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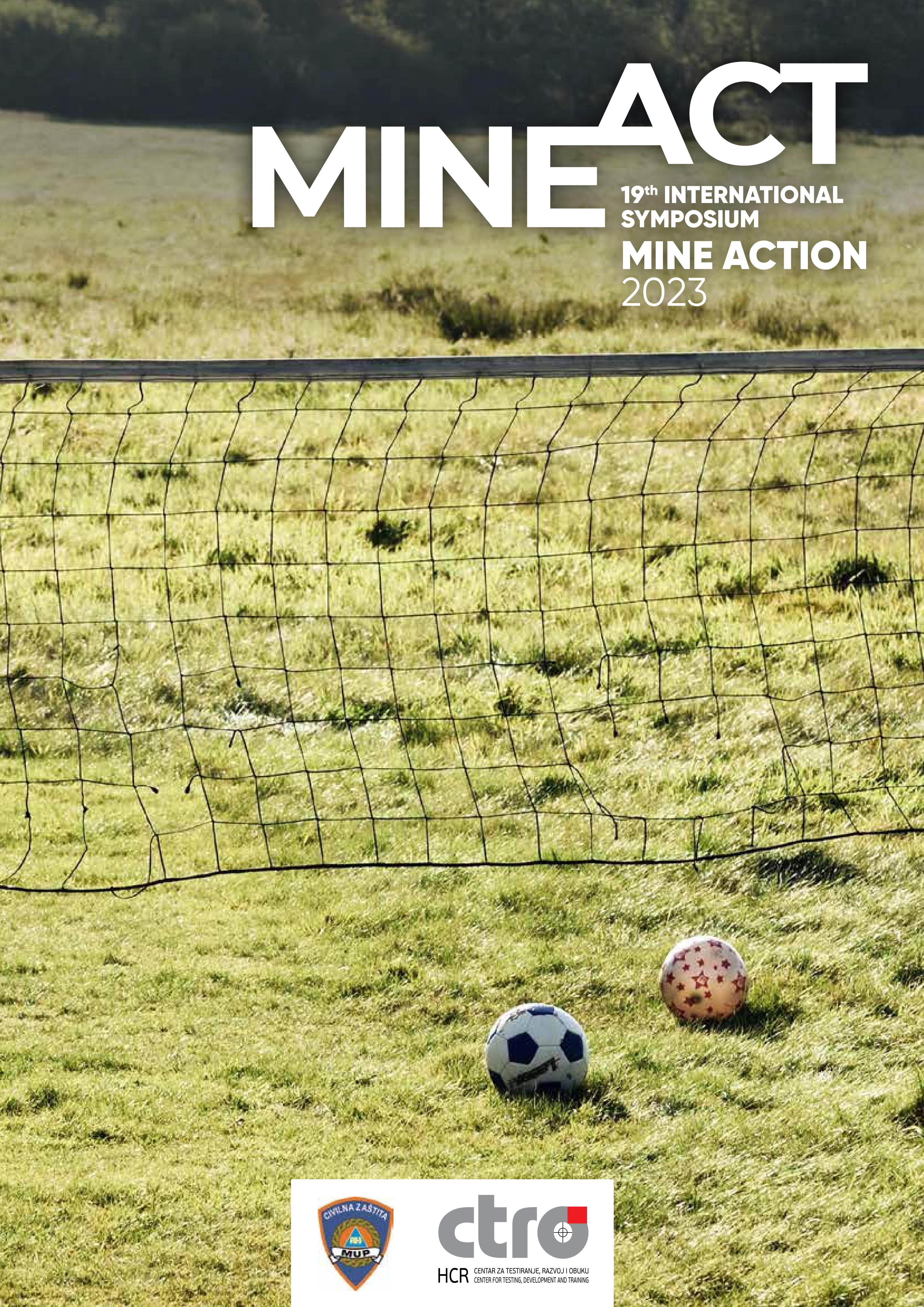
19th INTERNATIONAL SYMPOSIUM
MINE ACTION
2023



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19th INTERNATIONAL SYMPOSIUM

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2023

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UKRAINE –
NCY RESPONSE
ALLENGES AND
OPPORTUNITIES

Humanitarian Mine Action in Ukraine. Ukrainian Dimension

Tymur Pistriuha [1]

Introduction

In 2014, at the beginning of combat action in the East of Ukraine, the huge problem of contamination by explosive remnants of war (ERW) appeared in the middle of Europe. Even before the full-scale invasion of the Russian Federation on 24 February 2022, Ukraine was in the top five countries with a mine problem. [1] Unfortunately, today Ukraine is the most contaminated country in the world.

