EOD COE considerations

for future EOD development

A Book of Papers

The NATO Explosive Ordnance Disposal Centre of Excellence (NATO EOD COE) supports the efforts of the Alliance in the areas of training and education, information sharing, standardisation, doctrine development and concepts validation.

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A Book of Papers – *EOD COE considerations for future EOD development*

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Preface

Dear Reader,

The paper you are about to read is the first attempt of the EOD COE community to consolidate efforts and work out cross-department analytical considerations. *EOD COE considerations for future EOD development* outlines the current threats and challenges within technological progress in various areas. Chapter I concentrates on conflicts in Ukraine, Yemen and Syria where authors present the conflicts' character, intensity and inventive approach to eliminating the enemy. Chapter II collects the selected types of cutting-edge technology being tested or already employed. Since the types of technologies are a plethora, the author concentrates on those which may have an impact on the EOD mission. The third chapter is an attempt to summarize the EOD transformation efforts within NATO and illustrate the various ways to synchronize all NATO countries on the same platform. The last chapter focuses on EOD training depicting the main tools being utilized by instructors and lecturers, which have a lot in common with technologies used on the battlefields.

I would like to encourage readers to consider this paper as an inspiration for analytical discussions about the future battlefield. By the time the soldier and the piece of device reach the frontline, it requires years of preparations, endeavour and research. The well-prepared soldier is the final stage of combat training conducted over years based on the lessons learned from other conflicts. The conflicts vary depending on location, climate, culture and wealth. Just within Europe, one can find arid and wooded, hot and freezing areas. Conflicts may have different faces like conventional in Ukraine, asymmetrical in Afghanistan or mixed in Gaza Stripe. EOD is being shaped by these aspects as well. Commanders will account application of EOD teams based on the conflict character as it will determine the number of teams and their assets.

In The Conclusions, LTC Damian Piórko along with EOD SMEs attempted to visualize the future EOD scene fitted with the latest inventions trying to predict how many of the nowadays' technologies will become standard soon. Regardless of the opinions expressed by many pundits that some types of technologies are pricey for military EOD, let's not forget that the same robots or drones can be adopted by commercial companies, State/Local Police, Border Guards or Fireguards, which significantly increases the attractiveness of the technology. That means inventors make things versatile.

Anyone who would like to share their thoughts on the content of this paper we heartfeltly invite you to contact us.

Director of EOD COE
COL Frantisek Mihalovic

Chapter I – Various conflict zones shaping EOD activities

Modern weaponry in the Russia-Ukraine conflict

The subchapter was compiled based on articles published in EOD Express No. 9,10/2023 and 2,3/2024

Background of the current conflict in Ukraine

The Russian-Ukrainian War is an ongoing international conflict between Russian separatists backed by the Russian Federation on one side and Ukraine on the other. The roots of the conflict date back to February 2014, when Ukraine started the so-called "Revolution of Dignity". In the aim to save its interests in Ukraine, Russia annexed Crimea and supported pro-Russian separatists fighting the Ukrainian military in the Donbas area. The eight years of the conflict escalated in February 2022, when Russia launched a "Special Military Operation" (SMO).

Russian troops' composition at the beginning of the SMO and in 2023

At the beginning of the SMO, Russians used **Battalion Tactical Groups (BTG)**. A BTG (Батальонная тактическая группа), is a combined manoeuvre unit deployed by the Russian army, usually based on a mechanised battalion of three mechanised companies reinforced with the tank company, air-defence, artillery reinforced with the rocket artillery, engineering, and logistical support units formed from a garrisoned army brigade.

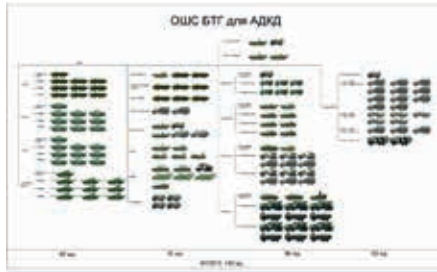
In August 2021, Russia's defence minister claimed the country had about 170 BTGs. Each BTG has approximately 600–800 officers and soldiers, of whom roughly 200 are infantrymen, equipped with vehicles typically including roughly 10 tanks (T-72, T-80, T-90, and its variants) and 30 infantry fighting vehicles (BMP-2, BMP-3, and BTR 82 and its variants).

Due to the enhanced requirements for the command and control of such units, the commander of the BTG instead of the lieutenant colonel can be in the rank of the brigadier-general.

Very soon after the intervention was recognized, that the BTG structure did not fit with SMO operation requirements, **as lack of the infantry does not allow to conduct of more comprehensive urban operations and hold lines.** Also, Russia

underestimated the number of troops needed to be deployed, they were not capable of holding the occupied area, as they were outnumbered by the Ukrainian armed forces.

Above mentioned shortages of the BTGs led the Russian Armed Forces to the conclusion, that the BTG was not the best solution for the operation and **they introduced back old structures based on typical battalion, brigade, and division structures.**



Picture 1. Battalion Tactical Group example[1]

After old structure implementation closely supported by the partial mobilization, Russians managed to stabilize the front lines and reached several achievements (Bakhmut, Kupiansk frontlines, dated to August 2023).

Conflict in Ukraine has proved that infantry, mechanised and tank units still play important roles on the battlefield. But from the beginning of the conflict, it is visible, that to succeed on the battlefield, one needs to achieve technological superiority in many areas, some of which are being currently developed.

Guiding unguided bombs

Air superiority goes hand in hand with the possibility to bomb the enemy without being forced to fly to areas covered by the enemy air defence. Russian air forces are in possession of huge stockpiles of non-guided bombs, which they started to convert its UMPC modules to precise long-distance flying guided bombs. UMPC stands for **"Unified Planning and Correction Module".** The module consists of wings and control units that are installed on conventional aviation bombs.

In January 2023, the first information emerged that Russia was using general-purpose bombs with wing kits to strike targets in Ukraine. From the beginning of April, Russians started to use planning bombs in mass, using at least 20 planning bombs per day. Russian Su-34 and Su-35 operate these bombs without entering the Ukrainian air defence zone.

Picture 2. UMPC module on the FAB-500 aerial bomb[2]

The guided bomb is very inconvenient to detect and intercept. The dimensions,

1 Source: https://www.globalsecurity.org/jhtml/jframe.html#https://www.globalsecurity.org/military/world/russia/images/btg-image01.jpg|||Battalion%20Tactical%20Group

2 Source: Russian-Winged-Dumb-Bomb.jpg (1920×1080) (twz.com)

and lack of detectable parameters like radiocontrast, heat traces, and noise make them almost invisible to the air defence. One of the very important advantages is cheapness and therefore mass character of usage. As experiences from the previous long-lasting conflicts show a **mass character in the war is the key to victory.**

New guided bombs solution

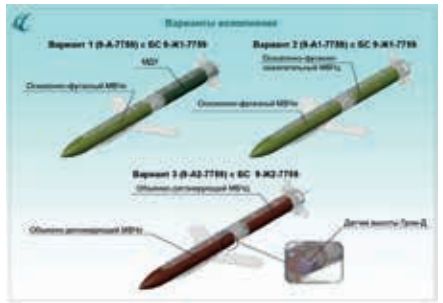
The latest **high-precision ammunition "GROM" (Thunder)** has been used during the SMO in Ukraine. It was developed by the Tactical Missiles Corporation.

"Thunder" is based on a modular basis, which allows it to use three types of aviation ammunition.

The first is the **9-A-7759 guided missile** with a high-explosive fragmentation warhead weighing 315 kilograms. In terms of its combat effectiveness, it is 1.8 times superior to the free-falling aerial bomb OFAB-250-270. Aiming at a target with known coordinates is done with a satellite navigation system GLONASS.

The second is a **guided gliding bomb 9-A1-7759**. This version instead of a motor module has two high-explosive fragmentation charges with a total mass of 480 kilograms. The maximum flight time is about 260 seconds. During this time, it can cover up to 65 kilometres.

The third type of ammunition in Grom's arsenal is also the **9-A2-7759 gliding bomb** but with a volume-detonating warhead (vacuum or thermobaric warhead) weighing 370 kilograms. The total weight is 488 kg. It is equipped with a laser sensor that allows one to determine the optimal height of the explosion.



Picture 3. High-precision ammunition "GROM" variants[3]

The maximum launch altitude of the Thunder is more than 10 km. Its carriers can be Su-34 fighter-bombers and MiG-35 multipurpose fighters as well as SU-57.

Drones in bulk

Another massively used weapon is a **drone**. Drones are not used only for reconnaissance like **Orlan-10, Orlan-30** (Орлан-10/30), but started to be used as a main means of armour destruction. Some of the most known are **ZALA Lancet drones, GERAŇ-2** (Shahed 136) and for the first time in modern conflict massively used a variety of **FPV drones**.

3 Source: 1582810613_9-a-7759-grom-ktrv-3.jpg (1024×708) (topwar.ru)

FPV stands for "first person view" and it means that one can see what the drone "sees" in real-time through a built-in video camera. This means you can fly the drone in a bird's eye view, giving you real-time flying experience.

Picture 4. ORLAN-10 drone[4]

FPV Drones are small, high-speed quadcopters with manual control, a minimum of electronics, and good resistance to electronic suppression. They are very effective as reconnaissance and kamikaze drones but require skill from the operator. To be effective as a kamikaze, drones are equipped usually with improvised ammo/explosives, like hand grenades, and a variety of ammo used for grenade launchers, including antitank versions used with RPG-7 ammunition.

To meet the needs of its armed forces, the Russian defence industry began to actively develop new unmanned aerial systems last year. New participants, small

Picture 5. ZALA Lancet drone[5]

Picture 6. Lancet drone attack on MIG-29[6]

Picture 7. GERAŇ-2 (Shahed 136) in launching vehicle[7]

Picture 8. "Dobrynya" FPV drone[8]

4 Source: spesifikasi-orlan-10-drone-canggih-rusia-dengan-kemampuan-menakjubkan-ehr.jpg (850×567) (sindonews.net)
5 Source: 9a200fb76a238b328a88c9a92e5c9d80e057dc4c.png (1200×630) (svidomi.in.ua)
6 Source: e56066866fc000d32707ad922b983a69 (2246×1256) (yimg.com)
7 Source: 960x0.jpg (710×400) (forbes.com)
8 Source: dobrynja-4.jpg (800×800) (topwar.ru)

"garage" enterprises as well as big ones are joining the work in this direction, offering certain samples. One of the UAV samples named **"Dobrynya"** was shown by Concern VKO "Almaz-Antey" at the end of the last year and is now in the stage of mass production. Based on information from the producer, the company is capable of producing up to 3000 pieces of drones per month and assembling them from up to 75% of domestic materials.

Munition laser-guided

Besides drones, one of the technologies widely used on the battlefield is **laser-guided artillery ammunition**. As long as the Ukrainian side is mostly using M 982 Excalibur delivered by the NATO countries, the Russian side is relying on their so-called **"Krasnopol" semi-automatic laser-guided artillery** weapon systems invented in the former Soviet Union and later produced in Russia. Several variants have been developed, for 120mm mortars, 122mm, 152mm, and 155mm howitzers respectively.

Picture 9. Guided ammo "Krasnopol"[9]

The laser guidance is mostly done by the forward artillery observer, or the target is illuminated by drones, for this purpose mostly used ORLAN -10/30 Tactical UAVs.

Picture 10. From left to right: 122 mm Kitolov-2M, 120 mm Gran and 155 mm Krasnopol-M2[10]

Based on calibre, the **Krasnopol** is capable of hitting targets moving at speeds up to 36 km/h on a maximum firing range of up to 25 km. A hit probability is 80% against a stationary target and 75% against a moving target. The warhead is a high explosive fragmentation type. This allows it to be used against heavily armoured vehicles such as tanks owing to the steep trajectory of the projectile which can defeat the relatively thin armour on most vehicles.

New air-to-surface missile solutions

„LMUR" or **"Изделие 305"** is a new light multi-purpose air-to-surface missile solution. The LMUR's 25kg high explosive warhead can be delivered at a maximum range of 14.5 km, which is superior to that of the other Russian helicopter-launched

9 Source: Krasnopol_M2_925.jpg (925×616) (armyrecognition.com)
10 Source: wikipedia

ATGMs. It has an optical/thermal imaging seeker. It can be used in two different modes. In the first one, the target is marked by the operator before the launch, and the carrier helicopter can turn away directly after the missile launch. In the second mode, the missile is launched without it being locked on a target. It first flies in its direction, using inertial guidance with satellite navigation providing corrections. The image from the seeker is transmitted back to the helicopter via a datalink pod. The operator can select the target and change it while the missile is flying toward its area. LMUR weight is 105kg, maximum flight speed is 230m/sec, flight altitude does not exceed 600m. As a launching platform can be used additionally modified helicopters Mi-8, Mi-17, Mi-28, Mi-35 or Ka-52.

Picture 11. LMUR missile[11]

New means of traditional mining

In the "Special Military Operation", minefields play an important role. There were mines in different areas that slowed down the current offensive of the Ukrainian armed forces and inflicted serious losses on its equipment and manpower. Various means are used to lay mines, including **remote mining systems**. The Russian army has several systems for **remote mining**, that are using different means of delivery to the area of interest. One of them is the newly used distance mining system **"Zemledeliye" (Agriculture)**.

ISDM "Agriculture" has two separate blocks, each consisting of 25 launchers with a calibre of 122 mm. The firing range of the system is from 5 to 15 km. The ISDM ammunition is contained in missiles, the warheads of which are filled with anti-tank **PTM-4M** or anti-personnel mines **POM-3**. The ISDM system is equipped with satellite navigation, a computer, and a weather station, which allows operators to make adjustments and take into account the effect of weather on missile flight. The preparation of data for shooting and the vehicle itself is highly automated and doesn't last longer than three minutes.

Picture 12. Remote mining system "Agriculture"[12]

11 Source: https://en.topwar.ru/224575-raketa-lmur-v-jekspluatacii-i-na-vystavke.html
12 Source: https://en.topwar.ru/214205-isdm-zemledelie-proizvodstvo-i-postavki-prodolzhatsja.html

PTKM-1R Top-attack Anti-tank mine smart munition

The **PTKM-1R** is a Russian-made smart munition to defeat tanks by aiming exactly at the least protected part of a tank or a self-propelled gun, its roof. This Top attack Anti-tank mine is capable of selecting what armoured vehicle to hit, it chooses only the equipment that meets the specified parameters in terms of noise and ground vibration. It is installed manually, at a distance of 5 to 50 m from the probable route of the target making it quite difficult to detect. When the target comes within a 50m radius of the mine, the seismic sensor commands to launch the combat element. The combat element follows a ballistic trajectory and its sensors – thermal and radar-scan the earth's surface. When the sensors detect the target, the warhead is detonated and strikes the target from above. The height of the mine is 510mm, its weight is 19,9kg, and the declared armour penetration is 70mm. In the mine self-destruction time from 1 to 10 days can be set up.

Picture 13. PTKM-1R anti-tank mine[13]

Thermobaric punch

Heavy flamethrower systems TOS-1A "Solntsepek" became known as one of the most effective weapons against the infantry. TOS-1A consists of a launcher with a package of 24 guide tubes on the chassis of the T-72 tank and a transport-loading vehicle. The firing range is up to six kilometres. One full salvo of the "Solntsepeka" covers 40,000 square meters with a gas cloud. Above the target, the projectile opens and the powder enters the atmosphere, forming a cloud. It explodes instantly, and the temperature at the epicentre reaches 1500 degrees.

Picture 14. Heavy flamethrower systems TOS-1A "Solntsepek"[14]

Ballistic power

When talking about the state-of-art-technologies, one should mention Russian **rocket technologies** which are at the top among rocket-capable producers. One of the many types of rockets, first time in modern conflict used on the battlefield is **KH47M2 KINZHAL (Dagger)**.

13 Source: https://roe.ru/eng/catalog/land-forces/engineer-equipment/ptkm-1r/
14 Source: https://www.ukrinform.net/rubric-ato/3722338-ukrainian-defenders-destroy-russian-solntsepyok-system-in-zaporizhzhia-direction.html

KH47M2 KINZHAL is a Russian hypersonic air-launched ballistic missile. It has a reported range of up to 2,000 km and speeds up to Mach 10 (3400m/sec). It can carry either conventional or nuclear warheads and is usually launched by MiG-31K interceptors. Due to the speed and possibility of conducting manoeuvres, the missile is very difficult to identify and intercept by current means of air defence.

Picture 15. KH47M2 KINZHAL under MIG-31[15]

Electronic warfare complex "Krasuha-4"

Mobile electronic warfare system **"Krasuha-4"** suppresses spy satellites, ground-based radars, and airborne systems AWACS (Airborne Warning and Control System).

Complex "**Krasuha-4"** fully covers an object from radar detection at 150-300 kilometres, and may also cause damage to enemy radar electronic warfare and communications systems. The complex functioning is based on creating powerful jamming at the fundamental radar frequencies and other radio-emitting sources.

This complex is placed on BAZ-6910-022 four-axle-chassis.

The **Peresvet (Пересвет)**, is a Russian laser weapon for air defence and anti-satellite warfare first time deployed in the area of the SMO in the autumn of 2022. According to the available information

Picture 16. Electronic warfare complex "Krasuha"[16]

Picture 17. Combat laser Peresvet (Пересвет)[17]

15 Source: Kh-47_Kinzhal_air-launched_nuclear-capable_hypersonic_missile_Russia_925_001.jpg (925×609) (armyrecognition.com)
16 Source: https://defence-blog.com/ukrainian-troops-blow-up-russian-hi-tech-warfare-system/
17 Source: 1580459134_01-blk-peresvet-laser.jpg (1196×1090) (topwar.ru)

from open sources of the producer, it is capable of incinerating targets up to three miles away within five seconds. The system can blind enemy satellites in orbits of up to 1,500 km and *"disable them during their fly-past by means of laser irradiation"*.

New sapper solutions

The **sapper robot "Prohod-1"** was constructed on the basis of the BMR-3MA (which has the same chassis as the T-90A Main Battle Tank), it uses enhanced mine protection, and one can also spot a large number of dynamic protection elements on the vehicle's body. The complex tests were conducted back in 2016, but since then there has been no news about it. Compatibility with modern roller mine flails KMT-7 and KMT-8 is provided. In its basic configuration, the vehicle is operated by a crew of two and can carry three sappers. The vehicle can be equipped with a remote-controlled machine gun of 12.7 mm calibre. The robot for demining is equipped with several antennas, in order to jam the control signals of radio-controlled mines. The Prokhod-1 complex is capable of operating in three modes: under the control of a crew of 2 people, remotely under the control of an operator with a command post based on KAMAZ, and in automatic mode with predetermined movement parameters. The robot creates passages in minefields of 4.5 meters wide in combat conditions, even under enemy fire and is equipped with a new TMT-S mine flail to neutralize contact mines, as well as cutters that cut the wire-operated land mines.

