World War II

At the turn of the twentieth century, in addition to increasingly advanced firearms and artillery guns, a growing number of mines were used. The British army deployed large numbers of pressure-operated anti-personnel mines during the Second Boer War between 1899 and 1902 to halt Zulu fighters in Sudan. The Russian army also successfully used mines to protect the flanks against the attacking Japanese infantry during the Russo-Japanese War of 1904-1905. It was during World War I when, as a result of the positive lessons learned, the rapid development of mines and their applications took place.

Initially, mines made from standard artillery shells were used. They were positioned below ground level so that their fuse was slightly above ground. In many cases, shells with long-delay chemical fuses – of up to 48 hours – were planted in this way, which were used effectively against infantry. Since these devices were relatively easy to detect visually, it was important for the defenders to constantly monitor and cover them with fire, otherwise these shells could have been destroyed with charges attached to them by troops specially trained for such missions (Sloan, 1986).

Another preferred technique of "remote demining" was with fire. This meant shooting artillery fire at the mined area and attempting to destroy the mines using the blast impact. However, this procedure was not always reliable. In many cases, the force of the explosion did not activate the explosive devices hidden in the ground, just scattered them or caused an incomplete explosion, leaving a significant amount of dangerous materials to deactivate in the area. This is especially true when large-calibre devices were in use. Another disadvantage of applying this method was that the ground surface changed as a consequence of the series of explosions, which significantly affected its subsequent possibility.

In World War I, the advent of tanks significantly changed the techniques of demining. Mine rollers and mine ploughs that could be mounted on tanks appeared. It was towards the end of World War I, when a minesweeper was mounted on a French-made Renault FT-17 tank (Schneck, 1998) for the first time, significantly increasing the speed of the attacking troops. After the end of the war, mine detection and clearance procedures were developed on the basis of experience gained in the handling and destruction of explosives and unexploded ordnance.

However, given the scale of the proliferation of mines in World War I, the tactical and operational use of the above-mentioned tools was not directly proportional to this. After the end of the war, the main direction of the military technological developments did no longer focus on these devices and mines, and their utilisation became somewhat peripheral.

In 1929, engineer Gerhard Fischer, living in Hollywood, developed a device labelled "metal detector". It was a rather heavy (10 kg) structure, but it was quite simple to handle and did not require any special training. It was a very popular tool in municipal construction services, where it was used to locate pipelines, rails, cables, and other metal objects under the ground. The "metal detector" was not used for military purposes, consequently, manual mine detection – prodding – and clearance remained the basic technique.

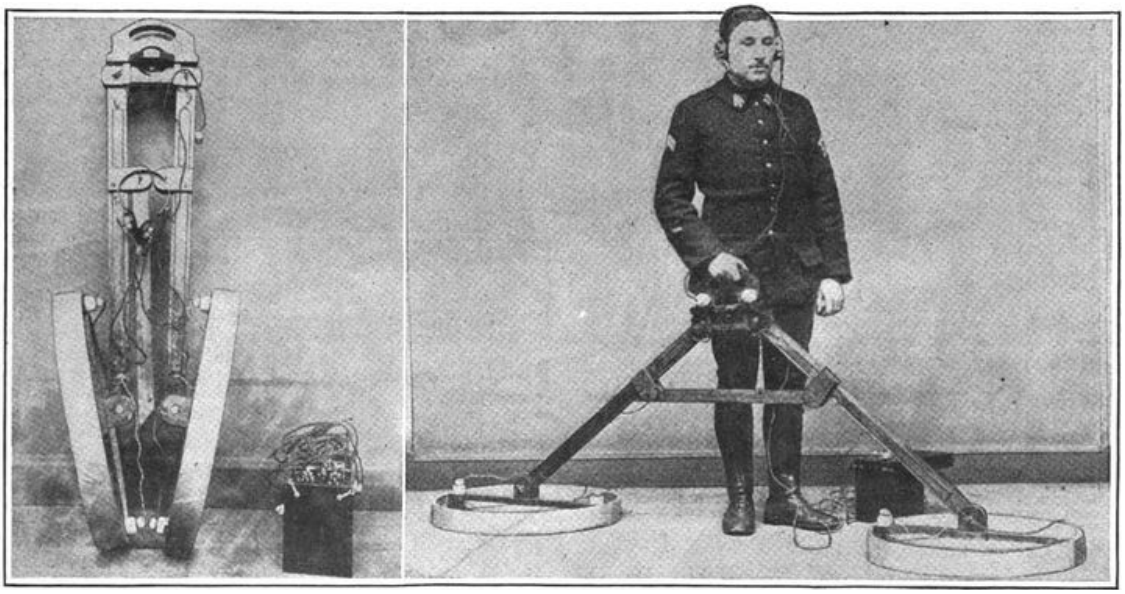


Figure no. 2: *A metal detector in folded and ready to use position*
(Source: Provin, 2017)