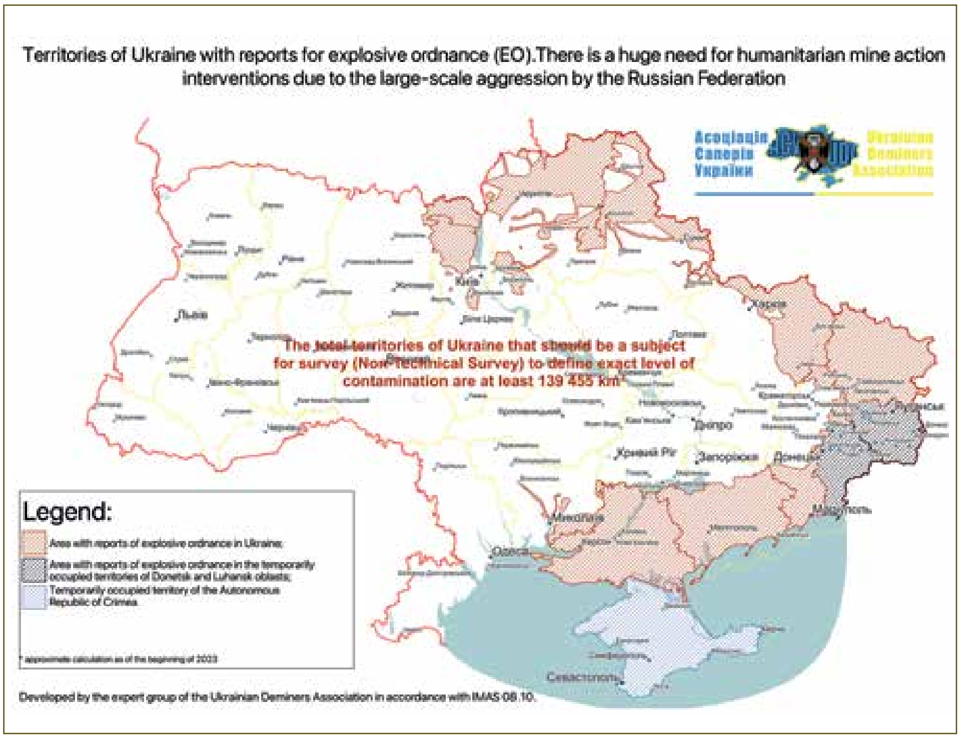
On 12 November 2018 a national non-governmental (non-profit) organization «Ukrainian Deminers Association» (hereafter – UDA) was created. The main goal of the UDA is solving problems on Humanitarian Mine Action (hereafter – HMA) in Ukraine. [2]

The UDA was created by the initiative group of deminers and currently, the members of the organization are 331 people from all regions of Ukraine.

The UDA is a certified mine action operator, included in the list of MA operators [3], is a permanent member of UNDP Protection and FAO Clusters, Mine Action sub-cluster. The organization is an active participant of HMA activities (meetings, round tables, conferences, etc.) under international organizations (UNDP, PCU OSCE etc.) and governmental authorities (Ministry of Defence, State Emergency Service, Ministry for the Reintegration of Temporarily Occupied Territory, etc.). The UDA is listed in the database of the HMA organizations of the Geneva International Center for Humanitarian Demining [4]. The members of the UDA are part of various working groups aimed to solve state issues in the HMA sphere, in particular, the lawmaking process.

HMA Problems in Ukraine

1. Since 24 February 2022 UDA experts have conducted Desktop Study on Mine Action. We have fixed MA incidents, analyzed combat actions, movement of troops, etc. In June 2022 we submitted all collected data to National Mine Action Authority. Based on UDA calculation the total territories of Ukraine that should be the subject of the survey to define the exact level of contamination are at least 139,000 square km.