Picture 18. "Prohod-1"[18]

The nonlinear transitions detector solution

"KORSHUN" or **"NR-900EK3M"** is a detector of nonlinear transitions which is designed to detect mines and explosive devices equipped with electronic fuses (initiation systems) installed on the ground surface, in the ground (snow), under road surfaces, and on the objects. The detector allows to detect mine-explosive devices with fuses of pressure and tension action. The "KORSHUN" application allows to check roads, terrain, and individual objects for the presence of

Picture 19. Russian detector of nonlinear transitions "KORSHUN"[19]

18 Source: 1588176045_6.jpg (820×533) (topwar.ru)
19 Source: 1338925551_2.jpg (700×465) (topwar.ru)

mines, improvised explosive devices, and other explosive items containing electronic components as well as carry out operational search and investigative measures to identify caches of weapons, ammunition, and explosive devices. It also enhances sappers' safety by examination of suspicious objects, searching, and neutralization of sabotage and terrorist means. The detection range of objects lying on the ground is up to 8m and for the objects buried 150mm below ground is detection range up to 2m.

Conclusion

Based on results achieved by the both sides of the conflict (till the end of August 2023) it was predictable, that the end of the SMO would still not be possible to estimate in the near future.

West countries still continue to support the Ukrainian effort with many kinds of weapons and ammunition as well as intelligence information.

Russia, also recognised, that from a rapid military solution, they got into a long-lasting conflict. For a new reality a Russian military industry complex heavily influenced by a variety of Western sanctions was not ready.

The first steps to reacting to a new situation were made in May 2022, when new laws were introduced to ensure supply for the Russian army. Since that time Russian military industry complex made huge leaps forward and currently is ready to supply the Russian army with the requested numbers of a variety of equipment and ammunition. Some of the factories started to work on three shifts seven days a week, and some new ones were built. From November 2022 till now, several military satellites have been launched to get a better overview of battlefield areas. A huge investment was made in semiconductor replacement, and it seems that currently, Russia is capable of producing sufficient semiconductors needed for their sophisticated weapons. New enterprises for drone production started to supply a variety of drones from FPV drones up to Geraň-2 drones previously supplied to Russia by Iran Islamic Republic. Some of the deficient ammunition has been delivered from North Korea as well. The rest of the most needed parts of the equipment are delivered via third parties, in fact, Russia can get all parts of the special equipment despite West restrictions, including parts from the USA.

It seems that Russia managed to go over the main problems connected with Western sanctions, therefore before the end of the SMO, a significant development in Russian military technology is predictable.

Russian methods of combating FPV drones

The subchapter was compiled based on information published in EOD Express No. 9,10/2023 and 2,3/2024

Since the beginning of the SMO both sides of the conflict have accumulated sufficient experience in working with unmanned vehicles and, importantly, they have managed to collect significant resources and knowledge to put its usage at new quantitative and qualitative levels.

Since SMO was converted to a war of attrition, the usage of FPV drones has become more or less a forced strategy for both sides. Instead of spending hours ploughing up enemy positions with artillery fire, the enemy is conducting a targeted hunt for individual equipment and military personnel with the use of FPV drones. First of all, it is low-cost, and with a well-trained FPV operator, results can be achieved quickly and accurately with less collateral damage.

Despite all the mentioned positives, FPV drone implementation on the battlefield can be met with enemy countermeasures, therefore its effect can be significantly eliminated. Elimination of FPV drones can be achieved in four main ways: **using EW** (Electronic Warfare), **kinetic weapons, mechanical means of protection**, or **changing tactics**.

In theory, the Achilles heel of FPV drones is their remote-control system, which can be influenced using electronic warfare. It means, that for successful military operations, each unit has to have such kind of anti-drone equipment.

Bulat 3mx drone detector

Russian military personnel began using the Bulat mini-drone detector. The Bulat passive drone detector was developed by the Russian company **3mx**. The detector is based on a Chinese model that was completely "redesigned and modernised", the developers assembled their radio parts, made their boards, and changed the firmware. The device can detect and identify the most popular drone brands such as DJI, Autel, and various FPV drone models at a distance of up to 1 kilometre. Developers are constantly improving the detector by adding new data on drone models provided by Russian military personnel. The detector is easy to use and detects

Picture 20. Bulat 3mx drone detector[20]

20 Source: bulat-3.webp (700×700) (topwar.ru)

frequencies from 900 MHz and 2.4 GHz to 5.2 GHz and 5.8 GHz. The Bulat UAV detector weighs 285 grams and can operate for up to 5 hours. The device has a 5V power supply and a 4000 mAh lithium battery.

EW Backpack for dismounted infantry

Currently (March 2024), Russian AF is using or experimenting with several types of EW to protect individuals or vehicles on the battlefield. One of the current examples of a **backpack** for dismounted infantry testing during life-fighting in the Donbas area was documented by a Russian commander as follows: *"Yesterday the **backpack** (Picture 21) passed the battle test. During the battle for the enemy's stronghold, the group came under attack from FPV drones, the box jammed everything within a radius of 150-200 meters, and the FPVs fell perfectly – from 8 to 10 pieces. The stormtroopers are happy, everyone remains alive. Without the backpack, there would be 200 (KIA) and 300 (Wounded)"*[21].

Picture 21. EW backpack unknown type used by Russian stormtroopers[22]

Based on the shape, the tested Russian backpack might be a Chinese Rongxin 8-Channel Portable Drone Jammer Manpack or its modified copy.

Electronic warfare equipment RP-377 Lesochek

The Russian army began using RP-377UVM1L Lesochek (Лесочек) jamming stations. The RP-377 electronic warfare system is designed for radio jamming of mine explosive control channels. The complex is also used to suppress the navigation channels and geolocation of enemy UAVs; for this purpose, the antennas of the complex are usually installed horizontally. The range of the RP-377 "Lesochek" complex is about 100 meters in the horizontal plane and up to 200 meters in the vertical plane. The RP-377UVM1L jamming station can be installed on any device, from cars to tanks.

Picture 22. EW Lesochek RP-377 mounted on APC BTR-82[23]

21 Source: https://en.topwar.ru/armament/drones/
22 Source: 1707900801_output.jpg (800×504) (topcor.ru)
23 Source: cfb29b4e-71d8e4a16ddd4726d19c2eb23af35119.jpg (920×465) (mil.in.ua)

Burner (Быжигатель) handheld electronic warfare system

Units of the Russian National Guard began to use the latest complex for the detection and suppression of UAVs "Byzhigatel". There is no technical information about the "Burner" handheld electronic warfare system. Despite the manufacturer being unknown, it seems that the shape of the "Byzhigatel" matches the Chinese **SkyfendHunter** anti-drone jammer. The complex is reported to be effective. With omni-directional antennas, Hunter detects and alerts drone signals in all directions within a 2km range. Upon a drone entering the detection zone, Hunter swiftly obtains its model, frequency band, and direction. It then automatically adjusts the jamming frequency, targeting the RF or GNSS signals specific to the detected drone model, effectively neutralising the drone threat beyond visual range.

Picture 23. EW "Burner" handheld electronic warfare system[24]

Complex for combating FPV drones "Saniya"

The Saniya electronic warfare system is designed to combat FPV drones and was developed by the Russian company **3mx**. The complex is equipped with eight antennas and is available in stationary and mobile versions. The complex does not work all the time, but automatically turns on only when radiation from FPV drones is detected; for this purpose, it is equipped with the Bulat drone detector, which we have already discussed. The Saniya electronic warfare system suppresses drone operating frequencies of 450 MHz, 900 MHz, 1.2 GHz, 1.5 GHz, 2.4 GHz and 5.8 GHz. According to the manufacturer, drones are detected at a distance of up to 1.5 km and suppressed up to 1 km.

Picture 24. EW "Saniya" mounted on tank T-80 BVM[25]

Volnorez (Волнорез) Anti Drone Jammer System

Volnorez was designed to counter kamikaze drones that would attack the Russian war fleet. The Volnorez system forms a protective shield around the combat vehicle. Under the jammer system, the FPV kamikaze drone becomes unable to receive commands or transmit data to its operator. According to Russian sources, the system

24 Source: sddefault.jpg (640×480) (ytimg.com)
25 Source: b3465a3d9d1aab7f.jpg (1200×650) (defence-ua.com)

operates in the frequency range from 900 MHz to 2000 MHz and interferes with signals from drones at a distance of about 600 meters. This frequency range is in line with the operational frequencies of most drones currently in use. The Volnorez system disrupts the drone's communications with its control station, causing the drone to go off course and lose contact. This capability significantly fortifies vehicles against drone interference. The EW system installed on the vehicle ensures full 360-degree coverage, providing comprehensive protection. Additionally, the system can be controlled remotely, adding a layer of flexibility and adaptability to effectively counter a variety of drone threats.

Picture 25. EW "Volnorez" mounted on tank T-80 BV[26]

Kupol-PRO portable anti-drone system

The Kupol-PRO UAV counter-surveillance system is produced by Russian company Avtomatika Concern JSC. The complex "Kupol-PRO" of circular action can work in 10 frequency bands and suppress the navigation, control, and data transmission channels of drones at a distance of up to 4 km. The effective radiated power of the complex is 80 watts. The weight of the complex is 4 kilograms.

Picture 26. Kupol-PRO portable anti-drone system[27]

Triton

The Russian company PPSh (Лаборатория ППШ) has developed the Triton electronic warfare system (комплекс Тритон) to protect tanks from FPV drones. The complex can be installed on tanks and other equipment, it can also protect infantry positions and even be installed on trees.

According to the developer, the product is designed to suppress control channels and data transmission of FPV drones in the ranges 868\915\1300\2400 MHz (4 suppression ranges). Control is carried out via a remote control for maximum operator safety. Both autonomous operation from the built-in battery and power supply

26 Source: Russia_unveils_portable_tank-mounted_drone_jammer_to_counter_Ukrainian_attacks_925_001.jpg (925×602) (armyrecognition.com)
27 Source: 3854d2b89bdcb496d501277c45d4cacc.JPG (1416×2128) (roe.ru). Link to an article on Russian military web "What to use for a drone" https://en.topwar.ru/231992-s-chem-idti-na-drona.html

Picture 27. Left - Triton electronic warfare system for vehicle. Right - Triton electronic warfare system backpack[28]

from the vehicle's onboard network are possible. Company PPSh is developing and producing quite a sizeable variety of anti-drone systems from individual anti-drone protection up to heavy vehicle protection. Videos: "Лаборатория ППШ комплекс Тритон": https://www.youtube.com/watch?v=GRNtcugGlPI

Tests of the Russian electronic warfare system Triton for protection against drones: https://www.youtube.com/watch?v=dF0uu_ijIS4

Russian kinetic weapons to combat FPV drones

Since of massive usage of cheap FPV drones against expensive technologies (tanks, APCs, antiaircraft…) have become very important to use and develop kinetic weapons, that can be cost-effective to eliminate them. Anti-aircraft technologies like **Pantsir S, Sosna R, Tor, Gibka-S, or 2K22Tunguska** are too expensive and vulnerable. Some promising technologies based on laser **(RAT complex)** or programmed ammunition (**57mm Derivation air defence**) still need to be worked on before the acceptance by the Russian army. Therefore, forward units are forced to use another means of FPV drone kinetical destruction, between them the most popular is becoming **shotgun**.

Picture 28. Arena-M mounted on T-72B3M tank[30]

Typical anti-drone infantry fighter carries a detector that detects UAVs, an electronic warfare backpack suppressor and additional energy batteries (power banks). The main weapon of this drone hunter is a TOZ-34 shotgun a hunting rifle, which based on information from one of the specialists is excellent at shooting drones down[29].

28 https://vk.com/wall-123538639_ https://focus.ua/digital/603314-v-rossii-zapustili-proizvodstvo-treh-versiy-reb-triton-kogo-zashchityat-ot-dronov-vsu

29 See the link to the video "Russian soldiers defeat FPV drone with shotgun: https://www.aktualnikonflikty.cz/viewtopic.php?f=14&t=5&start=18920

30 https://en.topwar.ru/236653-kaz-arena-m-na-stadii-ispytanij-i-dorabotok.html. More info: Russian tanks will be protected from drones by the Arena-M complex video: https://www.youtube.com/watch?v=UWGOt21NJcU

Another means of kinetic destruction against drones currently in the final stage of testing is the **Arena-M active protection system** for armoured vehicles.

Arena-M complex operates radars that monitor the situation around the vehicle in automatic mode. If the object flies towards the vehicle and the flying object parameters are evaluated as a threat, protective ammunition is launched against its calculated trajectory. It causes ammunition to be destroyed at a safe distance from the combat vehicle and therefore does not damage it. Based on the producer's information, the Arena-M will be possible to install at all currently deployed tanks of the T-72, T-80, and T-90 series, as well as on BMP-2 and BMP-3. This solution has one significant shortfall – it is dangerous to own infantry, as the safety distance from the protective ammo detonation should be at least 30m. Technology itself is still in the testing stage and based on gathered information, the first serial Arena-M will occur on the battlefield no sooner than at the end of 2024.

Russian mechanical means to combat FPV drones

In response to drone danger, Russian researchers began to construct various types of structures designed to prevent ammunition from hitting the target. Most popular become a variety of grilles, visors, nets, spaced armour, and improvised shielding. Some of those structures are combined with ERA dynamic protection (Kontact-1, 5; Relikt) and drone jammers. Due to their effectiveness, some of them are being serially factory-produced.

Picture 29. Factory-made protection mounted on T-72B3M tank[31]

Picture 30. Improvised protection mounted on BMP-2 with factory-made additional space armour on vehicle sides

Russian changes in tactics to combat FPV drones

To eliminate enemy FPV drone effectiveness, several tactical changes were introduced by Russian forces.

To reduce losses, attacks are conducted by small attack groups supported by anti-drone fighters equipped with drone detectors, jammers, and shotguns.

Snipers are enhanced with a third person to monitor the air.

31 https://en.topwar.ru/237406-kogda-zaschita-tehniki-ot-dronov-stanet-serijnoj.html

To eliminate the loss of heavy equipment, infantry is dispatched by armor and then immediately armor goes back to safety.

Active hunting of enemy drone operators by specialized drone units was introduced.

No weapons and personal gatherings within range of FPV drones are permitted. The use of decoys, and lures become a new state of the art of soldiers' improvisation.

All of these are supported by intelligence services work to gather info about enemy frequency management and then to suppress frequencies…

Conclusion

Someone could raise questions, about how that information is connected to the EOD. The answer can be done with another question: do we have enough information about drone threats? Does our TTP reflect current drone threats, or if we need to modify it? Can we use some of the introduced anti-drone solutions to protect our EOD specialists?…

As it is visible from this short analysis, successful fighting with FPV drones requires a comprehensive approach. All lessons learned during the SMO by the Russian military and other specialists are analysed and new approaches are quite quickly implemented (despite deep-rooted bureaucracy) in the army. No less important is the equipment producers' ability to react to army requirements and their flexibility to produce and modify required equipment.

With Russia's endless natural resources, technical-scientific potential, and soldier ability for improvisation we can talk about the very robust basement for successful results against a variety of potential adversaries.

Conflict in Syria

By the EOD officer of the EOD Technologies Department 2nd Lieutenant David Slatkovsky

Background of the conflict

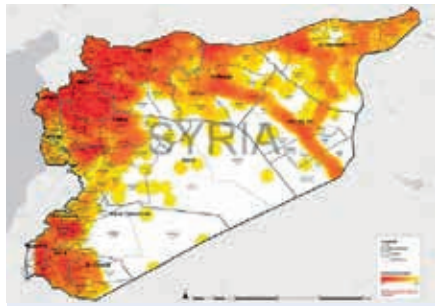
The origin of the Syrian civil war dates back to the year 2011, when an Arab spring brought a massive wave of protests and demonstrations in Arab countries, including Syria. Simultaneously, the unrest created an opportunity for other militant organisations from outside of Syria like ISIS to gain control over some areas in Syria. [1]

The escalation of violence and military support from major countries to both sides of the conflict culminated in a devastating civil war and a massive refugee crisis ongoing until this day. Overall, more than 600'000 people have been killed and many millions more have lost their homes / fled to Turkey, the EU and other countries as a result of the war. [2]

Participants of the conflict in Syria

On the one side of the Syrian conflict are the Syrian Armed Forces, which are official governmental forces supported by Russia, Iran and Hezbollah, all providing air support, weapons supply, militias and mercenaries as well as intelligence and training of Syrian government troops. [3]

Their opposition, however, consists of multiple factions and militias, each looking to achieve different goals, connected by the common goal of overthrowing the Syrian government. Some want to retain Syria as a secular government. Others want an Iranian-style Islamic republic, while others want a theocracy modelled on the 1990s Taliban in Afghanistan.