World War II warfare was characterised by the mass use of mines, so much so that opposing parties deployed nearly 300 million mines during operations. They were constantly developing their combat tools and their use. The methodology of mine lying was based on mathematics in order to make mines as efficient as possible. According to certain calculations, in World War II, 20% of tank losses were caused by mines. In addition to anti-tank mines, an increasing number of anti-personnel fragmentation and blast mines were also in use. Although it was the Germans who were the main innovators in the field of mine technology during this period, British soldiers were the first to use coherent minefields consisting of pressure-activated antipersonnel mines along the Egyptian-Libyan border in North Africa, against Italian forces to slow down their advance. In order to ensure the freedom of movement of the troops, the elimination of minefields became a priority. *"Detecting and removing mines, demining in particular, comprise an extremely difficult but particularly important job"* (Guderian, 1999, p. 229). Accordingly, in World War II, all states attached great importance to research and development in this field. Various programs were implemented in the field of mine detection and demining, with the primary goal of accelerating procedures and improving the survivability of the engineer troops involved in these activities. The emergence of induction-based metal detectors was a milestone in this process (Stolfi, 1972). The first vehicle-mounted induction mine detector – mounted on an R-35 tank – was developed and tested by the French in the interwar period. At the same time, British, American, German, Italian, and Soviet troops were also conducting significant research aimed at developing a portable induction mine detecting instrument. According to Soviet sources, the Red Army had such a device called "IZ" as early as before the outbreak of World War II. An improved version of this device, called VIM-210, was commissioned later, in 1940, at the Red Army engineer-sapper subunits. The special feature of the model was its multifunctional application, as the device could be disassembled, so its components could be mounted on devices other than the original factory-made shaft. It could be substituted with a prodding stick used for manual demining, a rifle barrel, or even a tree branch (Веремеев, 2008).



Figure no. 3: *Soviet engineers with a VIM-210 mine detector during the Great Patriotic War*
(Source: https://yandex.com/collections/card/5d287655af206497847a031e/, 2019)

By early 1942, all nations fighting on the European battlefields had already introduced induction mine detecting equipment (Blanche et al., 2015).

Based on the experience gained from a large number of practical use, troops serving in the areas of operations were provided with more and more advanced devices, thus making mine detection increasingly efficient. In late 1942, a frequency modulation version of the devices' sensors was fielded, which already was possible to tune to the ground, thus enabling measurements to be made in relation to the nature and pollution of the given area. The high development level of the technical solutions used is proven, for example, by the fact that the PRS-1 induction mine detector, commissioned by the Americans in 1943, was used in the US Army until the early 1980s, with only minor modifications and technical improvements.



Figure no. 4: *American soldier with a PRS-1 induction mine detector in 1944*
(Source: Type 95 Ha Go tanks and California National Guardsman Sweeps for Mines Leyte 1944)

The use of induction mine detectors greatly accelerated the search of an area. By using them, the engineer troops were able to clear mined areas in a relatively short time or to breach them in order to ensure safe passage through minefields. Given the principle of operation of such devices, they could effectively be used only in the case of metal-containing mines. Recognizing this fact, the objective of mine developments of the opposing parties was to achieve the lowest possible metal content while effectively maintaining the operation of the explosive device. Thus, by 1943, non-metallic mines had appeared on the battlefields.

In Germany, very good quality non-metallic mines were mass produced by mine manufacturers. One of them was the "Topfmine", which, because of its shape, was commonly referred to only as a 'bread mine'. The body of the mine was made of a mixture of lignite powder and bitumen, but quite special versions of it were also produced, such as the "Topfmine 4531" made of faience, or the "Glassmine 43", which was made of glass, also by the Germans. The Soviet Red Army also produced large numbers of non-metallic mines, typically made of simpler materials such as glued wood, plywood, cardboard, of simple waste wood. With the proliferation of non-metallic mines, the applicability of induction mine detection devices got limited, resulting in the return of traditional, manual mine detection and clearance.

In order to further complicate manual clearance, mine manufacturers provided the mines with an additional igniter socket at the bottom or side, in which a pull-action igniter was placed, thus securing the mine against removal. For such a purpose, the Red Army successfully used the MUV igniter developed in 1932. From 1942, a structure very similar to the Soviet fuse was manufactured in Germany under the name "Z.Z.42" and in Czechoslovakia under the name "RO-1".

In addition to securing mines against removal, the mass use of trip-wire-operated booby traps, according to the terminology of the time: touch mines, presented another problem. Detecting these types of mines, especially in areas already covered with foliage, was a rather time-consuming and dangerous task.

Germany was the first in the world to develop an aerial remote mining system. In 1939, mine dispensers were developed for the Ju-87 bomber and explosive devices of type SD-1 or SD-2 were loaded in these containers, also known as bomb magazines. There was also a type that detonated the device on the ground when it was removed from its original location (Lukács, 2002).



Figure no. 5: *German SD-2 bomblets in a broken dispenser*
(Source: Live Journal, 2018)

Such explosive devices were used, on the one hand, to bomb infantry columns and groupings, and on the other hand, to make it more difficult for the enemy to use a particular section of terrain. The majority of the explosive devices in the bomb dispensers were simple percussion detonators, only some were fitted with a delay fuse or a counter-removal, also known as anti-lift, detonator. Although it was the Germans that were the first to develop the aerial remote mining system, later it was introduced and successfully applied by other nations, for example, in North Africa. During World War II, the aerial remote mining system was not yet used for laying minefields, and the dispensed mines were usually used against vehicle columns or assembly areas. Since the dispensed mines remained on the surface of the ground, they were visually detectable. Their deactivation, as it was not known what type of fuse the mines contained, was in most cases done with an attached demolition charge. However, there were also cases when the mine was removed of its position with a grappling hook fixed to a minimum 50-metre-long rope and thus an explosion was initiated.