From 24 February 2022, which marked the start of the large-scale armed attack by the Russian Federation, to 26 March 2023, the Office of the UN High Commissioner for Human Rights (OHCHR) recorded that 253 people were killed by mine/UXO and 492 injured. [5] Ministry for the Reintegration of Temporarily Occupied Territory reported also high numbers of mine victims. The worst part is that both UN Agency and Ministry say that this number is there much higher, because during active hostilities it is impossible to accurately count all the victims of the war and mine victims as well.

1 NGO "Ukrainian Deminers Association", Ukraine, tymur.pistriuha@gmail.com

2. Humanitarian demining began almost immediately after the de-occupation of the northern regions of Ukraine. The deminers that were involved in UDA projects started their activities in the Makariv hromada of the Bucha raion of the Kyiv region, and then in the Chernihiv region. Non-technical survey were also held in 3 regions: Kyiv, Chernihiv and Sumy.

According to the results of last year, the UDA managed to hand over the first demining site - an agricultural field with a total area of 22 hectares - to the Makariv hromada (Land Release process). In fact, it was the largest contribution in last year.

Since May 2022, non-technical survey specialists involved in UDA projects have been conducted NTS in the following regions:

from May 2022 - Kyiv region;
from June 2022 - Chernihiv region;
from September 2022 - Sumy region;
from December 2022 - Kharkiv region;
from February 2023 - Mykolaiv region;
from March 2023 - Dnipropetrovsk region.

Unfortunately, from the safety point of view, our deminers have not received permission to start work in the Kherson region yet.

3. On 6 December 2018 the Ukrainian Parliament (Verkhovna Rada) adopted the Law on Mine Action in Ukraine. On April 25, 2019, and September 17, 2020, significant changes were made to the law. As a result, two mine action centres as an operational body were created in Ukraine [6]. It brings Ukraine to the effective execution of humanitarian demining tasks.

4. One of the key issues in the humanitarian demining of liberated territory of Ukraine regions is that the hostile party is not a signer of the Ottawa Convention [7] and the aggressor uses anti-personnel mines actively, which are the greatest threat to the civilian population.

The Russians not only actively use anti-personnel mines, but are also developing this direction. There have already been many cases of using the POM-3 "Medalyon" mine of the latest model. It was first demonstrated by the Russians at the defense exhibition "Army-2019" in 2019.

Not a complete list of explosive items that you can find in Ukraine due to Russian aggression against Ukraine:

- a large number of unexploded ordnance of the canon, jet artillery systems, mortar mines;
- different various of grenades and grenade launches;
- anti-personnel (PFM-1, PMN, PMN-2, etc. prohibited by the Ottawa Convention) and anti-transport mines;
- cluster munitions;
- improvised explosive devices (IED), booby traps (surprises) (such as MS, ML) installed for non-extermination with various sensitive sensors;
- the latest designs and designs of the regular ammunition of the Russian Army;
- mined areas of agricultural fields, forests, infrastructure objects (roads, bridges, overpasses, buildings, etc.), but even houses (e.g Bucha, Irpin, Borodianka). [8, 9].

5. It should be noted, that the Ukrainian national capacity for humanitarian demining was increased significantly. In particular, Ukrainian deminers gained knowledge and a huge practice, a valuable experience; humanitarian demining operators became more technical equipped; the first Ukrainian MA operator – Demining Solutions company appeared.

But the scale of the tragedy is so gigantic that, of course, today Ukrainian potential and capacity is not enough to solve this problem.

This year, our state determined that agricultural land is a priority [10]. Of course, these are huge territories, which are very difficult, long and dangerous to provide manual clearance. Yet, in fact there is no use of any remote-controlled mine clearance system, e.g. MV-4, MV-10, etc. for humanitarian demining of agricultural land. Involving the above-mentioned machines would increase effectiveness significantly and save the lives of deminers.

The results of the conference "Military-Technical Cooperation between Ukraine and Croatia on the Mechanical Clearance. Experience, Status and Prospects" (November 26, 2020, Kyiv) with the participation of all HMA state bodies showed that Ukraine needs multi-mission EOD robotic system MV-4 and MV-10 [11].

7. Nevertheless, the key point of humanitarian demining issues in Ukraine is the lack of financial support by donors.

During the opening of the exhibition "War through the eyes of pyrotechnicians of the State Emergency Service" (4 April 2023, during International Mine Awareness Day) the Resident Representative of the United Nations Development Programme (UNDP) in Ukraine Jaco Cilliers [12], said that the complete demining of Ukraine will cost 35.7 billion dollars [13].