Picture 31. Intensity of conflicts in Syria[4]

1 https://www.britannica.com/event/Arab-Spring
2 https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551330/EPRS_BRI%282015%29551330_EN.pdf
3 https://www.aljazeera.com/features/2020/10/1/what-has-russia-gained-from-five-years-of-fighting-in-syria
4 Reliefweb. 2022. Explosive ordnance in Syria: Impact and Required Action - Report Summary | May 2022. https://reliefweb.int/report/syrian-arab-republic/explosive-ordnance-syria-impact-and-required-action-report-summary-may-2022

United States involvement in Syria has been a part of the larger scale operations in the region aiming to fight and defeat the Islamic State, although their support has been utilized also by militias fighting against President al-Assad's regime. [5]

Recent Incidents

- On July 10th 2023, five civilians were killed in a car bomb explosion in Jarabulus city in northern Syria. The fatalities occurred when an explosives-laden vehicle blew up on Sunday in the countryside of Ghandoura town and the YPG/PKK terrorist group was suspected to be behind the attack. [6]
- On August 24th 2023, the Russian warplanes carried out three aerial strikes in the western countryside of Idlib. Furthermore, a warplane renewed its strikes on Idlib's countryside and targeted two military headquarters of HTS (Sunni Islamist insurgent groups coalition) near Ain Sheib in the west of Idlib. No causalities were reported in either of the air strikes.[7]
- On October 5th 2023, at least 123 were killed, and at least 150 wounded people were killed following a drone attack on a graduation ceremony for government forces. A source said that three loud sounds, resembling explosions, were heard in the city but details about the incidents are very unclear. [8]
- On November 19th 2023, fifteen victims were injured Saturday in a bombing terrorist attack in the Afrin district in northern Syria. The bomb in the cargo bed of a freight truck in the town centre of Afrin, which is under the control of the opposition in northern Syria, was detonated while the vehicle was travelling[9]
- On December 6th 2023, The Syrian Democratic Forces (SDF) on Wednesday confirmed that prominent SDF commander Roni Welat (Shervan Hassan) was killed in a 'terrorist attack' in Deir ez-Zor on Tuesday. The UK-based Syrian Observatory for Human Rights (SOHR) also confirmed the commander's death, reporting that he was killed by an improvised explosive device (IED) [10]
- On January 9th 2024, eight soldiers and one civilian were killed, 13 others were wounded in a terrorist attack with an explosive device on a military bus in Syrian al-Badyiah to the south of Palmyra," Defense Ministry said in a statement. [11]

5 https://www.cfr.org/global-conflict-tracker/conflict/conflict-syria
6 https://www.yenisafak.com/en/news/car-bomb-kills-5-civilians-in-syrias-jarabulus-3666311
7 https://www.syriahr.com/en/308422/
8 https://www.middleeasteye.net/news/syria-drone-attack-government-military-college
9 https://www.dailysabah.com/politics/15-injured-in-bomb-attack-in-northern-syria/news
10 https://www.kurdistan24.net/en/story/33368-SDF-commander-killed-in-IED-attack-in-Deir-ez-Zor
11 https://sana.sy/en/?p=323299

- On January 16th 2024, authorities in Daraa managed to kill one of the ISIS terrorists wearing a suicide belt before blowing himself up among a patrol member, east of the city. In addition, an IED was found in the al-Kashef neighbourhood, and it was detonated by an engineering unit. [12]
- On January 23rd 2024, Units of the Syrian Arab Army in the Daraa countryside dismantled several explosive devices on the side of the road in the towns of Busra al-Harir in the northeastern countryside of the province, while a border guard unit was also able to shoot down a drone near the Syrian-Jordanian border. [13]
- On January 28th 2024, Three US Army soldiers were killed and more than 30 service members were injured in a one-way drone attack overnight on a small US outpost in Jordan. [14]

These incidents are just a few examples of regular occurrences in Syria to provide an overview of threats to everyday life besides the conflict.

Weapons & ammunition used

The ongoing Syrian civil war, which began in March 2011, is of course dominated by Cold War-era (and even 21st century) weapons, however, there is an astonishing mix of WWII gear – both Axis and Allied – in use. Some of these weapons had previously not seen combat for decades. Syria has one of the largest missile arsenals in the Middle East and is actively engaged in missile proliferation. [15]

Syrian government backed by Iran has worked for years to develop and produce sophisticated weapons technologies to use in the civil war, as well as in future conflicts. The Syrian governmental forces have sought to use this Iranian technical know-how to produce its arsenal of UAVs and advanced missiles for decades. The regime's aerial arsenal now includes more than 130 Ababil-T, Ababil al-Nawras, Ababil-3DI, Nawras, MiG-21 MF and Sahab-73 models as well as several hundred unguided and guided missiles that include Scud, M-600 Maysaloun, M-600 Tishreen, 220 mm and 302 mm warheads. [16]

The Khaibar-1, also known as the Khyber-1, M-302, or B-302, is a Syrian-made 302 mm unguided artillery rocket with a range of 100 km and a 150 kg payload capacity. It is essentially a clone of the Chinese WS-1 rocket, offering increased durability for storage and relatively higher accuracy compared to many indigenous Hezbollah/Hamas rockets. However, it lacks the spinning stabilization mechanism of rockets like the Fajr-5, potentially affecting its precision.

12 https://sana.sy/en/?p=323687
13 https://sana.sy/en/?p=324154
14 https://www.msn.com/en-us/news/world/first-on-cnn-three-us-troops-killed-in-drone-attack-in-jordan-at-least-two-dozen-injured/ar-BB1ho1UG
15 https://www.nti.org/analysis/articles/syria-missile/
16 https://etanasyria.org/policy-brief-disrupting-the-syrian-regimes-domestic-weapons-programs-may-2023/

The 220mm artillery rockets originally designed by the Soviet Union in the 1970s were intended for use with their BM-27 'Uragan' multiple rocket launcher (MRL). Rebranded as the Raad-2 and Raad-3 by Hezbollah, these rockets possess a range of 60-70 km and are equipped with a 50 kg high explosive (HE) warhead filled with 6 mm anti-personnel steel balls. These rockets measure approximately 4.8 meters in length and weigh around 280 kg. Notably, Hezbollah's launchers diverge from the conventional Soviet design. Instead of the typical three layers of launch tubes (comprising two layers with six tubes each and one layer with four), Hezbollah's launchers feature a single layer housing four tubes. This alteration is believed to have been made by Hezbollah to accommodate a lighter launch vehicle[17].

Picture 32. Uragan MLRS with 220mm rockets (Informative)[18]

The Ababil-2, a versatile unmanned aerial vehicle (UAV), features a slender 2.9-meter-long fuselage, a 3.25-meter wingspan, and one or two triangular fins on its vertical tail, depending on the model. With a weight exceeding 30 kg and a payload capacity of 40 kg, it offers flexibility in its missions. These modern UAVs primarily employ plastic construction, thanks to advances in polymers and composites, resulting in weight savings and improved performance. Ababil-2 achieves speeds of up to 370 km/h, cruising at around 300 km/h, and boasts a flight duration of 1.5-2 hours, with a range of at least 120-130 km. The UAV's ceiling reaches heights of 3-4 km. Variations of Ababil-2 include models with autopilot and remote-control capabilities, allowing pre-programmed flight or operator guidance. The launch options include zero-length JATO platforms, pneumatic truck launchers, catapults, or solid propellant boosters. For recovery, parachutes or skids facilitate landings. Ababil-2 serves various purposes, from target drones used in air defence training to surveillance variants (Ababil-S or Ababil-R), twin-tail versions (Ababil-T), and the larger Ababil-CH. Additionally, loitering munition models like the Qasef-1 and Qasef-2K, with a 30-kg warhead, have been employed by Yemeni Houthis for radar component attacks. Despite its success, the Ababil-2 family is showing signs of age, as newer technologies are available, allowing Iran to develop more advanced UAVs for similar missions. Nevertheless, the Ababil-2 remains operational alongside these advancements.

Picture 33. Ababil-2 Surveillance drone[19]

17 https://missilethreat.csis.org/country/hezbollahs-rocket-arsenal/
18 https://www.militarytoday.com/artillery/bm27_uragan.htm
19 https://www.flickr.com/photos/froderamone/10412373873/in/photostream/

The M-600, or "Tishreen Guided SRBM," is a Syrian copy of the Iranian Fateh-110 missile. The Fateh-110 and M-600 have ranges of 250-300 km, making them among the longest-ranged weapons. Both missiles carry a 450-500 kg high explosive (HE) warhead and are GPS-guided, providing them with a CEP of 50 meters. They are nearly 9 meters in length and weigh approximately 3,450 kg at launch.

Picture 34. Fateh-110 (Fourth generation)[20]

Maysaloon is a variant of Tishreen but without the guidance system, designated for targeting areas where less precision is required.

The Scud missile, part of the Soviet Union's Cold War arsenal, included variations known as the R-11 (initial version) and the R-17 (later R-300) Elbrus. NATO designated the R-11 as the SS-1b Scud-A, a missile with its roots in V-2 rocket technology. However, the R-11 featured a more compact design and a groundbreaking engine developed by A. M. Isaev, simplifying propulsion and preventing oscillation.

Syria first received the Scud-B (Russia: R-17 "Elbrus"/NATO: SS-1-C) from North Korea in the late 1980s, and the Scud-C (Russia: R-17M "Elbrus-M"/NATO: SS-1-D) shortly thereafter. With assistance from North Korea and Iran, Syria established its production line, and now assembles, maintains, and repairs its Scud B and C missiles. The exact nature and status of Syria's Scud-D (Russia: R-17VTO/NATO: SS-1-E/DPRK: Hwasong 7) is unknown, however, Reports indicate that Syria's Scud-D is a modified Scud-C with a longer range and advanced guidance system.

NATO codename	Scud-A	Scud-B	Scud-C	Scud-D
U.S. DIA	SS-1b	SS-1c	SS-1d	SS-1e
Official designation	R-11	R-17/R-300		
Deployment Date	1957	1964	1965	1989
Length	10.7 m	11.25 m	11.25 m	12.29 m
Width	0.88 m	0.88 m	0.88 m	0.88 m
Launch weight	4,400 kg	5,900 kg	6,400 kg	6,500 kg
Range	180 km	300 km	600 km	700 km
Payload	950 kg	985 kg	600 kg	985 kg
Accuracy (CEP)	3,000 m	450 m	700 m	50 m

Table 1 – Scud missiles characteristics[21]

20 https://upload.wikimedia.org/wikipedia/commons/a/ac/Fateh-110_fourth_generation.jpg
21 https://web.archive.org/web/20071215141138/http://www.janes.com/security/international_security/news/misc/sws_scud010426.shtml

Picture 35. Hezbollah Missiles & Rockets (informative)[22]

These models utilize a single liquid-fuel rocket engine, burning kerosene and corrosion-inhibited red-fuming nitric acid (IRFNA), with unsymmetrical dimethylhydrazine (UDMH) as a liquid igniter. They can achieve a maximum speed of Mach 5.

According to "iTrace", the EU funded portal for documentation of used weapons and ammunition all over the world, these following items have been documented in Syria since the beginning of the Arab Spring (excluding small-arms and small-calibre): [23]

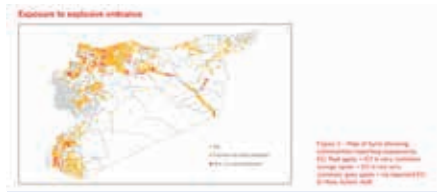
- **Rocket Launchers:**
  - Type 69-1 40mm (Chinese)
  - Al-Nasirah 40mm (Iraqi)
  - RPG-7 (North Korean, Iranian)
  - RPG-7V (Russian, Bulgarian)
- **Anti-Tank Guided Weapon**
  - 9M113 "Konkurs" ATGW or 9K111 "Fagot" ATGW (Russian)
- **Artillery**
  - 130mm M-46
- **Shoulder Launched Rockets**
  - OG-7 40mm (Bulgarian, Chinese, Romanian)
  - Different 40mm shoulder-launched (Iranian, not specified)
  - PG-7PM 40mm (Bulgarian)
  - PG-7V 40mm (Bulgarian)
  - PG-7VM 40mm (Polish, Bulgarian)
  - PG-7VG 40mm (Russian)
  - PG-7S 40mm (Russian)
  - Type 69 40mm (Chinese)
- **Surface-To-Surface Rockets**
  - OG-9 73mm (Bulgarian) surface-to-surface
  - 9M22U 122mm (Russian)
  - Fadjr-1 107mm (Iranian)
- **Disposable Rocket Launchers**
  - RPG-22 72.5mm (Bulgarian, Russian)
  - RPG-26 72.5mm (Russian)
- **Mortar Bombs**
  - 81mm (Turkish, not specified)
  - M68 P1 82mm (Croatian)

22 https://i0.wp.com/missilethreat.csis.org/wp-content/uploads/2018/06/Hezbollah_chart_FINAL-03.jpg

23 https://itrace.maps.arcgis.com/apps/dashboards/d5ca74f2db4846af9d7f62fec3c820f7

  - W87 82mm (Chinese)
  - NR431 60mm (Belgian)
  - NR473 60mm (Belgian)
- **Hand Grenades**
  - MKE-2A (Turkish)
  - RGD-5 (Russian)
- **Anti-Tank Guided Missiles**
  - 9M113M Konkurs-M 135mm (Russian)
  - 9M133-1 152mm (Russian)
  - 9M131 130mm (Russian)
  - 9M131M 130mm (Russian)
  - 9K38 Igla (Russian)
  - MILAN 115mm (French)
- **Large Caliber Ammunition**
  - 23 x 152mm B (Russian)
  - OF33 130mm (Russian)
  - OF-482M 130mm (Russian, North Korean)
  - Ж-482У 130mm (Russian)
- **Mines**
  - TM-62M (Russian)
- **Others (fuzes)**
  - O-4M rocket fuze (Bulgarian)
  - VP-7M rocket fuze (Russian, Bulgarian)
  - VP-7 rocket fuze (Russian)
  - M206A2 grenade fuze (Turkish)
  - UZRGM-2 grenade fuze (Russian)

EO Threat



Picture 36. Exposure to EO[25]

One in two people in Syria is at risk of death and injury by Explosive ordnance. It is estimated that **between 100,000 and 300,000 EO have failed to detonate** in Syria, therefore posing an active threat of explosion in contaminated areas. Additionally, IEDs and landmines are used extensively across the country enhanced by the increased number of drone strikes and ongoing violence. All of these threats show no signs of stopping and with the war raging it is expected these numbers will continue to grow in the following years. [24]

24 Reliefweb. 2022. Explosive ordnance in Syria: Impact and Required Action - Report Summary | May 2022, https://www.hi-us.org/sn_uploads/document/Report_EO-in-Syria_ENG_2022_1.pdf

25 Reliefweb. 2022. Explosive ordnance in Syria: Impact and Required Action - Report Summary | May 2022.

Given the extreme levels of EO, it is therefore no surprise that in 2020 there were an average of 76 recorded EO accidents per day, equivalent to one every 20 minutes, and that one in two people in Syria are estimated to be at risk of EO contamination. [26]

Picture 37. Victims of EO accidents in Syria[27]

Conclusion

To sum up the whole situation in Syria from an EOD point of view, the information and numbers included in this article could help us create an overall picture of what can soldiers expect in terms of unexploded ordnances and IED threats.

The populated areas of Syria, especially in the north and west of the country are heavily congested with EO threats. However, landmines and drone strikes ensure, that there is no place in the country, where one can feel safe without proper examination of the area.

The UXOs and ammunition monitored in the area indicate a variety in the origin of weapons used in this conflict, both sides being supported by several allies from all over the world. The most explosive ordnances found belonged to countries of the former Warsaw pact, predominantly Russia. However, involvement of other countries cannot be understated, especially Iran and Turkey, as well as groups like Hezbollah and ISIS, who either participate actively in this conflict or just supply the weapons and ammunition to either side.

Based on the results compiled in this article, personnel that would take part in the conflict or happen to appear on Syrian soil should expect to come across mostly older Russian ordnances, complemented by Turkish, Iranian and Bulgarian. To a much lesser extent but not excluding appeared ordnances of other countries like China and Romania, however, it shouldn't come as a surprise if any other explosive ordnances are found.

26 UN OCHA, 'Humanitarian Needs Overview Syrian Arab Republic', March 2021, https://reliefweb.int/sites/reliefweb.int/files/resources/syria_2021_humanitarian_needs_overview.pdf

27 https://unmas.org/sites/default/files/unmas_syria_facts_figures_may_20.pdf

IED attacks of all kinds are also a common occurrence, especially in the vicinity of military areas, but also in everyday life in the streets of Syrian cities, largely endangering not only soldiers but also civilians.

Besides the threat of regular weaponry and unexploded ordnances, the threat of drone attacks is becoming more dominant and it may be difficult to adapt to this new kind of threat. Drone strikes are very difficult to detect, unless it is too late and due to the nature of aerial attack with small flying devices, regular safety precautions may not be sufficient. Iran is one of the most important developers of military drones and has a big impact on this conflict, as Iran is one of the main contributors to the Syrian government, one could expect most of the rebel-held areas to be stroke by drone attacks, despite the fact, that the other side has used this tactics as well.

Intense conflict, huge congestion of UXOs, especially in the populated areas, combined with the ever-present threat of IED attacks and an increasing number of drone strikes makes Syria arguably one of the most dangerous places on the Earth and even extreme caution is required but may not suffice to preserve the life of those, who happen to be in this war-torn country.

Conflict in Yemen

By the EOD officer of the EOD Technologies Department 2nd Lieutenant David Slatkovsky

Background of the conflict

Yemen has been grappling with an armed conflict between the Saudi-backed Yemeni government and the Houthi militia for more than nine years, which has led to widespread security chaos across the impoverished Arab country.

It all began in January 2011, when a number of the country's most powerful tribal and military leaders aligned themselves with the pro-democracy protesters calling for President Ali Abdullah Saleh to step down. When negotiations to remove Saleh from power failed, loyalists and opposition fighters clashed.

In November 2011 Saleh transferred the power to the vice president, Abd Rabbuh Mansur Hadi, who took over his responsibilities immediately. Unable to improve conditions or maintain stability, however, Hadi's government faced armed confrontation and rebellion that in 2014 devolved into a civil war. [1]

War participants

- Houthis (political Shia rebel group) & people loyal to former president Saleh
- Forces loyal to the Hadi government
- Saudi Arabia-led coalition: Saudi Arabia, UAE, Sudan, Bahrain, Kuwait, Quatar, Egypt, Morocco, Jordan
- Supported by: USA, France, UK (weapons, intelligence, logistics)
- Southern Transitional Council (STC) – separatists fighting for the independence of South Yemen (supported by UAE)
- Al-Qaeda & ISIS

Recent Incidents

- *25 July 2023*, two soldiers were killed in a bomb blast in Taiz province (7 others injured). IED explosion placed along the military patrol route. [2]
- *09 July 2023*, Two Yemeni demining workers were killed while attempting to disarm stacked landmines laid by the Iran-backed Houthis in the northern province of Saada. The casualties monitoring group, the Yemeni Landmine Records, said the workers were operating as part of a team in the government-controlled Al-Bouqa area when two anti-tank mines placed on top of each other exploded as they tried to defuse them. Hamza Ahmed, 14, was killed while tampering with an IED disguised as a drink can in the Al-Jahmelia

1 https://www.britannica.com/event/Arab-Spring
2 https://english.news.cn/20230725/465e95ef60604bcbb4b735bd73daabf0/c.html

neighbourhood of Taiz. In a separate incident, a 13-year-old boy died after a mortar shell he was playing with exploded while tending sheep in the Taiz countryside. [3]

- *25 Sep 2023*, an improvised explosive device (IED) detonated during a Yemeni military patrol in the turbulent southern province of Abyan, killing at least five soldiers, a security official told Xinhua on Monday. An IED planted on the side of a road was triggered by a passing military vehicle the powerful blast destroyed the vehicle and killed all five soldiers inside. [4]
- *01 Oct 2023*, A Yemeni government soldier was killed and several others were injured in a Houthi drone attack in the northern province of Saada, the second such incident in a week. The Houthis launched a barrage of explosive-laden drones at a military parade held by Yemeni government forces. [5]
- *31 Nov 2023*, Yemen's Iran-backed Houthi group said it launched a "large number" of drones and ballistic missiles towards Israel. [6]
- *06 Jan 2023*, two officers of the Yemeni government forces were killed on Saturday in a roadside bombing in the country's turbulent southern province of Abyan[7]. The explosion occurred when a military vehicle carrying the officers and soldiers was passing through a valley. The vehicle was hit by an improvised explosive device that had been planted previously on the road.
- *31 Jan 2024*, an oil tanker in the Gulf of Aden is on fire after a missile attack by Yemen's Houthi militants, in the latest incident linked to the Iran-backed group in the key shipping route. [8]
- *06 Feb 2024*, an improvised explosive device (IED) detonated by al-Qaeda militants killed two government soldiers in Yemen's southern Abyan province. The security official said the government forces were raiding the Omayran Valley, a hotbed for terrorist activities when the device exploded. The explosion hit one of their military vehicles, killing two soldiers on the spot, six other people sustained varying injuries. [9]

These are just a few examples of regular occurrences of explosive-related incidents to help create a better picture of what is everyday life like but do not fully showcase the level of threat that is imposed on soldiers and civilians in Yemen.