Due to the dangerous and time-consuming nature of manual demining, R&D experts paid increasing attention to the development of technical mine detection and clearance. In addition to the effective use of mine rollers and mine ploughs, a mechanical demining system nicknamed “flail”, which was introduced as a prototype in World War I, was increasingly used. The essence of the system is that a rotating shaft or drum is mounted on an armoured platform. On the surface of the drum long chains are fixed at a suitable distance with balls of different shapes. The structure, rotating at a high speed, delivers severe impacts on the ground, causing the mines underneath to detonate, while neither the operating personnel travelling in the vehicle nor the device itself get damaged. It was used effectively, mainly to clear areas with anti-personnel mines between 1939 and 1945.

In addition to the above mentioned detection methods, experiments were also carried out in the field of animal-assisted mine detection before and during World War II. According to certain sources, dogs suitable for explosive detection were trained experimentally in the Soviet Union as early as 1938. In the Soviet-Finnish “Winter War” in the spring of 1940, dogs were already used in anger to search for mines, and exploiting the positive experience, the capability was further developed and large numbers of dogs were used in mine detection tasks during the Great Patriotic War as well.

4. The Post-World War II Years

World War II saw the use of an amount of explosive devices unprecedented in human history. The detection and clearance of explosive devices continued steadily in parallel with the combat actions. This was especially true for urban combat, as the success of the operations depended on the inspection of public spaces and buildings and their clearance from booby traps (Bucsák et al., 2015). However, this activity was limited to the level necessary for the successful completion of operations, so that the complete demining of areas was still to be done. Consequently, after the end of World War II, the main task of military units was to clear the territories of the countries of ammunition and mines.

Millions of unexploded ordnance, grenades, and artillery shells, infantry ammunition and hand grenades remained in the areas of former combat operations. Most of them were fired and unexploded devices that occurred in large numbers in or near abandoned firing positions, former ammunition supply points, temporary field depots, or along roads (Horváth, 2018). In many cases, the clean-up and the reconstruction of infrastructure of large

cities were hampered by aerial bombs and large-calibre artillery shells buried several meters below the buildings' ruins.

Initially, the political and military leaderships of countries were unable to adequately assess the extent and magnitude of the threat posed by such explosive devices, or the complexity, requirements of manpower and equipment, and practical possibilities for their elimination. Since no such a large number of explosive threats there had been experienced throughout the country before, the leadership of the newly formed armies had no experience in detecting and neutralizing them. The increasing number of casualties underlined the need for mine and ordnance clearance in the areas. The detection and destruction of the vast amount of dangerous materiel left behind posed a huge task for military forces. From the end of the war in Hungary until November 1946, for example, the Explosive Ordnance Disposal subunits removed more than 2,500 tons of dangerous explosive devices in the country (Gellért, 1981). In the post-World War II years, in addition to manufacturing the technical equipment necessary for demining and disarming tasks, military development programs focused on developing increasingly effective explosive devices due to the growing confrontation between the two victorious superpowers, the establishment of blocs and zones of influence.

In 1946, the Indochina War broke out between the French Colonial Army and Viet Minh. In the first years of the eight-year-long armed conflict, it was a low-intensity guerrilla war. Viet Minh troops mainly used mines and booby-traps, but not in very large numbers. As a result of the development of the equipment of the warring parties, by 1949 the former guerrilla war had evolved into a war between two opposing armies equipped with modern weapons, and mines were used in mass during the military operations. The conflict spilled over to neighbouring Laos and Cambodia as well, where huge areas also became mine-infested. Consequently, it can be stated that in the wars and armed conflicts in the immediate aftermath of World War II, the detection of explosive devices was still mainly focused on mines and minefields, and was limited to the search for and destruction of various types of mines concealed below ground level or on the surface of the ground. These tasks continued to be carried out by military forces as part of engineering support, and after the end of armed conflicts the focus was on providing safety and security to the area.

5. Conclusions

Throughout the wars in human history, the detection and deactivation of explosive devices has always been paramount. In parallel with the development of explosive devices, the set of tools, methodology, and procedures of their detection also developed. Ensuring the freedom of movement of troops is still one of the most important tasks on the battlefield today. NATO's engineering doctrine (AJP-3.12 (A) NATO STANAG 2238, 2010) determines demining as a core task and part of engineering support, and the doctrine may also include explosive ordnance disposal, as one of its other support tasks.

Since the second half of the twentieth century, there has been a tremendous development in the use of explosive devices. State-of-the-art technical tools can be found in both the deployment and protection toolbox. An important change in this period is that the threat posed by explosive devices through terrorism has become part of our daily lives. The second part of this study will present this period.

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