Based on world practice, the «year of the war is ten years of demining». Taking into account that the war in Ukraine more than 9 years and not finished yet we can predict that the costs of complete demining of Ukraine will be even higher than Mr. Jaco Cilliers noticed.

Conclusion

Ukraine has been facing a huge problem as contamination of its territory with mines/ERWs for more than 9 years of war and the situation becomes worse day by day. Based on the UDA analysis of the humanitarian demining problem in Ukraine, key points for solving these issues are:

- comprehensive financial support by international donors and organizations directly for clearance of contaminated areas;
- continue implementation of Mine Action regulatory framework in Ukraine;
- absence in Ukraine of the mechanical clearance process by multi-mission EOD robotic system for agricultural land;
- development of Ukrainian capacity for humanitarian demining, in particular, Ukrainian operators in close cooperation with international partners.

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[3] Webpage of Ministry of Defence of Ukraine. Access: https://www.mil.gov.ua/content/protyminna/pmd22032023.pdf

[4] Webpage of the Geneva International Center for Humanitarian Demining. Access: https://www.gichd.org/en/resources/organisations/

[5] Report of UN High Commissioner for Human Rights (OHCHR) dated 27 March 2023;

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[7] the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction, Oslo, 18 September 1997;

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[9] Посібник з базової ідентифікації боєприпасів в Україні В. 3.0 08.03.2023

[10] Webpage of the Cabinet Ministry of Ukraine. Access: https://www.kmu.gov.ua/news/minreintegraciyi-onovleno-aktualnij-perelik-gromad-u-rajonah-bojovih-dij-na-tot-i-tih-shcho-v-otochenni

[11] Multi Mission EOD Robotic System MV-4, MV-10, DOK-ING, 2020;

[12] Webpage of UNDP in Ukraine. Access: https://www.undp.org/ukraine/resident-representative

[13] Webpage of Censor article about exhibition “War through the eyes of pyrotechnicians of the State Emergency Service” https://m.censor.net/ua/news/3410086/oon_povne_rozminuvannya_ukrayiny_koshtuvatyme_357_milyardiv_dolariv?fbclid=IwAR1Q2s-fRbcIydF_GDDi45HGf6znsUyyu2DwvQHGSBAJBWhjsyIJZ-Qepik

Representing Ukraine in The Journal of Conventional Weapons Destruction, 2014–2023

Jennifer Risser*, Bryn Hebert*

From the 2014 Russian annexation of Crimea to the present-day war in Ukraine, *The Journal of Conventional Weapons Destruction* at the Center for International Stabilization and Recovery has published fourteen articles focused specifically on mine action operations in Ukraine, providing timely information regarding contamination, clearance efforts, victim assistance, innovative approaches to risk education, the environmental impact of explosive weapons use in Ukraine, and pioneering survey methods, such as the use of open-source research for survey and operational planning the sector is employing as the conflict continues to unfold. Contributing organizations include The HALO Trust (HALO), Danish Demining Group (DDG), Danish Refugee Council (DRC), Swiss Foundation for Mine Action (FSD), Organizations for Security and Co-operation in Europe (OSCE), Mines Advisory Group (MAG), the Conflict and Environment Observatory (CEOBS), and Norwegian People's Aid (NPA).

Following the 2022 Russian invasion of Ukraine, *The Journal* has accepted articles on mine action operations in Ukraine on a rolling basis, encouraging organizations to detail how they are currently operating and planning for future actions in the country, how the sector is pivoting and adapting their work in response to the current conflict, what lessons donors and implementers have learned from previous conflicts and how these are influencing the sector's response, and analyses of how the situation in Ukraine will shape the sector for the foreseeable future.