- *January 2024*, Houthi attacks on international shipping lanes continued through January, prompting a military response from the United States. Far from deterring Houthi forces, US-led strikes strengthened the group's

3 https://www.arabnews.com/node/2334866/middle-east
4 https://english.news.cn/20230925/de3f69de249b48d7818d0e99c4098e9b/c.html
5 https://www.arabnews.com/node/2383656/middle-east
6 https://www.msn.com/en-gb/news/world/yemens-houthis-say-they-launched-missiles-drones-at-israel/ar-AA1j9EQJ
7 https://english.news.cn/20240107/d50b89818cd8448fbccecba33326d49c/c.html
8 https://www.msn.com/en-us/news/world/oil-tanker-on-fire-in-gulf-of-aden-after-houthi-missile-attack/ar-BB1hkaqo
9 https://english.news.cn/20240207/7b6befc427cc49268d35362dbdf69abe/c.html

resolution and spurred yet another escalation of the attacks, with an increasing number of ships in the Red Sea and Gulf of Aden falling under missile and drone attacks[10]. The US forces targeted a "Houthi UAV ground control station and 10 Houthi one-way UAVs" that "presented an imminent threat to merchant vessels and the US Navy ships in the region[11].

Weapons & ammunition used

- **Mines** [12]
  - VS-1.6 222mm (Italian) – anti-vehicle
  - PMN (Russian) – anti-personnel
  - GLD150A (Chinese) – AP
  - M3 (Belgian) – AV
  - TM-57 (Russian) – AV
  - TM-46 (Russian) – AV
  - PPM-2 (German) – AP

Leaked documents show a list of weapons from France, the UK and the US used by the Saudi-led coalition:

- **Caesar howitzer** (French), 155mm, mounted on an all-wheel-drive truck chassis, can fire six shells per minute onto a target up to 42 km away.
- M-109 (American), turreted self-propelled howitzer
- M-198 (American), medium-sized, towed 155 mm artillery piece
- FH-70 (GER, ITA, UK), towed 155 mm howitzer
- PLZ-45 (Chinese), The PLZ45 is a tracked 155mm self-propelled howitzer

Picture 38. Caesar howitzer on the border between Yemen and Saudi Arabia in 2018[13]

Picture 39. Population of Yemen under direct threat of bombs, 2018[14]

10 https://acleddata.com/2024/02/05/yemen-situation-update-january-2024/
11 https://www.aljazeera.com/news/2024/2/1/us-military-targets-10-houthi-drones-in-new-yemen-strikes
12 https://itrace.maps.arcgis.com/apps/dashboards/d5ca74f2db4846af9d7f62fec3c820f7
13 https://made-in-france.disclose.ngo/en/chapter/yemen-papers/
14 https://www.francetvinfo.fr/economie/emploi/metiers/armee-et-securite/des-armes-francaises-sont-bien-presentes-au-yemen-selon-une-note-confidentiel-defense_3397913.html

From this, we can deduce that mostly standard NATO 155mm artillery shells and UXOs can be found in Yemen.

Overall EO Threat

Yemeni authorities and the Saudi-funded Masam demining program estimate that **the Houthis have planted more than 1 million landmines and improvised explosive devices in the country over the past decade**, making Yemen the most mined region of the world since World War II.

33 Masam deminers had been killed and 52 injured in landmine blasts since 2018 and project teams had defused **405,818 landlines, unexploded ordnances, and IEDs** spread over 47,485,089 square meters of Yemeni soil **in the last five years**. Mine placement persists. In fact, **numerous areas had been cleared**, but they have since been **re-mined in greater numbers and with more hazardous techniques**.

Tricks and techniques used by the Houthis in the production of mines and explosive devices are constantly evolving, and the Houthis are constantly striving to improve their mines and explosive devices and equip them with new technologies.

Yemen has one of the world's highest rates of contamination with landmines and other deadly explosives, the International Committee of the Red Cross has warned, nine years after the start of the brutal civil war. The impoverished Arab nation is among the three worst-affected countries. [15]

For example, in August 2023, **dozens of civilians were documented as killed and injured** due to the explosion of the coalition's remnants and its factions in Yemen.

According to the Executive Center for Mine Action, "37 civilians were killed, including 12 children, due to the explosion of cluster bombs and remnants of the coalition during the August 2023." [16]

Picture 40. US-UK Airstrikes in Yemen[17]

The US-UK operation is aimed at weakening the Houthis' capabilities to carry out complex attacks on international shipping. To this end (March 2024), the US-UK strikes have been of two types. The first type involves pre-planned degradation barrages on stationary military assets, including radars and underground weapon storage bunkers. These attacks are usually more numerous and carried out during the

15 https://www.citizen.co.za/news/news-world/yemens-explosives-contamination-among-worlds-worst/
16 https://alkhabaralyemeni.net/2023/09/03/234271/
17 https://acleddata.com/2024/02/05/yemen-situation-update-january-2024/

quieter hours of the night. A second type includes more limited dynamic targeting of pop-up mobile weapons systems. These attacks have been more frequent, with 15 missiles and launchers bombed before they could fire at ships. [18]

Based on available information, the UK forces deployed Royal Air Force Typhoon FGR4 fighter jets armed with Paveway IV guided bombs, while the U.S. forces utilized their warship and submarine-launched Tomahawk Land Attack Missiles and precision-guided munitions in addition to fighter jet strikes. [19]

Conclusion

To sum up the situation in Yemen in regards to the explosive threat, the whole country is covered by mines and explosive ordnances originating from many different countries. On the Yemeni grounds can be found a massive number of landmines – Russian, Chinese and also from West-European countries, endangering both civilians and soldiers in the country.

Furthermore, the long-lasting war is responsible for numerous UXOs from American, French, UK, Chinese, German and Italian howitzers and artillery. The fact, that in the region operated also Al-Qaeda and ISIS organizations implies that weapons like RPGs and missiles of the former Warsaw Pact countries would also leave a trace in the form of many unexploded ordnances.

The UK and US strikes have targeted positions in the western part of Yemen with predominantly Paveway IV guided bombs and Tomahawk missiles, on top of some other American and British ammunition carried by their fighter jets. Finding remnants of these ordnances therefore shouldn't come as a surprise.

On top of all of that, the instability of the region created space for the placing of improvised explosive devices, posing a further danger to both, civilian and military personnel in the country. Furthermore, Iran's backing provides rebels with access to many drones, which are slowly becoming more and more popular in different conflicts around the world.

All of these threats combined make for a very dangerous place for soldiers as well as ordinary civilians. In case of the need to remain in Yemen, extreme caution is advised, for various UXO, IED, mine and drone strike threats.

18 https://acleddata.com/2024/02/05/yemen-situation-update-january-2024/
19 https://www.fdd.org/analysis/2024/01/23/u-s-uk-forces-bomb-houthis-advanced-weapons/

Chapter II – Technology in the service of EOD

A review of selected technologies

By the Head of the EOD Technologies Department Lieutenant Colonel Damian Piórko

The rapid progress in technology development has pushed scientists and researchers into a new dimension. The discovery of a new technology entails the possibility to be applied in many areas. This specific "rat racing" of entrepreneurs in Artificial Intelligence, Mixed Reality and distant detection is on one hand outstanding but, on the other hand, terrifying. EOD is inherently affected by this advancement, and regardless of any national approach, it will be moving forward and keeping pace dictated by industry. To face these challenges, the NATO and EU agendas are diligently conducting various projects not only to exploit the progress in tech but to keep the upper hand over the potential enemy. This chapter will attempt to gather and sum up the latest cutting-edge technology information that has shaped EOD.

Based on numerous observations made during innovation-oriented conferences, seminars and expos in the last two years, it must be firmly stated that two features prevail: **remotely controlled vehicles and distant activities** (i.e. detection, neutralisation, identification, and evidence collection) **enhanced by the sensors**. These two are supported by other growing technologies such as autonomous devices, AI, multi-, hyper-spectral imaging, etc. Merging of multi-technological aspects leads to the production of deeply advanced devices/equipment easing EOD operator executing their task.

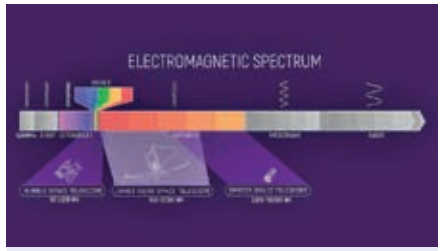
Multi- and hyper-spectral imaging

These two technologies are overgrowing and facilitate explosive ordnance detection immensely. Although researchers and trained soldiers are exploiting drones, Ground Penetrating Radars (GPR), and Remotely Operated Vehicles (ROV) equipped with these technologies, it is still not clear to many its functional principles.

These days, researchers are using hyperspectral imaging (HSI) and multispectral imaging (MSI) on a large scale to detect the presence of UXO or any other objects. How do these technologies work?

The visible spectrum of light for the human eye ranges from 400nm (violet) to 700nm (dark red). HSI is a method where a broader spectrum of light is captured and yet not visible to the naked eye. It starts within the spectrum of ultraviolet (UV) and

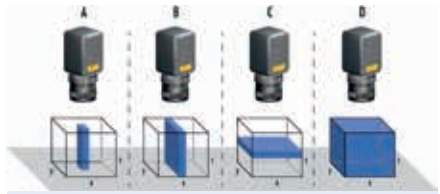
ends in infrared (IR). This opportunity to see the "invisible" significantly helps scientists to discover not only soil and nature changes but deep space as well (see picture 41).



Picture 41. Electromagnetic spectrum[1]

There are four manners to scan the area with HSI (picture 42):

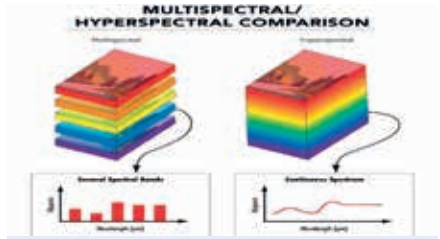
a. Whiskbroom (point scanning),
b. Pushbroom (line scanning)
c. Area scanning
d. Single shot.



Picture 42. Scanning modes[2]

The most desirable one is a single shot when the whole pixel (cube) is filled with the desired data at once.

MSI is characterised by a lesser number of spectral channels used for scanning to HSI and doesn't produce continuous wavelength data collection like HSI. Nonetheless, MSI is being used to great effect in the industry when the subtle differences in scanned areas are not required. Notably, in agriculture when the detection of withered foliage affected by diseases needs to be determined or in waste management where waste discrimination i.e. plastic, paper, rubber, etc. is vital for proper disposal.



Picture 43. MSI and HSI spectrum characteristics[3]

The application of HSI and MSI is enormous nowadays. It ranges from weather forecasts and environmental changes to archaeological works. For military purposes, these technologies are being applied successfully. Apart from the night vision application distant detection of various objects i.e. UXO, IEDs, and disturbed soil are targeted by the researchers.

Various projects utilizing HSI and MSI have been conducted by NATO research entities or third parties for the benefit of the NATO Alliance. European Defence Agency, C-IED COE, TNO and many national enterprises have gone through myriad projects/tests to prove this technology valuable. These technologies are not fully trustworthy in combat use anyway. The detection of an object depends on a

1 https://webbtelescope.org/contents/media/images/4188-Image
2 https://www.edmundoptics.com/knowledge-center/application-notes/imaging/hyperspectral-and-multispectral-imaging/
3 Ibidem

lot of factors. Since IR measures radiance emitted or reflected, its output might be contorted by the time of the survey (morning, noon, and evening). The material the object is made of will have an impact on the final result i.e. wooden one will accumulate heat and discharge it for a longer period, however, its intensity will not be tantamount to the metal object. Metal antitank mines will undoubtedly present a distinct signature presence in the ground and their probability of detection rises in time. Other factors like shade, air temperature, vegetation, scanning altitude, camera, sensor, and lens quality may irreversibly affect the outcome of the survey. Therefore, the use of drones equipped with HSI/MSI cameras during a combat task would be irrational, unless, IR is used to detect enemy positions and movement.

Laser technology

Light Amplification by Stimulated Emission of Radiation (LASER) is a well-known technology, however, more familiar to Hollywood movie fans. Nonetheless, laser use in the military is growing rapidly and the first tangible tests were carried out in the last decade successfully. On the USS PONCE in 2014, LAWS 30 kW laser was tested. The beams, contrary to the Star Wars series, were not visible, albeit able to destroy small boats and drones effortlessly. The system can be controlled by Xbox-like pads, which makes it approachable for the young generation[4]. Another system called High-Energy Laser with Integrated Optical Dazzler (HELIOS) made by Lockheed Martin is even more powerful and discharges a beam of a whooping 60 kW.

Picture 44. HELIOS performance[5]

Turkish is another country working on various aspects of Laser Weapon Systems to the extent it has developed bespoke lasers for the Air Force, Navy and Army as follows:

1. High Power Laser System (YGLS) – ASELSAN, TUBITAK, Bilkent University
2. Laser Defense System (LSS) Project – ASELSAN
3. IŞIN High Power Laser System – TÜBİTAK BİLGEM, ASELSAN, TÜBİTAK MAM, TÜBİTAK UME, Bilkent University
4. Rifle-Mounted Laser Weapon (TÜBİTAK) – TÜBİTAK
5. Vehicle Mounted Laser System (ARMOL) – TÜBİTAK BİLGEM
6. Laser Anti Drone System (LaDRONS) – SAVER[6]

4 https://www.youtube.com/watch?v=XKwRI9CmCBM
5 https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/directed-energy/HELIOS_Infographic_FINAL.pdf
6 https://www.sahaistanbul.org.tr/en/degerlendirmeler/the-importance-of-military-laser-systems-in-the-force-multiplier

Since those laser projects represent various purposes, YGLS for instance *"aims to neutralize a mortar representative element moving at a speed of 20 meters per second at a distance of 1,500 meters with a 20-kilowatt laser power source, within 10 seconds[7]"*.

ARMOL laser installed on a vehicle has a power of 1.25 kW with the possibility to be increased up to 5 kW and can pierce through 22 mm armour steel from a distance of 500 m.

Picture 45. ARMOL installed on a vehicle[8]

One has to take into account that laser, doesn't matter how fancy it may sound, can be limited by many factors. To begin with, is weight. The more powerful the more heavy and bigger it is. Thus, vehicles and aircraft may find it difficult to be equipped with numerous of these "bijou". In turn, weather conditions like precipitation, dust storms and fog may significantly ruin its capacity. Researchers are working diligently on how to tackle the issue.

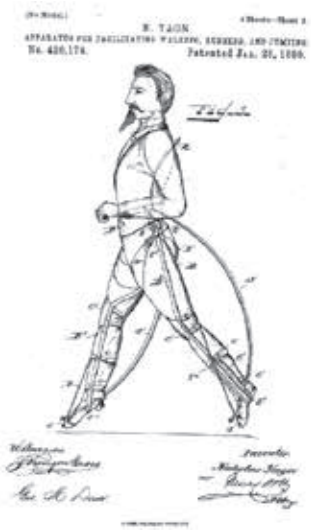
Since an energy of 10^4 J is required to attack an object and vaporise one cubic centimetre by the laser, most of the 81mm mortars can be burnt off or destroyed in high-order (explosion) with an exposure time of approx. 30 seconds. Naturally, the more powerful laser is the less time is required to burn off an object. Therefore, an anti-rocket system installed in the base would be heavier and high-powered to destroy as soon as feasible a rocket before hitting the base. Time to detect the target, aim and "punch" with the beam an incoming threat, generates astronomical costs for the system. On the other hand, "one shot" by laser costs from 1 to 10 dollars. Initial expenditure might be terrifying, however, saving money on own guided rockets might pay off relatively soon.

What would be the laser application for EOD? Unarguably, destruction and safe neutralization of UXOs and IEDs. Most of the EOD missions are finalised by the low-order (deflagration, burn-off) attempt and the procedure of placing proper high-energy tools. The latter takes time, though. By having in possession at least 1 kW portable laser EOD operator would safely and quickly deploy it and attempt to conduct a low-order procedure without the necessity to approach the object. The purchasing of the whole kit i.e. plastic bond explosives, tools, accessories, detonation cords, fuses, firing wires, etc. to neutralize objects would be minimised and limited to buying just one laser. Admittedly, having high-energy tools is a must in the event of laser malfunction or restricted access to the object. For IEDD tasks, a laser would cut the wires effortlessly, and burn off a source of power and homemade explosives. On top of that, dazzling potential triggerman would be an option as well. A suicide bomber in SVBIED would be stopped by damaging the engine, being dazzled or simply being blown off from the distance accidentally by the beam of laser.

7 https://www.defensehere.com/tr/turk-savunma-sanayii-lazer-silah-sistemleri
8 https://www.sahaistanbul.org.tr (…)

Exoskeletons and exosuits

Releasing the burden to humans by applying wearables "machines" is not an invention of modern times. Yet, in 1890 Russian inventor Nichal Yagn patented an apparatus facilitating walking. *This design of an "apparatus for facilitating walking" involved long springs attached to each leg, designed to give soldiers in the Russian Army an advantage when running*[9].



Picture 46. The first patented exoskeleton[10]

As a result, for almost 130 years researchers have been tirelessly perfecting exoskeletons to reach the point where they would be cost-effective, fixable, light, and customized. Customized, since the recipients are many i.e. soldiers, construction site workers, rehab caseloads, and all the workers where lifting is their main domain.

Exoskeletons entirely changed the lives of those with spinal cord injuries, "welded" to the wheelchairs without any hope for standing up, let alone walking without assistance. The state-of-the-art exoskeleton XoMotion helps people with limited motion to walk independently. Siamak Arzanpour, CEO of Human in Motion Robotics Inc., says *"It has 12 motors that are working synchronously together to generate stable and natural gaits. The brain of the robot should generate commands for the motors and the motors should execute them in milliseconds, otherwise, the robot will not walk smoothly and it may fall"*[11].

Picture 47. Siamak Arzanpour presenting his XoMotion exoskeleton[12]

The military approach to exoskeleton utilisation is forced by distinct needs contrary to medical requirements. Soldiers move in environments which may change within one mission from a boggy area to the forest or be affected by the different types of precipitations. Marching, running, crawling, squatting and simply walking with the burden of up to 60 kg require a versatile "device" to meet the expectations. Simultaneously, any serviceman involved in combat tasks desires

9 https://www.researchgate.net/publication/348466799_Review_of_Current_Spinal_Robotic_Orthoses#pf7
10 Ibidem
11 https://www.ept.ca/features/wearable-robot-aims-to-free-patients-from-wheelchairs/
12 https://www.ept.ca/features/wearable-robot-aims-to-free-patients-from-wheelchairs/

Picture 48. ExoM Up-Armoured Exoskeleton, Mehler protection, combining exoskeleton and body protection[13]

to be protected, thus protection is another aspect of the military exoskeleton. The researchers bring up the question of what would be the most desirable "reliever" to endure climate factors, austere environment, not constraint movement and provide protection and safety.To seek the solutions EOD COE, in cooperation with NATO HQ, decided to run a project to determine prerequisites for the exoskeleton for EOD operators.

The Integration of the Exoskeleton in the Battlefield (IEB) was a project conducted by EOD COE from 2017 to 2019 and was commissioned by the NATO HQ. The purpose of that enterprise was *to provide NATO with information regarding possible exoskeleton solutions and suggest necessary steps for the introduction of exoskeleton technology to support EOD operations*[14].

The project team had accomplished 5 workshops where approx. 100 persons representing the military and industry were involved, and *the CONOPS* and *Minimum Military Requirements* were meticulously written to accomplish the effort. *Technical report: Integration of Exoskeleton Technologies in The Battlefield Technology Readiness Assessment* was made by NATO Communications and Information Agency after a summary of the last workshop in 2019. The main output of the whole undertaking was to leave the decision of commercial companies to cooperate with the military on exoskeleton development. The project proved that this technology may encounter many drawbacks. Selected pros and cons are encapsulated in the chart below.

Pros	Cons
Relieve the burden on the soldiers by transferring a substantial amount of the EOD load to the ground	**Difficulty walking** on slopes
Make it easier to carry an artillery shell	Some **difficulties with the size, fit, and comfort** of the exoskeleton on EOD operators

13 https://mehler-systems.com/product-news/shaping-the-future-introducing-the-exom-up-armoured-exoskeleton/

14 Concept of operations (CONOPS) for the integration of the exoskeleton in the battlefield project, 2019, I-EOD COE – 59 - 8/2019

Reduce discomfort and pain caused by the weight of the bomb suit on the soldier's neck, shoulders, and upper back	Some **interference in wearing** certain elements of some exoskeletons under different bomb suits
Reduce the buildup of heat inside the bomb suit by lifting the bomb suit away from the soldier's body	Metal components and three-dimensional structures next to the soldier's body **are undesirable** because an impact event induced by an explosion could drive these structures into the body.
Maintain user's stability, balance and motion control.	

Table 2. Some selected positive and negative outcomes of the IEB project

To dodge the complexity of exoskeleton adaptation for EOD, an **exosuit** may come in handy. The latter is a variant of exoskeleton, however, with some constraints. Namely, it is an unpowered wearable exosuit with no actuators or motors. It means it could be used by the soldiers with great effects but mostly by EOD assistants to EOD leader. An exosuit is a solution when lifting heavy objects is required since it is built of elastic strips to provide relief to a spine. It might be appreciated by any activity where loading, unloading of goods, boxes, ammunition or doing some earthworks i.e. digging the trenches would significantly decrease the number of injuries, exhaustion or overstraining. The exosuit is cost-effective and doesn't require specialized service.

Picture 49. Soldiers of the 101st Ft Knox move an artillery piece while some wear the SABER exosuit[15]

To sum up, the ideal format for the EOD team would be to have the EOD leader doffing a powered exoskeleton and the rest of the team wearing an exosuit. Anyway, the decision is nation-driven and the ultimate purchase would depend on various factors e.g. capabilities, range of tasks, procedures and regulations.

15 https://www.forbes.com/sites/borislavmarinov/2022/08/16/saber-brings-mass-adoption-of-military-exoskeletons-one-step-closer-to-reality/?sh=265d013b366b

Heads-Up Display (HUD)[16]

Information is commonly known as more precious than any valuable element that could be found in the soil. Even now, during the war in Ukraine, providing real-time information to the defenders is giving them an upper hand over invaders. For the EOD operator, it is crucial to be provided with every required information to assess the threat posed by Explosive Ordnance. Therefore, the application of numerous types of cameras or sensors based on infrared and thermal systems to detect CBRN substances, sources of electricity in IEDs, explosives or to execute tasks in an obscured environment seems to be justified. What is more, having this information depicted on the visor/goggles would be a desired solution. During the Demonstrations and Trials 2021 event, the idea of Heads-Up Display for EOD was presented by Med-Eng company where potentially integrated information could be processed and displayed to the operator. This could in the future tremendously enhance the decision-making process and in connection to the smartphones, save all data to analyse the operation in real-time and subsequently. Such fusion of data coming from different sources would decrease the tension of the EOD operator, and make him feel more comfortable and mission-focused.

Let's not put into oblivion a fact, that HUD may falsely react to the change of moisture, instant precipitation, sun or heat exposure, etc. The next factor that would affect soldiers themselves is an additional battery and nuisance that the visor may create. Some traditional visors contort the vision, which degrades target assessment or may lead to injury while walking. When the battery is run out or malfunction appears, the wearer will be left to sink or swim and will be thrown back to traditional manners of gathering information. Soldier vision impairment is another challenge for engineers.

Picture 50. An example of a HUD display information package[17]

Auxetic materials

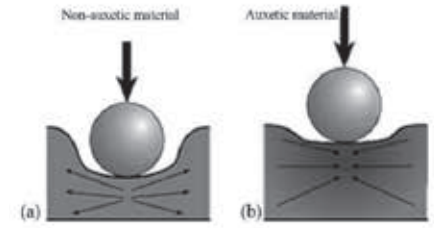
To apply any cutting-edge technology sensors, a modernized bomb suit for **protection** is required. That could demand an application of other features such as integrated respiratory protection and shock and splinters resistance. The complexity of the latter was raised during the D&T21 conference where information about the application of auxetic material was presented. The characteristics of auxetic material make it more resistant to indentation i.e. *"when a non-auxetic material is subjected to indentation, the load applied by the indentor locally compresses the material. To*

16 The three articles: *Heads-Up Display (HUD)*, *Auxetic materials*, and *„Living"* sensors were a part of a publication in the *C-IED Report edition Spring 2022*, and were based on the DaT21 post-event analysis.

17 https://www.youtube.com/watch?v=x8p19j8C6VI&t=34s

compensate this localized pressure, the material is spreading in the direction perpendicular to the applied load"[18].

What is more, auxetic materials are more resistant to shear forces and fracture than "regular" ones[20]. As a consequence, this technology may revolutionize future bomb suits and any other wearable attire for the EOD operator. The advantages for the wearer would be enormous. However, the determination of the affordability and functionality is still unknown.



Picture 51. Indentation behaviour in non-auxetic (a) and auxetic (b) materials[19]

Another "prodigious" material that may extremely improve the safety and durability of any EOD asset is graphene. It is a hundred times stronger than steel and more elastic at the same time. The heat and current are conducted better than in copper and silver. As a result, graphene might be deployed in manufacturing night vision nano goggles, helmets or armoured vehicles. An application of graphene in 3D printing would substantially facilitate the use of improvised highly energetic tools by EOD operators to defeat the EO and simultaneously plummet the costs of its procurement. The question is only how these 3D printings would be replicable and reliable compared to certified commercial ones.

„Living" sensors

Having experienced military missions in Iraq and Afghanistan it is well known that the utilization of Military Working Dogs (MWD) may substantially facilitate patrolling and enhance the security of the base's entrance. *NATO ATP – 3.18.1. Allied tactical publication for explosive ordnance disposal* enumerates different types of such dogs with unique sensor systems to detect mines, Improvised Explosive Devices (IED), drugs, and explosives themselves. It is estimated that a dog, depending on the breed, can remember 600.000 various smells. With their 200 billion olfactory receptors, dogs outnumber human beings considerably, since a man has 5 billion merely. Nevertheless, during the D&T21 visitors could obtain more information about honeybees for a mine detection service. This remarkably interesting topic was presented by the representatives of the University of St Andrews and Croatian Mine Action Centre – Centre for Testing, Development and Training d.o.o. The project is named "Biological method (Bees) for Explosive Detection". In general, the goal is to "exploit" bees in mine detection with two methods: passive and active. The first method serves to confirm mine existence within the area, while the latter to pinpoint the exact

18 Auxetic Materials – A Review, V. H. CARNEIRO, J. MEIRELES, H. PUGA; Department of Mechanics Engineering, University of Minho, Campus de Azurem, Guimar ´aes, Portugal, p.564 -https://www.researchgate.net/publication/259865336_Auxetic_materials_-_A_review

19 Ibidem, p.565.

20 Ibid.

Picture 52. Bees serve human mankind again[21]

mine. The whole process is supported by Unmanned Aerial Vehicles to track the bees' activity and subsequently analysed by computer software.

Some unfavourable opinions might emerge, as bees could detect only minefields and this is not rather an EOD domain. Nonetheless, the project may develop in the future and extend detection to IEDs and UXO. This scheme most certainly would require a static and slow procedure, and exists rather in a post-conflict period, but one should bear in mind, that it would be another exquisite tool for the deminer.

Additive manufacturing

Additive manufacturing (AM) is a process of production of three-dimensional objects by the computer and printing them. 3D printing has become popular to the extent it is being used on an industrial scale. By using graphic software or 3D scanners one can "build" any structure solely limited by the printer's size. Since the availability of computers, software, applications and computer peripherals is effortlessly accessible, when affordable, anyone can purchase a 3D printing kit and manufacture manifold objects. Therefore, criminal activity doesn't remain passive and tries to adapt inventions to their needs.

There are three different types of 3D printers:

1. **Extrusion Based**
   - **a.** FFF/FDM (Fused Filament Fabrication/Fused Deposition Modelling)
   - **b.** Bioprinting
   - **c.** LMD (Laser Metal deposition)
2. **Resin Based**
   - **a.** SLA (Stereolithography)
   - **b.** DLP (Digital Light Processing)
   - **c.** LCD/MLCD (Liquid Crystal Display/Monochrome LCD)
   - **d.** Volumetric
   - **e.** HARP (High Area Rapid printing)
3. **Powder Based**
   - **a.** SLS (Selective Laser Sintering)
   - **b.** DMLS (Direct Metal Laser Sintering)
   - **c.** Jet Fusion[22].

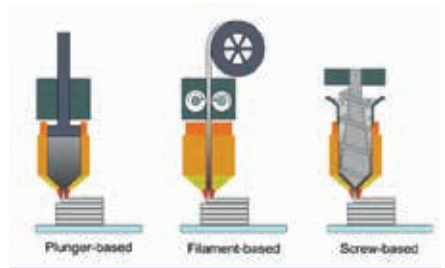
21 Source of the picture: https://www.express.co.uk/news/uk/974470/scots-scientist-trains-bees-locate-landmines-croatia

22 https://www.youtube.com/watch?v=DMWzMpjSJLM&t=275s, Types of 3D Printers - 11 Different Types of 3D Printers - Introduction to 3D Printing

Since the FFF/FDM is the most common way of 3D printing worldwide, this method will be described in this subchapter. The remained information can be watched in the link provided in footnote #22.

FFF/FDM is a technique "that deposits a continuous filament of composite or thermoplastic material to build 3D parts layer by layer. The filament is fed from a spool through a heated extruding nozzle, which heats the material and deposits it onto a build platform"[23].

In general, what would be the potential advantages and disadvantages of 3D printing:



Picture 53. Material Extrusion Additive Manufacturing[24]

Advantages	Disadvantages
Low running costs	Harmful (toxic) printing materials
Wide variety of printing materials available	Visible layers lines disturb the appearance
Time-saving for printing small objects	Continuous movement of the printing head to avoid the accumulation of the deposited material
Low-temperature process	Some objects may require printing "pillars"
Equipment can be used at home and any other location	Possible leakage between the layers
No supervision is required	May require additional sealing procedures
User-friendly	Object may change shape while exposed to high-temperature

Table 3. Gains and drawbacks of 3D printing

Thanks to the broad availability of this technology any rabid hobbyist can produce any type of object that may be an equivalent of a home tool, car repair kit or toy. Quality would be probably questionable, however, for hobbyists a final result overrides cost.

23 https://www.twi-global.com/technical-knowledge/faqs/what-is-material-extrusion

24 https://www.researchgate.net/publication/332110896_Bayesian_networks_in_additive_manufacturing_and_reliability_engineering

Presently, military servicemen are successfully trying to mimic some of the tools by 3D scanning them and easily having them printed out. Such as mines, hand grenades, rifles, guns anything can be done by the FFF/FDM method. That opens new possibilities to complement the lack or shortage of original tools in the stock. For practice purposes, these printed objects would be an excellent counterpart to pricey training kits, however, there is a peril that these counterparts wouldn't mimic fully originals.

Picture 54. A set of 3D-printed clamps[25]

As far as EOD is concerned, 3D-printed tools emulating high-energy mouldings (i.e. Alford tools Vulcan) would pose a significant solution to the lack of such material in the depot. When deployed to distant areas, where commodity delivery might be obstructed, 3D printing would enormously increase the execution of the task and constitute safety. EOD operator by possession of a 3D printer would customize tools and final effects, cost-effectively produce them in larger quantities, design the whole process and even experiment leading to the potential discoveries. Despite these gleeful sides downsides may discourage. Namely, 3D printing may take a long time and CAD modelling requires handling the software. A printer takes up a lot of space and requires electricity, which in a desert and less developed areas might be a dare. The repeatability of the printed object is not the same having an impact on the quality and certainty of the desired final effect. Any failure of action when injury or death occurs and is attributed to the 3D-printed explosive charge/tool may get someone in trouble. In this case, scientific assistance and validation would be required to establish a framework for how to exploit such "improvised" material. The added value of that technology is the creativity and innovation that EOD operator would show. Cleverness would lead to new solutions, discoveries and tactics alternation. Various designs would build up a database and be shared within the EOD community. This would lead to improvement in the EOD operators' safety. What is more, the design would be scalable to match the user's needs. Since the ammunition database is much further away, one shouldn't expect the AM product database to be available soon.

Despite many advantages, commercial manufacturers will suffer income loss if the widespread use of AM is sustained. 3D scanners may solely worsen the situation leaving soldiers a door ajar to enter 3D printing even easier. By doing testing soldiers may create new tools to neutralize bombs, mines, etc. safely. This gives soldiers an upper hand over entrepreneurs, who are deprived of the live ammunition for testing.

25 https://www.selfcad.com/blog/best-3d-printed-tools

Artificial Intelligence: A potential Game Changer for the EOD Community

By the Analyst of the Lessons Learned and Analysis Branch LTC (ret.) Vojtech Fucek

The field of Explosive Ordnance Disposal (EOD) is constantly evolving, demanding innovation and adaptation to address emerging threats and complex situations. Artificial intelligence (AI) has emerged as a powerful tool with the potential to significantly transform the EOD landscape, offering new capabilities and enhancing existing practices.

Understanding AI in EOD:

AI encompasses various technologies that enable machines to mimic human cognitive functions, including learning, problem-solving, and decision-making. In the context of EOD, AI can be applied in numerous ways, such as:

- **Image and video analysis:** AI-powered systems can analyse bomb disposal footage, X-rays, and other visual data to identify suspicious objects, analyse explosive ordnance (EO) components, and classify explosives with greater accuracy and efficiency.
- **Data analysis and threat assessment:** AI algorithms can process vast amounts of data from various sources, including intelligence reports, past incidents, and social media, to identify patterns, predict threats, and assess the potential risks associated with specific situations.
- **Remote EO disposal:** AI-controlled robots/unmanned systems can be deployed in hazardous environments to handle explosive devices remotely, minimizing the risk to EOD personnel.
- **Decision support systems:** AI can provide real-time guidance and support to EOD teams during operations, offering critical insights and recommendations based on real-time data and past experiences.

Benefits of AI for EOD:

The integration of AI into EOD operations holds immense potential for various benefits, including:

- **Enhanced safety:** By enabling remote manipulation of explosives and providing real-time decision support, AI can significantly reduce the risk of casualties among EOD personnel.

- **Improved efficiency:** AI-powered systems can automate repetitive tasks, analyse data faster, and identify threats more effectively, allowing EOD teams to focus on critical decision-making and complex situations.
- **Greater situational awareness:** AI can provide EOD teams with a comprehensive overview of the situation by analysing data from various sources, leading to more informed decisions and improved response strategies.
- **Improved simulation and scenario training:** AI can be used to create realistic simulations and scenarios for EOD training purposes. These simulations can mimic various situations, such as diffusing improvised explosive devices (IEDs) in urban settings or handling threats in hostile environments. AI algorithms can adapt the scenarios based on the trainee's actions, providing personalized training experiences.

Challenges and Considerations:

Despite the promising potential of AI in EOD, several challenges and considerations need to be addressed:

- **Ethical considerations:** The use of AI in autonomous weapons systems raises ethical concerns, and it's crucial to ensure responsible development and deployment of AI in EOD operations.
- **Data security and bias:** The effectiveness of AI relies heavily on the quality and security of the data it is trained on. Mitigating bias in AI algorithms is crucial to ensure fair and ethical decision-making.
- **Human oversight and control:** While AI can offer valuable assistance, it should not replace human expertise and judgment in EOD operations. Human oversight and control must remain paramount.

The Future of AI in EOD:

As AI technology continues to evolve, its integration into EOD operations is likely to become seamless and widespread. Collaboration between EOD professionals, AI developers, and ethicists is crucial to ensure responsible and effective implementation. By harnessing the potential of AI while acknowledging its limitations, the EOD community can navigate the future with greater efficiency, enhanced safety, and unwavering commitment to protecting lives and property.