Background

Ukraine's explosive remnants of war (ERW) and mine contamination dates to the First and Second World Wars, the conflict in eastern Ukraine starting in 2014, and most recently, the 2022 Russian invasion. Ukraine is a State Party to the *Anti-Personnel Mine Ban Convention*; and in November 2020, its second extension request was approved by the Eighteenth Meeting of States Parties in November 2020. The request noted further contamination along the contact line and in the Luhansk and Donetsk regions (Oblasts) in eastern Ukraine, and the use of anti-personnel mines by armed groups hindering its efforts to estimate the scale of contamination.[1] More recently, due to heavy combat in the east and south, and emplacement of anti-personnel mines and improvised mines, new contamination resulting from the ongoing invasion means that Ukraine faces many years of clearance before it can fulfill its treaty obligations.[2]

Legal framework on mine action was absent until January 2019, as noted by Henrique Garbino in his article, "Ukraine's Newly Adopted Mine Action Law: What Does this Mean for HMA Programs."[3] The Law on Mine Action was approved on 25 January 2019; however, it was not implemented, and no national mine action authority nor center was established.[4] As indicated by Garbino, legislation would "unleash the full potential of mine action in Ukraine by de-conflicting competing efforts and facilitating bureaucratic procedures."[5] Nevertheless, the legislation "has shown significant gaps and created further uncertainty, especially in relation to direct donor funding and government budget for its implementation."[6] The slow development of national mine action "infrastructure" has created challenges for

* Center for International Stabilization and Recovery

1 "Ukraine," *Landmine & Cluster Munition Monitor*, last updated 22 February 2021, http://www.the-monitor.org/en-gb/reports/2022/ukraine/impact.aspx

2 "Ukraine," Clearing the Mines 2022, Mine Action Review, https://www.mineactionreview.org/assets/downloads/Ukraine_Clearing_the_Mines_2022.pdf

3 Garbino, Henrique, "Ukraine's Newly Adapted Mine Action Law: What Does this Mean for HMA Programs?" *The Journal of Conventional Weapons Destruction*, 2014, https://commons.lib.jmu.edu/cisr-journal/vol23/iss1/7/

4 "Ukraine," *Landmine & Cluster Munition Monitor*, last updated 22 February 2021, http://www.the-monitor.org/en-gb/reports/2022/ukraine/impact.aspx

5 Garbino, Henrique, "Ukraine's Newly Adapted Mine Action Law: What Does this Mean for HMA Programs?" *The Journal of Conventional Weapons Destruction*, https://commons.lib.jmu.edu/cisr-journal/vol23/iss1/7/

6 ibid

responding to increased contamination in the wake of the Russian invasion.

Contamination and Survey

Following the Russian invasion of Ukraine on 24 February 2022, Andro Mathewson in his July 2022 article "Open-Source Research and Mapping: Explosive Ordnance Contamination in Ukraine," notes "the scale of EO contamination in Ukraine has reached unprecedented levels ..."[7] The Mine Action Review also notes that the full extent of mine contamination is unknown, but reports indicate explosive ordnance (EO) contamination including anti-personnel mines, anti-tank mines, improvised mines, and cluster munitions.[8,9]

In their 2017 article, "21st Century Survey in Eastern Ukraine and the Use of Technology in Insecure Environments," authors Nick Torbet and Patrick Thompson (HALO) identify how mobile technology can be harnessed for survey in areas experiencing conflict and where humanitarian access is restricted. Following the 2014 conflict, HALO's ability to conduct non-technical surveys in certain areas of Ukraine was restricted due to security concerns and ongoing conflict. As a result, HALO's use of mobile technologies enabled a systematic assessment of the region, facilitating the ability to conduct non-technical surveys once the situation improved. The article illustrates "how tablets, applications, and geographic information systems can enhance the capacity of humanitarian organizations to identify hazardous areas in insecure environments."[10] The authors note how four layers of information gathering can inform future non-technical survey: remote mapping, rapid assessment, hazard points, and preliminary survey reports.

Years later, in 2022, Andro Mathewson (HALO) documents how the Russian invasion of Ukraine had become "'the first open-source war," where almost every aspect of the conflict on the ground has an online counterpart—from logistics and guidance systems to humanitarian aid delivery and conflict mapping."[11] Open-source research is the collection of information, largely online but also through verbal and written confirmation. Mathewson summarizes HALO's use of various platforms including Twitter, Telegram, Facebook, Reddit, YouTube, as well as local Ukrainian news and media outlets, and lastly, publicly available databases.