The future of EOD is undoubtedly tech-augmented, and AI is poised to play a pivotal role in this transformation. By embracing this evolving landscape, the EOD community can ensure continued success in safeguarding our world from explosive threats.

Conclusions:

This article was intended to provide the EOD COIs with a picture of what AI is, how it can be utilized within the EOD, what challenges are still to be addressed, and to inspire the EOD COIs to be proactive in these developments of EOD capabilities.

For those who might still have reservations about AI's role in EOD, consider that this very article and its accompanying image were created with the assistance of AI, requiring only minor adjustments by the EOD COE representative.

The EOD COE firmly believes that AI represents a significant game-changer in the field, and is already working on the "AI for EOD" study (more details to be provided at https://www.eodcoe.org/). The EOD COIs are welcome to join this endeavour for the collective benefit of EOD capabilities.

Picture 55. The picture created with https://www.bing.com

Extended Reality in EOD

By the EOD officer of the EOD Technologies Department 2nd Lieutenant David Slatkovsky

In a world where technology continuously evolves, extended reality (XR) has emerged as a transformative force, reshaping the way we interact with the digital and physical realms. XR refers to technologies combining real and virtual settings to produce engaging and immersive experiences26. It encompasses all technologies that alter the real world or our perception of it in any way and includes augmented reality (AR), virtual reality (VR) and mixed reality (MR).

Augmented Reality (AR)

Augmented reality is a groundbreaking technology that seamlessly merges digital information with the real world. It enhances our perception of reality by overlaying computer-generated content, such as images, videos, or 3D objects, onto our immediate surroundings. The purpose of AR is to augment the environment and let virtual elements interact with real objects to create intended meanings27.

Virtual Reality (VR)

Virtual Reality is a transformative technology that transports users from their physical surroundings into entirely computer-generated environments. By wearing specialized VR headsets or goggles, individuals can experience a sense of presence in these virtual worlds, where their movements and interactions are tracked and integrated in real-time.

Mixed Reality (MR)

Mixed Reality represents a dynamic convergence of both the physical and virtual realms, where digital objects and information interact and coexist harmoniously with the physical environment. MR systems enable users to see and interact with computer-generated 3D holograms that appear as if they are part of their real surroundings.

Application of XR in military projects

One of the main applications of extended reality and its variations is the military. As governments all around the world are striving to find a technological edge, extended

26 https://cointelegraph.com/explained/what-is-extended-reality-xr-explained
27 https://cointelegraph.com/learn/augmented-reality-vs-virtual-reality-key-differences

reality presents unlimited possibilities to enhance the capabilities and effectiveness of their soldiers. All branches of the military can profit from the extended reality and its usefulness cannot be understated despite the technology still being fairly new.

Tactical Augmented Reality (TAR) – *CERDEC*

The U.S. Army's CERDEC is developing a Tactical Augmented Reality (TAR) system for military use, offering soldiers helmet-mounted AR technology to replace traditional gear. TAR provides vital data like location of allied and enemy positions, eliminating the need for handheld GPS devices and enhancing situational awareness. The system integrates a thermal sight on the soldier's weapon, wirelessly connected to the AR eyepiece and a tablet, improving accuracy.

Picture 56. Tactical Augmenter Reality[29]

Additionally, soldiers can split the display to view weapon alignment and a frontal camera feed for safety, enabling them to see around corners without exposure. TAR includes its wireless network for squad communication and real-time data updates[28]. Tactical augmented reality heads-up displays can improve the soldiers' battlefield awareness, and reduce the number of devices that must be carried.

Synthetic Training Environment (STE) – *US Army*

Synthetic Training Environment is an augmented reality (AR) system being developed collaboratively by several research and army organizations in the USA. It aims to create immersive training environments that simulate both the physical and mental stresses of combat. One of its primary goals is to enable commanders to establish highly adaptable and ready units.

STE combines virtual, augmented, and physical realities, making it adaptable for a wide range of mission rehearsals and intuitive for effective training. It represents a promising step towards more realistic and effective military training[30]. STE will be integrated into the next generation of optics and weapons, allowing Soldiers to train, rehearse and fight with the same equipment. Goggle sensors will feature

28 https://defense-update.com/20170529_tar.html#google_vignette
29 https://defense-update.com/20170529_tar.html#google_vignette
30 https://www.peostri.army.mil/synthetic-training-environment-ste/

IVAS (integrated visual augmentation system), with a heads-up display that utilizes augmented reality to identify potential targets, find ranges and enable synthetic training[31].

EOD VR Training KIT (ETACS Project) – NATO EOD Centre of Excellence

The extensive use of virtual reality in different professions has also found its way into the EOD (Explosive Ordnance Disposal). The technological development in the realm of neutralizing the threats of explosives is more than welcome, however, may not be as simple as with other professions.

Therefore, NATO EOD COE decided to implement this technology into the training of EOD operators through self-studying of EOD knowledge utilizing 3D models and also practising EOD scenarios in the Virtual Training Ground by simulating the neutralization process of the threat disposal. VR offers many possibilities, and with continuous technological advancements, EOD COE works to develop software, that will support training EOD operators.

Picture 57. STE in practice[32]

Picture 58. ETACS visualization[33]

Conclusion

XR technologies have already demonstrated their worth in military training. They offer cost savings, enhanced safety for trainees, and improved cognitive skill development. Examples in this article are just a small representation of the application of spatial computing and the latest trends in different branches of the military.

All countries are striving to achieve the technological edge via extensive research and development. Moreover, the NATO countries are utilizing mutual connections

31 https://www.ausa.org/sites/default/files/publications/SL-20-6-The-Synthetic-Training-Environment.pdf
32 Ibidem
33 https://www.eodcoe.org/en/technology-dept/etacs/

and tend to collaborate in implementing the newest technologies into the military, share information to a relatively broad extent and advance together in achieving the desired level of compatibility and interoperability within the allied structures.

The military sector has been always using simulation systems. Lately, there has been a huge improvement in the training and battlefield performance of soldiers thanks to unique possibilities provided by extended reality. However, the XR technologies are still advancing, therefore it is necessary to stay updated and keep developing new projects using the latest technologies.

Additionally, the prospect of combining various technologies, including extended reality is more and more dominant in military projects enhancing the capabilities of soldiers to an even greater extent and we could expect more advances in technologies in terms of computing power and data storage, which are essential parts of any sensor fusion technology.

Chapter III – EOD Transformation

By the Head of Transformation Support Department MAJ Adrian PETER

Introduction

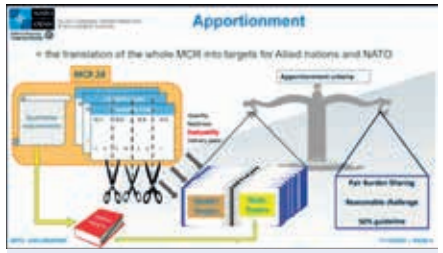
In line with the EOD COE's mission to *support and enhance the NATO transformation and operational efforts in the field of EOD*, the Transformation Support Department (TSD) is performing tasks in direct support of three mission pillars: *Lessons Learned and Analysis; Concept Development and Experimentation, and Doctrine Development and Standardization*. Nevertheless, TSD is indirectly supporting the *Education and Training* pillar by providing feedback and analysis for the training events delivered by the EOD COE.

In order to sustain EOD COE's Strategic Vision of being *NATO's catalyst for improvement and transformation of EOD*, the Transformation Support Department contributes to the achievement of the objectives stated in the EOD COE Strategic Plan by actively engaging Sponsoring Nations (SN), NATO Command Structures (NCS), NATO Force Structures (NFS), other institutions and organizations from EOD Community of Interest (CoI).

a. NATO Defence Planning: Multi-domain considerations for the planning of EOD capabilities

Capability Codes and Capability Statements (CC&CS)

Capability Codes and Capability Statements (CC&CS) are part of the NATO capability development process and are used to describe military capabilities. Within the NATO Defence Planning Process (NDPP), the CC&CS provide a common language for capabilities in Defence Planning (DP) and Operational Planning (OP). The CC&CS define the capabilities used in DP products e.g. the Minimum Capability Requirement (MCR), Capability Targets, Defence Planning Capability Surveys (DPCS) and other OP products. Capability Codes are a unique alphanumeric descriptor of a functional grouping of capabilities, while Capability Statements express capability requirements along the

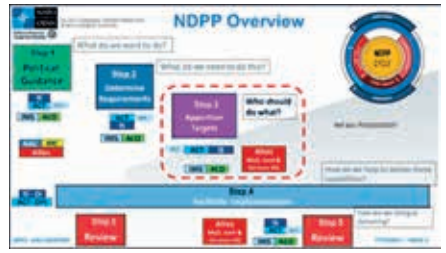


Picture 59. Source: NATO Staff Officer Defence Planning Course

Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities and Interoperability (DOTMLPFI) Lines of Development (LOD). CC&CS were employed for the first time in the 2004 Force Proposal and have been reviewed /improved in the subsequent NDPP cycles. They have been provided with a common language for describing capabilities at a sufficient level of granularity for DP purposes.

Defence Planning Advisory Groups

The EOD COE participates in the MILENG Defence Planning Advisory Group (DPAG) and C-IED meetings where the EOD COE subject matter experts (SMEs) provide support and expertise to all related tasks reflecting the NDPP planning domains mainly in the area of development and revision of respective CC&CS. The review of the CC&CS is built on the Capability Requirement Review and has incorporated recent changes and recommendations from relevant policies, doctrines, Allied Standards, Lessons Learned as well as operational requirements arising from the strategic environment. The current revision of the CC&CS was conducted within the scope of the Capability Requirement Review 2024 in which the newly identified Concepts and Multi-Domain approach is considered and particular attention was paid to the Defence and Deterrence Area (DDA) and the NATO Warfighting Capstone Concept (NWCC). The overall aim of the CC&CS revision is to re-validate and further develop them, as appropriate, in order to ensure their relevance for use in the forthcoming NDPP cycle. This review will be completed by the end of 2023 and be formally staffed and released near the delivery of the next MCR document. The Explosive Ordnance Disposal (EOD) capabilities in a land environment are described as the EOD-related CC&CS within capability areas of the Protect and Command Support under the Defence – Land Threat. The capability of executing underwater EOD tasks is described within the Defence – Maritime Threats as Underwater Explosive Ordnance Disposal (NUWEOD). Capabilities of executing conventional and CBRN EOD are described within the Defence – CBRN Threats.

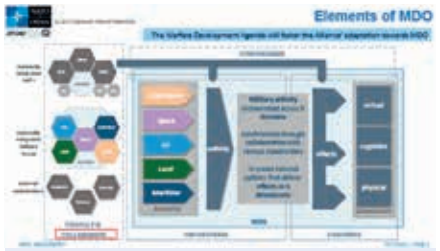


Picture 60. Source: NATO Staff Officer Defence Planning Course 2023

EOD capabilities within multi-domain operations

EOD plays a crucial role in ensuring the safety and security of military operations. As technology evolves and threats become increasingly complex, it is vital to anticipate and adapt to future challenges in EOD activities, that should be taken into account for the future development of its EOD capabilities. The EOD approach to NATO Multi-domain Operations (MDO) refers to the integration of EOD capabilities in the context of joint and combined operations across multiple domains (land, air, sea, space, and cyberspace). By integrating EOD capabilities into MDO, EOD

expertise aims to enhance the MILENG functions (mobility, protection, and sustainability) across diverse operational environments. To effectively fit within MDO, EOD capabilities need to be integrated and coordinated with other military elements, such as intelligence, surveillance, reconnaissance (ISR), communications, and manoeuvre units. This integration enables timely threat identification, responsive decision-making, and synchronized operations across multiple domains. The exact integration and application of EOD capabilities in MDO can vary depending on the threat, the specific operational requirements, and the mission objectives.



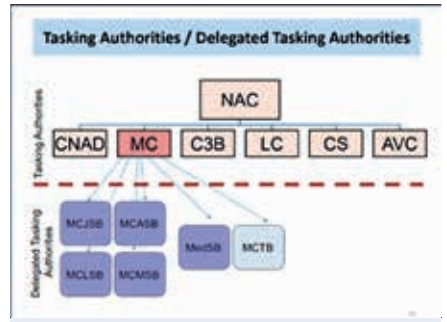
Picture 61. Source: Multi-Domain Operations Concept 2023

b. Doctrines evolution: *Standardization in the field of EOD*

NATO Standardization

NATO constantly evolved since it was established by the Allies in 1949. However, the thing that was not changed is the requirement for NATO forces and capabilities to be interoperable. NATO standardization, defined as *"The activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context"* greatly increases the effectiveness of the Alliance's defence capabilities with respect to doctrine, tactics, training, as well as materiel. Operational standardization encompasses all activities that affect interoperability across operating forces to include conceptual, organizational or methodological requirements. The MC is the responsible tasking authority (TA) for the development of operational standards. In this role, it directs and guides MC delegated tasking authorities (DTAs), i.e. established bodies under the MC, which initiate, develop and manage operational standardization activities. These bodies are the MC standardization boards (MCSBs).

The development of NATO standards and ensuring that they are kept relevant is in the hands of subject-matter experts (SMEs) provided by Allies, NATO partner nations and the NATO Command Structure (NCS), and organized in working groups (WG) under the MCSBs. For organizational reasons, working groups often establish panels or writing teams, responsible for a specific number of standardization documents and/or to provide a forum for carrying out work assigned by the boards.



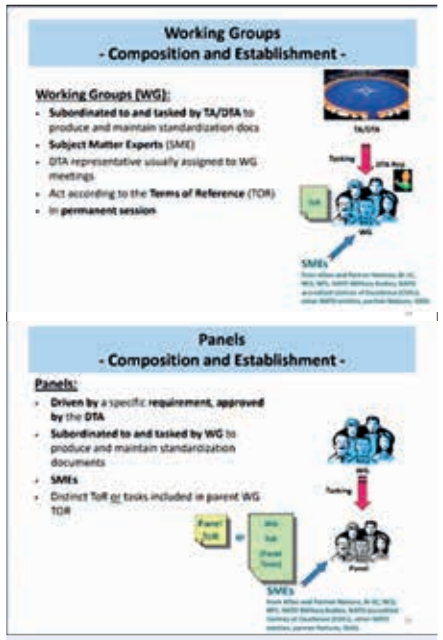
Picture 62. Source: Standardization within NATO Course 2022

Picture 63. Source: Standardization within NATO Course 2022

Contribution to EOD-related working groups

The EOD COE actively supports NATO doctrines evolution by providing EOD expertise. The SMEs participate in several working group meetings, writing sessions, workshops, seminars, conferences, etc.

The Explosive Ordnance Disposal Interservice Working Group (EOD WG) is part of the Military Committee Land Standardization Board (MCLSB) and is responsible for covering all standards related to EOD. EOD COE contributes to these WG meetings with several SMEs, usually covering all the panels. The vice-chairperson of EOD WG is the Director of EOD COE. The vice-chairperson of the Doctrine and Philosophy Panel (DPP) is the Head of the EOD Policy, Concept, Doctrine and Standardization Branch (PCDSB). EOD Terminology is also addressed by an SME from PCDSB.



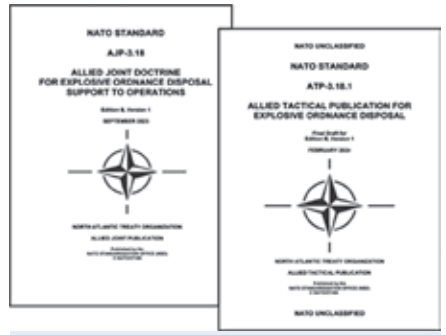
Picture 64. Source: Standardization within NATO Course 2022

The other working groups under the portfolio of EOD COE SMEs are Military Engineering (MILENG WG), Counter-Improvised Explosive Device (C-IED WG), Joint Chemical Biological Radical and Nuclear Defence Capability Development Group (JCBRNDCDG), Allied Joint Operations Doctrine (AJOD WG), Land Operation (LO WG), NATO Technical Exploitation Group (NTEG) and Force Protection (FP WG). Every WG usually organizes two meetings per year.

Contribution to NATO EOD Standards

The EOD COE is the custodian of AJP-3.18, *Allied Joint Doctrine for Explosive Ordnance Disposal Support to Operations*. This publication is the overarching NATO doctrine for all aspects related to EOD support to operations. The doctrine describes the EOD area of expertise of MILENG function and how EOD principles are applied during the planning and conducting of joint operations. It provides guidance for operational-level commanders to plan, conduct and monitor EOD support to operations. The newest version of this doctrine (AJP-3.18 B) has just been ratified (SEP 2023) by NATO nations.

The next publication is ATP-3.18.1, *Allied Tactical Publication for Explosive Ordnance Disposal*, which is a sub-standard of AJP-3.18. This standard describes the EO threat and how EOD principles are applied and capabilities are used during all the phases of operations on the tactical level. It further defines the command-and-control (C2) structure, the information flow and the operating considerations for EOD support. The newest version of this doctrine (ATP-3.18.1 B) is currently in the revision process.



Picture 65. Source: EOD COE PCDSB

The Allied Explosive Ordnance Disposal Publications (AEODPs) provide detailed information about EOD activities and tasks. They are a very useful tool for EOD staff and EOD force elements. Until today, NATO developed eleven different volumes of AEODPs.

Former Warsaw Pact Ammunition Handbook

One of the most wanted products of the EOD COE is the Former Warsaw Pact Ammunition Handbook (FWPAH). The EOD COE started with the production of FWPAH shortly after its official accreditation. The aim of this handbook is to

Picture 66. Source: EOD COE PCDSB

provide information on ammunition produced by states from the Former Warsaw Pact. The first volume is focused on Land Forces Ammunitions and consists of two parts. The first part is about Projectiles, Explosives and Grenades and the second part is about Mines, Explosives, Sub-munition and Grenades. The second volume continues with Land Forces Ammunitions describing Rocket and Missiles. The Air Force Ammunition, especially Aerial Projectiles, Bombs, Rockets and Missiles are described within volume three. The volume IV provides information about Artillery Fuses used by Former Warsaw Pact Armies.

c. Lessons Learned: Lessons Learned in the field of EOD

The ultimate goal of the EOD COE is to be a catalyst for the NATO transformation in the EOD area, and therefore several lines of operation should be in coordinated synergy. How does the Lessons Learned (LL) mechanism fit into that synergy? To answer that particular aspects, need to be considered:

1. The future EOD capabilities will not be the same as they are today. Their purpose will not be changed significantly but they will have to *reflect and adopt not only new technical possibilities but also to be very ready for new evolving threats* (as a potential enemy never *"sleeps"*). It means that the transformation in the EOD area should be boosted throughout (at least):
   a. *fast implementation of technological progress*, and
   b. *coordinated learning from own experience and approaches of current enemies*.
2. In general, technological progress is ongoing and influences any dimension (technology, social, human, politics, military etc.), and headways in one area stimulate progress in other areas. In addition, there is also exponential growth and cumulation of innovations, and this process is not only evolutionary but some new inventions or discoveries can turn out to be very revolutionary. Such a situation requires *steady monitoring and fast implementing* of these new possibilities on the one hand, and the other hand, it calls for the *analysing of new and upcoming threats* wherever such innovations could be misused.
3. *Coordinated learning from own experience and approaches to current threats* is crucial for getting informational advantages and it boosts EOD training to be ready for any variations and innovations of threats. Such a learning requires at least:
   a. Earned *trust and will/ motivation to share* some very sensitive lessons among allies
   b. Implemented *LL culture* within individuals, collectives, structures and organisations
   c. Established a very functional *LL mechanism* (including trustful and reliable lesson-sharing tools).

The aforementioned aspects have been serving the EOD COE's Lessons Learned and Analysis Branch (LLAB) as foundations for supporting the NATO transformation in the EOD area (see picture 1). The LLAB has been concentrating its efforts to:

a. *Monitor technological progress applicable within the EOD area*
b. *Analyse obtained findings for formulating recommendations or considerations to implement new possibilities*
c. *Promote trust, motivation, and LL culture/mechanism within particular EOD Communities of Interest (CoIs)*

Throughout the years the LLAB has learnt that the highlighted efforts have to tackle many challenges as sharing of very sensitive lessons explicitly brings many risks when any of all procedures and tools would be compromised. Such challenges influenced tools used for heading to settled efforts. The best results have been achieved by using the following tools:

a. *Organizing regular EOD Workshops.*
b. *Launching particular projects for the EOD CoIs.*
c. *Analyses of particular obtained entries* (e.g. outcomes from NATO EOD Demonstrations and Trials, particular EOD COE courses, EOD COE LL database).

These activities and works are very viable and fruitful in support of the EOD COE's Strategic Vision:

a. Regular workshops (introduced in 2012) *build up trust among those participating in person, provide platforms for new cooperation/ networking, LL sharing, promoting LL culture/mechanism, introducing innovations not only in the EOD area.*
b. EOD COE projects (e.g. *"AI for EOD Study"* or *"EOD COE Study on Ukraine"*) monitor the newest technological breakthroughs heavily influencing the EOD in the close and midterm future or provide insights into current operations (UKR) in which upcoming threats can be observed and identified for improving the future EOD training.
c. Particular LLAB analytical works serve as sources of new perspectives on specific *technological headways and their implementation into the EOD* and support *turning lessons into new considerations and recommendations* for particular EOD issues.

Picture 67. Source: EOD COE LLAB

d. Head of Transformation Support Department: Challenges for Transformation in the field of EOD

The changing and evolving security environment puts the Alliance's continued success at risk. While NATO remains a defensive alliance, the operating environment demands new ways of thinking, organising and acting. The operating environment is widening beyond traditional military bounds, with competition among different actors becoming more persistent across all instruments of power. This environment

Picture 68. Source: NATO Warfighting Capstone Concept (NWCC)

also features more diverse actors, with new weapons and technologies employed in new ways. To properly address the new and emerging threats, Allied Command Transformation (ACT) developed the NATO Warfighting Capstone Concept (NWCC). This vision is informed by the activities of potential adversaries but is proactively driven by the Military Instruments of Power (MIoP) own ambition for success in transitioning towards the 2040 operating environment. The warfare development imperatives *(Cognitive Superiority; Layered Resilience; Influence and Power Projection; Cross-Domain Command; and, Integrated Multi-Domain Defence)* offer a means for Allies to align their national conceptual and capability development efforts that pertain to the Alliance's political and military-strategic objectives.

In line with NWCC imperatives and guidance, the EOD COE will revise its own Strategic Vision and Strategic Plan in 2024. The objective of this revision is to keep the relevance of the EOD COE within NATO and to raise the opportunity for better cooperation with the important actors from CoI outside NATO. The Transformation Support Department (TSD) will be the leading element for these revisions.

TSD will continue to support all of the EOD COE's mission pillars: *Lessons Learned and Analysis; Concept Development and Experimentation, Doctrine Development and Standardization*, and *Education, Training, Exercise and Evaluation* by conducting specific tasks in accordance with the NATO Requests for Support (RfS) and decisions of the EOD COE Steering Committee. The already established working relations will continue to evolve by engaging more relevant actors from inside and outside NATO.

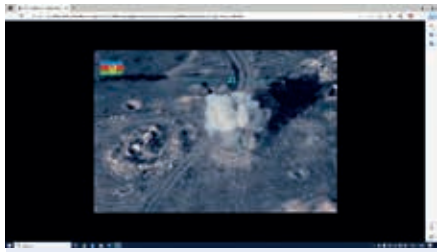
Based on the constantly positive feedback received by the EOD COE members from Sponsoring Nations (SN), NATO Command Structures (NCS), NATO Force Structures (NFS) and other institutions and organizations from the EOD Community of Interest, we can conclude that EOD COE is fulfilling its mission accordingly and it has the potential of overcoming all the future challenges in the EOD area.

Chapter IV – Education and Training approaches to EOD challenges

By the Head of NATO EOD E&T Development Branch MAJ Marek VLNKA

The current approach to EOD training has been influenced predominantly by changing the world security environment. The initial impulse was the illegal Crimea annexation in 2014. This event caused NATO to focus instead on the war against international terrorism back to the Article 5 type of operations. It means brushing up on the capabilities related to an extensive conventional conflict in Europe. This effort has been resolutely accelerated by the Russian invasion of Ukraine in 2022. The course of the conflict has shown possible gaps and deficiencies in DOTMLFP of the NATO and particular member states. Reflecting the situation the EOD capability is not an exception. A massive deployment of the artillery, mines, and IEDs is heavily challenging Ukrainian EOD-capable personnel every day. Additionally, new technologies are entering the game in a fundamental way. The massive utilization of drones as a weapon of choice or as a sensor and a counter-measure on the level of individual soldiers has changed the way we look at the battlefield from an EOD point of view today.

Drones as a decisive technology that has a parameter of the game-changer in conventional conflicts were proven and firstly massively used during the Second Nagorno-Karabakh War in 2020. Azerbaijan's widespread use of drones was seen as crucial in determining the conflict's outcome. The same importance of using drones in the various roles on the battlefield is seen during actual conflict. They provide reconnaissance, serve as carriers of the bombs, help with the targeting, and are utilized as loitering munition. We may conclude that they have become integral pieces of equipment for almost each offensive or defensive unit.

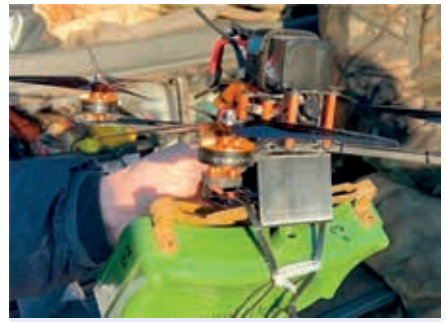


Picture 69. A drone providing the battlefield overview/reconnaissance[1]

Focusing on the EOD capability, drone implementation into the incident, and task management focused on incident scene surveillance. There have been initiatives to improve and extend the roles provided by drones, e.g. as a carrier of the equipment in general or for an RSP. This brings up challenges for EOD commanders in how

1 Source: The Ministry of Defence of Azerbaijan

to properly integrate this tool into the current organization of EOD teams. Does it require adding another member to a team as a drone operator or it is manageable by the current team structure? Moreover, it would require to incorporate the drone operator training into the EOD operator training program. Definitely, EOD operators have an advantage compared to the majority of the other capabilities and functions, that mastering the remotely operated vehicles is an integral part of the EOD operator training programs in every NATO country. This fact provides a solid basis to easily integrate drones into the standardized equipment through NATO.



Picture 70. A fragmentation antipersonnel mine attached to a drone with an improvised release mechanism[2]

The next modern technology, which completely changed the way we perceive the current and very recent approach to improvised explosive devices is 3D printing. We could experience the initial trends in isolated conflicts all over the world, but the war in Ukraine fully unfolded the technological potential. A good example is a printout used as a bomblet body filled with the main charge and metal pieces used for the fragmentation effect. Conventional or simple impact-initiated improvised fuses are successfully utilized in this setup. As a delivery method are largely drones with an aiming and release mechanism which makes it an easy, simple, and capable weapon of choice for an effective fight against individuals and small groups on the battlefield.

Picture 71. Release of a bomblet from a drone[3]

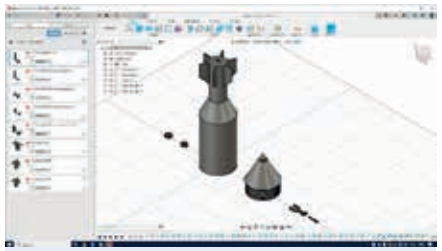
Picture 72. Modified RKG-3 anti-tank grenades with 3D-printed tail fins.[4]

It brings new challenges for EOD operators. Firstly, the new construction of the munition/IEDs should be taken into consideration. Despite the fact that utilized fuses are of standardized military construction and there are confirmed and tested RSPs for them, the new means of deployment must be taken into account. Additionally,

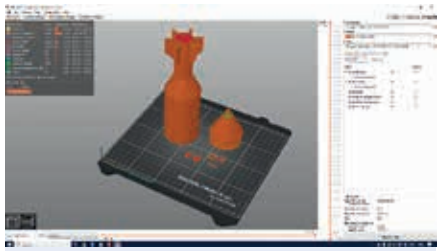
2 Source: Telegram
3 Source: Aerorozvidka
4 Source: Twitter

Picture 73. A modified VOG-17 grenade released by a drone[5]

these printouts should be incorporated into the Basic/Advanced IED courses curricula to provide EOD operators with essential information about their construction, function, deployment, and neutralization. Nonetheless, the important part of the training also should be a demonstration, which would provide information on the key features of 3D printing technology, e.g. the procedure of 3D printout production, materials and their attributes and software tools. Secondly, 3D printing technology can be used not just by adversaries but also by EOD operators during an RSP. It provides great options for the customization of EOD tools such as specialized charges containers which may perfectly fit EOD incident on-scene conditions. There are no tool limits related to the size, shape, angle, or material character. The only limitation in this matter is still the fact the software tools are not accessible to an average PC user.



Picture 74. An improvised bomblet model created in the Fusion 360 CAD software.



Picture 75. An improvised bomblet model sliced in the PrusaSlicer software and prepared for printing[7]

To bring a final 3D model into the physical form requires the first step - 3D object development. It is elaborated in a CAD (Computer-Aided Design) software environment. Even though these kinds of tools have become more user-friendly in recent years and producers of these programs are trying to make them available for a wide range of public non-professional users, it still requires some portion of engineering skills, which could be identified as a limitation for EOD operators.

Moreover, the second step of a physical 3D printout production is switching a 3D model into a form that is readable by a 3D printer. In this process, a model is completely sliced into layers of a very small width (tenths of a millimetre). These layers are laid down by a printing mechanism layer after layer to create a physical copy of a 3D model from a

5 Source: Twitter
6 Source: EOD COE
7 Source: EOD COE

computer. This process is called slicing. Similarly to CAD, slicing software is not a straightforward computer application operable by an EOD operator without some portion of training

The EOD community is aware of the user-friendliness of 3D printing technology. There are some initiatives to simplify the whole creation process from designing through the slicing and final operation of a printer. An operator just picks up a type of object suitable for a particular usage and adjusts the size, angle, or type of material to his needs. Then the software automatically performs the slicing procedure sets all attributes for the printer and starts the printing process. This will reduce the requirements of the operator to the necessary minimum and save a significant amount of time. With the enhancement of the 3D printing technology, and its toughness for the field application, a 3D printer will be a part of the EOD operator mobile tool set. It also brings up a question of 3D printer standardization within NATO and includes it in the doctrines.

The gradual advance in technology is not the sole observation of the conflict. There are further considerations that need to be taken into account for the EOD capability. As the war has moved to the attrition type of conflict with massive pollution of Ukrainian land with unexploded projectiles, cluster munition, and mines, Ukrainian EOD personnel capacity is absolutely insufficient to manage it. They are focusing on incidents within the urban areas, but the shortage of personnel and equipment is significant. The police officers, firefighters, or Ukraine State emergency services are responsible for performing the tasks, often in an improvised way. However, it created a highly dangerous situation for the EOD personnel and civilians, as they did not have the proper amount of time to complete the full EOD operator course.

Picture 76. An improvised Render Safe Procedure conducted by an Ukraine law enforcement unit[8]

The shortage of qualified personnel is a common symptom of all NATO countries. Within the EOD COI, this fact is more intense as the community is very small compared to the other capabilities and the time necessary to train a fully prepared operator is very long. Currently, many EOD community representatives from most NATO countries declared a partial decrease in their EOD personnel knowledge level. Firstly, the strong EOD operators' generation from Afghanistan and Iraq deployments retired in big numbers without proper exchange of experience in recent times. Secondly, it is very difficult to compete with other specializations within the military when the number of recruits is the lowest in decades. Moreover, the EOD specialization requires a specific sum of attributes laid on candidates with a unique attitude to their future responsibilities. The EOD community will need to adjust to the new competitive environment and try to find a new approach to attract qualitative personnel in the future.

8 Source: Ukraine State Emergency Services

The Conclusions

By the Head of the EOD Technologies Department Lieutenant Colonel Damian Piórko

For the last three decades, the profile of the warfare conduct has altered or at least the methods of leading the wars and conflicts have blended. The "traditional" **conventional war**, so much developed during WW II, that absorbed enormous resources and massive death toll seems to be nowadays too pricey consuming capital expenditure more for the sustainment and maintenance than the combat use itself. Keeping alive armies built on high-priced tanks, jets, and aviation is justified when the potential threat exists. The countries of the former Warsaw Pact still feel insecure as Russia has at its disposal a military potential that equals the top five NATO countries' strength (see chart …).

Type of equipment	NATO (top 5 countries)	Russia
Aircraft	16,9k	4,1k
Tanks	10,4k	12,4k
APC	76k	30k
Artillery	2,8k	7,5k
Rocket artillery	1,8k	3,3k
Self-propelled artillery	2,7k	6,5k
Battleships	1k	605

Table 4. Military potential of Russia and the top five NATO countries[1].

Russia has stuck to the role of being the artillery war's god, simultaneously being still a serious player on the land and waters. The character of the ongoing war in Ukraine points out that Russia, after the attempts of the BTGs failure application had to return to their "old and proven" tactics by using various types of artillery to shatter infrastructure. In turn, that pivotal swerve towards WW II tactics proved that Russia experimented with various approaches to the new venues. One of the examples is the use of drones on a massive scale and almost 800 launched high-precise missiles to hit vulnerable targets by Russia. That turnaround proved that aggressors in modern conflicts may still base their victory on tanks/artillery power and the sacrifice of the countrymen.

Since the foe exploiting their strength with conventional weaponry defenders deprived of this opportunity will turn to simple solutions i.e. partisan tactics and

1 https://www.komputerswiat.pl/artykuly/redakcyjne/rosja-kontra-nato-sprawdzamy-potencjal-wojskowy-odwiecznych-rywali/v1jnzv5#slajd-1

IEDs. This creates an entirely different picture of the battlefield which is dispersed, low-scale and resembles a flea-bite-war. Improvisation and imagination prevail over solid and deliberated operations. The 10-dollar worth of improvised explosive devices can immobilize a 5-million-dollar tank/vehicle. **Asymmetric warfare** challenges regular armies significantly and coerces them to alter the training system partially. Mine Resistance Ambush Protected (MRAP) vehicles were constructed for asymmetric type of warfare. V-shaped chassis was to diminish the IED explosion and protect a crew. That 0.5-1M dollars vehicle used to be immobilized by a 25 kg container of homemade explosive attached to some rudimental switch made out of wood and flip-flops sponge. One 9V battery or the welded pack of 20V batteries could have withstand weeks waiting for the prey. Such a way of leading war is an underdeveloped country's preserve.

What would be the result of the equation where asymmetric warfare blends with the conventional one? If the ongoing conflict between Hamas and the Israeli Armed Forces in 2024 be qualified as such a combination? How such types of conflicts i.e. conventional, asymmetric and both combined could have an impact on EOD performance and overall preparation?

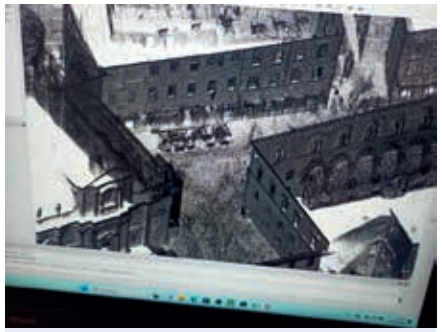
Undoubtedly, the conventional type will bring thousands of UXO and AXO which inevitably requires increased EOD capabilities. The bigger number of EOD teams would demand higher financial expenditure, yet for developing countries, it might be unaffordable. Police and commercial companies could support military in the clearance operations, however, IEDs are still a thorn in the mine action teams' flesh.

The first months of the war in Ukraine pointed out one of the dormant problems that emerged, namely **civil defence** or rather self-defence activities. Citizens of bigger towns and cities having seen that the aggressor was prevailing and advancing towards their homes took the plunge and commenced preparation of the Molotov cocktails, improvised grenades or HME to hinder that march. Any container filled with combustive material, fuel tanks, or high-pressured vessels could be perilous as well. That raised a question to what extent do these additional hazardous materials affect EOD job? Where is a limpid boundary between the Police and military in tackling the EO (including IEDs)? The number of incidents with EO might inundate and choke the EOD roster, therefore, additional qualified specialists would be in high demand. Would those be trained according to the same procedures as the military? If military, Police and commercial EOD teams don't follow the same procedures, how would the lab of level 2 process evidence exploitation and the judiciary system pronounce a sentence? Russian Federation having noticed the need for improvement of their capabilities started retrofitting many of their pieces of weaponry including bombs. Simple modernization changed the free-falling bomb into a flying one, by attaching wings and correction modules. Admittedly, this hasn't changed the EOD neutralization procedure, but it may imply issues with identification by AI or technicians themselves. Vacuum and thermobaric rockets/projectiles might be a challenge since the EOD teams across NATO cannot train on such a unique weapon.

Unquestionably, drones have proved to be a silver bullet on the battlefield in numerous aspects like reconnaissance, tiny bombers, and transportation means. Its applications are countless and depend on users' imagination. EOD technicians may face shortly drones not only laden with explosives but also peppered with sensors enhanced by **AI**. Drones may come in many shapes and sizes. Fly-like drones with the capacity to fly for at least one minute, carrying 1-2 grams of primary explosives can bring the EOD tasks to the next level, as those flies can be employed en masse. Hundreds of such petite insects could attack groups of people or CIS systems. Killing wouldn't be a priority, but causing chaos, injury and permanent psychological tension would be desired. The **miniaturisation** of the systems and invention of **tiny, long-life batteries** would revolutionise UAV and ROV employment.

AI used by the enemy may discriminate against the victim, so even EOD operators are exclusively aimed at. If the EOD team drives the particular vehicle and wears particular equipment i.e. bomb suit, AI will effortlessly identify these features and activate an explosive charge to eliminate the target. AI will identify badges, faces, ways of walking and uniforms. Any other first responders would be saved, not EOD. Does it mean future EOD missions will be done by AI, remotely with the human decision limited? The only limitation to AI controlling the mission is the database and machine learning algorithm. In 2016 AlphaGo, AI software, defeated 4-1 Mr. Lee Sedol a top world player in the game Go. Next, the same software beat another master Ke Jie 3-0 in 2017. The brightest minds couldn't deal with the machine counting a thousand times quicker and projecting dozens of moves ahead. As a result, if the enemy applies AI to their IEDs, bombs etc. EOD/IEDD/Demining equipment manufacturers will have to do it likewise.

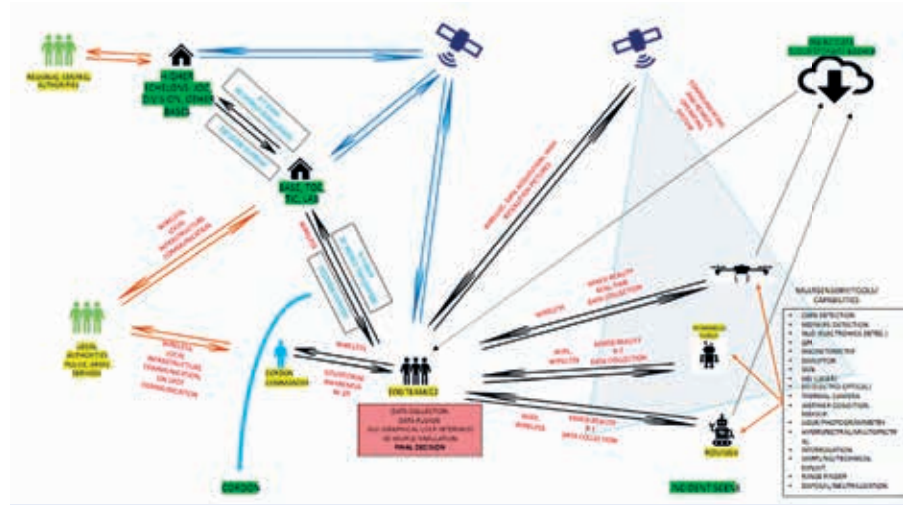
Situational awareness (SA) could be enhanced by **VR/XR** and **Lidar cameras**. The first could simulate various scenarios based on the scanned area by the UAVs and ROVs. Real-time delivered information could update the picture of the environment and help to decide the EOD team. The limitation of this solution might be substantial, starting from data transfer, passing through the processing of data and ending with final reliable environment emulation in goggles. Lidar camera solution to SA was presented during the 20 Mine Action Symposium in Dubrovnik in April 2024. Polish company Mandeye[2] presented the possibility of scanning with lidar technology hard-to-reach areas and built their model in 3D. Terrain can be scanned by the camera attached to humans, dogs, ROVs or any other movable objects.



Picture 77. Scanned area of Dubrovnik while walking across the downtown.

2 *https://edutech.expert/pl/products/lidar-mandeye-14202.html*

By taking into account all the information mentioned above, how would be a future battlefield formed by challenging communication and data transfer? In the picture 78 EOD COE SMEs attempted to raise that issue and project the foreseeable battlefield stakeholders that would significantly influence SA and task execution. The EOD team as the central entity would receive and transmit big data. Receiving information to build SA from ROV, UAV, and humanoid robot at once demands huge computing power, rich in information database and machine learning software to finally receive a reliable picture of the scene. Information could be saved in the online cloud and be shared with other parties i.e. higher echelon or other experts. VR tech would provide a realistic vision of the scene and foster a decision on EO neutralization or destruction. "The mechanical team members" like drones, UAVs and humanoid robots packed with multisensory (CBRN, weather, GPS, RGB/IR camera, HSI/MSI, etc.) and other tools to conduct neutralization or BIP in situ would transmit real-life data to the team and other stakeholders to decide on action. Storing information in the online cloud would allow accessing it by anyone authorised. Local authorities would have an immediate impact on the decision to BIP objects affecting the environment. The massive burden of accountability for the unexpected damage would be taken off the EOD team leader and diminish compensation claims. Higher echelons would be given immediate updates on the mission to accelerate their decision-making process. Forensic evidence would be provided immediately online to the 2nd-level labs and be proceeded by the specialists administratively awaiting for the physical evidence.



Picture 78. Communication network between the EOD team and other parties.

Having analyzed the communication network let's narrow down to the EOD scene. In the picture … can be seen the imaginative illustration of the future EOD environment where the EOD team operates being enhanced by various cutting-edge technologies. Most of the elements of that technology already exist and merely big data transfer and its processing give scientists sleepless nights. The next factor limiting the application

of the latest solutions is the rate of manufacturing costs to the success of the task execution. Supposedly, a 100.000 euro humanoid robot would be not cost-effective for a neutralization mission on a 20-dollar-worth IED.

The EOD team at EOD Control Point would be outfitted with:

- **laser** to conduct low-order operations or BIP from a distance,
- **3D printer** to customize the printed tools to adjust charge properly to neutralize particular objects,
- **exosuit** to lift heavy equipment at ease,
- **VR goggles** to observe the environment around ROVs/UAVs and built SA,
- **XR goggles** to search through the EO database to support mission success and to depict all necessary data from multisensory vehicles,
- **RGB cameras** to record missions and **LiDAR** to build SA,
- operating ROVs and UAVs to support the team leader's SA and conducting the action on the object i.e. breaking car's windows with drones,
- metal detectors with sensors precisely tracking down the surface covered by the head
- **tracking down the health status** of the EOD operator in a dead zone.

UAV and ROV:

- multisensory (CBRN, explosives, weather conditions),
- metal and wire detection,
- NLJD (electronics detection),
- GPR and magnetometer,
- disruptor,
- gun/drone jammers,
- HEL (laser),
- thermal, infrared and 360 camera,
- LiDAR,
- HSI/MSI (hyperspectral/multispectral),
- loudspeaker and microphone,
- sampling/technical exploit.,
- range finder

EOD operator within the dead zone:

- Exoskeleton,
- Bombsuit made of auxetic materials,
- XR HUD to increase situational awareness,
- RGB cameras (zoom in/out),
- Sensors to control health and environment (contamination and weather conditions),
- XR assistance to collect evidence (i.e. video recording and measurement) in situ and have them sent to C2 swiftly,

A potential course of action during EO incident enhanced by disruptive technologies:

SA before reaching the EO incident scene

EOD Team having received EODTASKORDER analyses the historical incidents in the tasked area based on AI-enhanced software (AI-enhanced EO database). A precise set of information helps operators to envisage projected EO and other threats. Direct connection to the ISTAR or patrol's drone hoovering over the incident scene significantly fosters assessment of the situation and determination of the EOD Control Point (ECP). RGB/IR cameras mounted to the vehicles and soldiers' helmets being on the scene, before the EOD Team's arrival, provide additional detailed information about the witnesses' testimonies, and the scene including weather and videos/pictures of the suspected object i.e. IED or UXO. Based on such initial information EOD Team decides if any additional measures would be required i.e. evacuation of the immediate area, cooperation with local authorities or services (fireguards, police, etc.).

While in the EO incident scene – reconnaissance and identification

EOD Team employs a **UAV** fitted with an **RGB/IR camera** to carry out reconnaissance to confirm/deny EO presence. The drone can **take samples** of the required material, which can be instantly tested by the operator at the ECP proving CBRN contamination, explosives or any other hazardous agents. Drones scan the area with **HSI/MSI technology** to confirm the presence of explosives or the presence of other EOs/ERW. **Magnetometers** and **GPR** sensors also rummage the ground seeking threats, building a map of scanned areas and marking the potential threats. AI-powered software singles out the EOs within the area by using an RBG camera to prove secondaries or tertiaries. Admittedly, there are no limitations to identify the whole minefield or group of mines.

Simultaneously, **ROV** can be deployed being fitted with multisensory devices. ROV scans its way to suspected EO. The **dual technology detection system** i.e. metal and GPR is fitted with **Precise Point Positioning (PPP)** and **Real-Time Kinematics (RTK)**[3] device to measure the scanned area up to a few centimetres extremely precisely. This builds the map of the scanned area, thus the EOD operator can use that trail to approach EO steadily. Next, the attached **LiDAR camera** builds up a map in 3D of the EO scene. **VR** module in ROV processes this information immediately to build the virtual scene, so that the EOD operator can get familiarized with the immediate surroundings of the EO in case, the drone is unable to reach the spot (e.g. confined spaces, dense foliage, etc.). This enormously enhances SA and facilitates the EOD team to prepare the decision on neutralization. Having analyzed the EO incident scene EOD team employs an ROV/UAV fitted with a disruptor to carry out low-order operations. If scarce time or a tactical situation demands an urgent decision laser or gun can be used to blow in place an EO.

3 More info – MIFI Maps Ltd, United Kingdom

Post-incident activities

Having neutralized or destroyed the EO, the next vital step is to collect evidence from the scene. All the samples of the soil, explosives and other items found suspected on the scene can be taken by the UAV/ROV fitted with the proper device to analyze the chemical compounds. Video and photographs are taken by the UAV/ROV with high resolution. This could immensely limit the presence of the EOD operator within the scene. Data generated from various detectors, analysers and sensors could automatically fill in the EOD report as an initial informational notification system. The detailed report could be sent subsequently. XR glasses scan items of evidence to build a database of forensics assisting the judiciary process. All collected pieces of information are shared with third parties in real time via the online cloud or wirelessly.

Setbacks

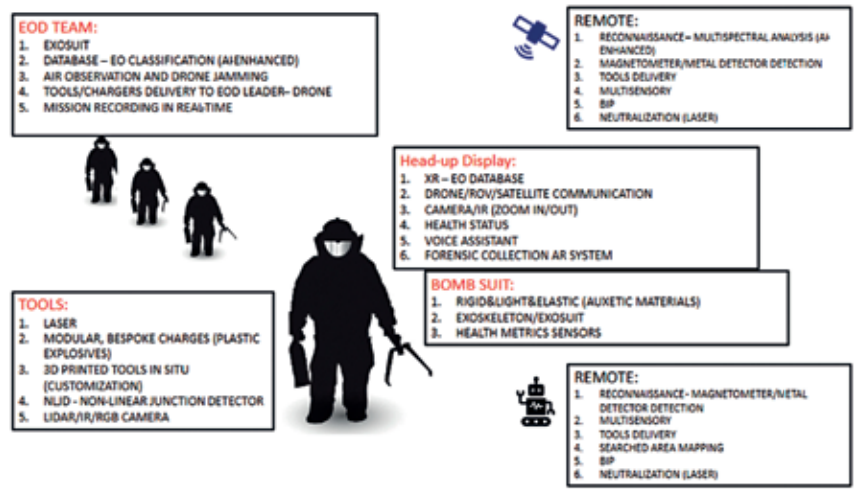
The above-presented vision may seem unrealistic, however, the pace of tech development is extremely high and dispersed. The inventions occur worldwide in places no one could expect. Engineers work on their projects in their basements or garages building breakthrough devices that might be sold to terrorist groups. China plays the role of a hub of tech inventions. Year by year, discoveries emerge from that country in many industrial branches streamlining processes in factories or simply connecting people globally. The first drawback of tech is its **pace**. Excessive rush of technology leaves it uncontrollable. Verbatim, all movable autonomous pieces of machinery could be potential UAV/ROV laden with explosives and controlled globally. The Internet network being built by Elon Musk will give access to steer any object anywhere. It is merely a question of time when **battery**-powered machines could fly, drive or sail hours covering hundreds of kilometres. So far, this possibility is limited, however, autonomous vehicles are being developed on a large scale. The next challenge is **computing power** and **processing all arriving information** from the sensors. This seems to be the largest inhibitor to apply on the battlefield. Even if such a computer is operating nowadays, still cost of that technology exceeding economics. EOD work is dangerous and costly accessories may be not willingly purchased by the military. **The reliability of the sensors** may be challenging. The same sensor working within an austere environment will provide manipulated data. Technology must provide reliable information to the extent, that EOD operator feels certain about actions they would like to take. Manufacturers willingly construct teaching aids, dummies, software, etc. to facilitate and enhance training, however, the combat support mission is still too intricate to ensure safety. Post-conflict zones seem to be approachable for various manufacturers, where their inventions can be tested and improved. Hopefully, today's disruptive technology will become common and combat operations will use a full spectrum of its capabilities to make EOD work easier.

EOD transformation challenges (by Maj Adrian Peter)

From the TSD perspective, some trends for improving EOD activities can be singled out, as follows:

1. Lessons Learned processes will be improved by Artificial Intelligence (AI) solutions (e.g. AI search engines, AI analytics, etc.), since the data that needs to be analyzed is increasing, the time when the information should be available should be reduced in order to keep the pace with the adversaries and the human capabilities are somehow limited.
2. The same types of solutions will be used for developing new NATO standards. Some of them are already in testing phase (e.g. AI CLAIRE, NATOTerm 2.0). Besides that, there will be a higher need to implement civilian standards for new emerging and disrupting technologies, instead of developing new ones, only for NATO use.
3. For Capability Development and Defence Planning, is highly unlikely that NATO will be able to develop other solutions than the current ones, which will be agreed by all nations, since these are highly connected with the nations' financial restrictions. In the future we will see, as today, different approaches and solutions for addressing the same gap.

In conclusion, we could say that the new emerging and disruptive technologies will play a pivotal role in NATO and AI solutions will be part of our daily routines.



Picture 79. EO scene handled by EOD team utylizing various types of technology.

Aerial bombs[1] from the Storage to the Battlefield

By EOD COE Chief of Staff COL Zsolt Szylagyi

The Russian UMPK (Unifitsirovannyi Modul Planirovaniya i Korrektsii) technology allows the glide bomb[2] to be directed to its target with a high degree of accuracy, making it a formidable weapon on the battlefield. The "Russian JDAM" (Joint Direct Attack Munition) has proven to be a significant threat to Ukrainian military assets, posing a challenge to their air defence capabilities and making it more challenging for Ukrainian forces to defend against aerial attacks[3].

The Russian arms manufacturers had developed "high-precision" munition, converting old free-fall bombs (FAB-250, FAB-500, and FAB-1500) into weapons that would glide to their target. Russia already had glide bombs, but the new UNPK technology combines an existing bomb with a simple guidance kit and equally simple bolt-on wings. This is not a cheap transformation, but still, it is much less than a missile costs. Russia's glide bombs rely on Russia's GLONASS satellite constellation.

Main characteristics	FAB-250 M-62	FAB-500 M-62	FAB-1500 M-54
Lenght (mm)	1920	2430	2310
Diameter (mm)	300	400	570
Total weight (kg)	227	497	1392
Warhead type	high explosive	high explosive	high explosive
Warhead weight (kg)	100	213	667
Fuze	impact	impact	Nose fuse, VDU and UPAV series

Source: https://weaponsystems.net

1 "Aerial bombs are munitions dropped from aircraft. They are separated from the bomb carriers by gravity or forcible separation and designed to cause destruction by the detonation of a high-explosive charges, incendiary action or other methods. They are designed to accomplish nearly all air combat missions in the conduct of military operations." *(Former Warsaw Pact Ammunition Handbook VOL 3 – Edition II., Published by NATO EOD Centre of Excellence, 2019)*

2 "A glide bomb or stand-off bomb is an aerial bomb with aerodynamic surfaces to give it a flatter gliding flight path in contrary to a conventional bomb without such surfaces." *(Former Warsaw Pact Ammunition Handbook VOL 3 – Edition II., Published by NATO EOD Centre of Excellence, 2019)*

3 https://www.youtube.com/watch?v=xVB_ny19jdY

The converted FAB bombs can only be used against fixed targets. The use of FAB bombs has become a critical element in the Russian offensive in Ukraine, especially in razing to the ground Ukrainian defences in and around Avdiivka, which fell in February.

Yuriy Ignat, a spokesperson for the Ukrainian Air Force, informed CNN in April 2024[4], that Russian forces have been launching "as many as 20 guided bombs per day". He goes on to clarify that these bombs are dispatched from Su-35 Flanker and Su-34 Fullback aircraft, which adeptly avoid entering Ukraine's airspace.

The use of "Russian JDAM"[5] highlights the evolving nature of modern warfare, with advancements in precision-guided munitions allowing for more targeted and effective strikes. As tensions continue to simmer between Russia and Ukraine, the deployment of these modified bombs underscores the ongoing military developments in the region and the potential for further escalation.

The Ukrainian military has been working to adapt and counter these new threats, investing in air defence systems and enhancing their capabilities to detect and intercept incoming munitions. The conflict between Russia and Ukraine has spurred a race for technological superiority, with each side seeking to gain an edge in the ongoing struggle for dominance.

Russian FAB-1500-M54 aerial bomb with UMPK gliding and guidance kit (Photo source: ttps://armyrecognition.com/)

Su-34 Fullback bombers with modified FAB-500M-62 bombs (Picture source: https://defence-blog.com)

A FAB-1500 bomb completely destroys a multistorey building in Krasnohorivka (Picture source: https://www.independent.co.uk/)

The international community closely watches these developments, acutely aware of the potential implications for regional stability and the broader geopolitical landscape.

4 https://edition.cnn.com/2024/03/10/europe/russian-guided-bomb-ukraine-frontline-intl/index.html

5 https://www.youtube.com/watch?v=lsHas7adx4o

As the situation unfolds, it is clear that the use of precision-guided munitions like the Russian JDAM will continue to shape the dynamics of modern warfare, underscoring the need for robust defence strategies and ongoing efforts to resolve conflicts through dialogue and diplomacy.

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