For the conflict in Ukraine, which is the "most active conflict on social media of all time,"[12] having access to this timely information enables organizations to prioritize regions with the highest levels of contamination and to map the conflict's effects. This in turn enables organizations to better plan for and conduct future operations, including explosive ordnance risk education (EORE). Despite its clear advantages, especially in active conflict zones, Mathewson cautions that open-source research does have its limitations and should be used in conjunction with existing humanitarian mine clearance practices.[13]

Explosive Ordnance Risk Education

Considering the tremendous contamination in Ukraine, EORE is and will continue to be vital to saving lives. As one of the five pillars of mine action, EORE plays a fundamental role "in long-term mine clearance and explosive ordnance disposal projects."[14] Furthermore, in their article, "Explosive Ordnance Risk Education in Ukraine During the COVID-19 Pandemic," authors Andro Mathewson and Asya Bolotova (HALO) state "one of the central elements of EORE is flexibility, which allows EORE programs to react and adapt quickly to changes in circumstances, increased conflict severity, and pandemics."[15]

7 Mathewson, Andro, "Open-Source Research and Mapping: Explosive Ordnance Contamination in Ukraine," *The Journal of Conventional Weapons Destruction*, 2022, https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/3/

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12 ibid

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14 Mathewson, Andro and Asya Bolotova, "Explosive Ordnance Risk Education in Ukraine During the Covid-19 Pandemic," *The Journal of Conventional Weapons Destruction*, 2021, https://www.jmu.edu/news/cisr/2021/09/25-1/11-251-mathewson.shtml

15 ibid

During the COVID-19 pandemic, as well as in the increasing number of conflict-affected and insecure environments mine action NGOs operate in, organizations have had to develop new and innovative ways in which to reach communities affected by explosive hazards. As discussed in "The Time Has Come for Digital Explosive Ordnance Risk Education," author Robin Toal (MAG, Mines Advisory Group) explains that "new approaches are crucial to try to reach as many people as we can, especially in challenging environments."[16]

Different methods of providing EORE in Ukraine have been discussed in *The Journal*. These include via mobile apps, through virtual educational sessions conducted over Zoom or other digital platforms, various social media platforms, and through the use of virtual reality (VR) simulation software as presented in Mathewson's and Bolotova's article. HALO implemented a VR program in Ukraine, using "real-life examples of ERW in conjunction with voiceovers giving instructional safety messages to create simulations of minefields and UXO located in building and fields." The benefits of VR include the user being "mentally, emotionally, and physically immersed in a situation, which stimulates their senses, allowing them to interact with the environment and preparing them for real-world conditions."[17]

The benefits of adapting traditional EORE approaches in Ukraine were already known prior to the 2022 conflict. As highlighted in "Saving Lives in Eastern Ukraine: Alternative EORE Approaches," author Olena Kryvova discussed the Foundation Suisse de Déminage's (Swiss Foundation for Mine Action, FSD) 2020 program to provide EORE to residents living near the government- and nongovernment-controlled areas (GCA/NGCA) of Donetsk and Luhansk Oblasts, separated by the contact line. The article discusses their two-pronged approach to reach civilians, including the use of social media to target the population that could not travel to the GCA during the pandemic. FSD found that their social media campaign was also able to reach internally displaced persons (IDPs) who had relocated to other areas of Ukraine following the 2014 conflict in the east.[18]

Additional benefits of digital EORE include that it is not affected by weather, time of day, or other force majeure situations. Digital EORE can reach large numbers of people and can be accessed in many locations, including insecure environments, and bypasses the complexity of areas currently in conflict.[19] Furthermore, while distance learning requires more planning, digital risk education sessions require little travel time and monitoring is made easier as sessions can be recorded and questions and answers addressed more quickly, notes Mathewson and Bolotova.[20]

Several Journal authors identified lessons learned when developing and applying digital EORE to conflict-affected areas, such as Ukraine. When developing a new digital platform, Kryvova found that "a period of at least three months should be allowed to develop a regular audience, conduct the needs assessment, and design the most suitable way of interacting with the audience."[21] All authors mentioned in this section noted the importance of continually updating digital EORE content to maintain viewers' interest and to prevent complacency amongst a population. Additionally, as social media is a congested and competitive environment, digital EORE must be tailored to the audience it is meant to reach. As noted by Toal, "animated ads worked best with young people while live action videos were popular in all contexts where they were published."[22]

16 Toal, Robin, "The Time Has Come for Digital Explosive Ordnance Risk Education," *The Journal of Conventional Weapons Destruction*, 2022, https://www.jmu.edu/news/cisr/2022/10/261-2/11-261-toal.shtml

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22 Toal, Robin, "The Time Has Come for Digital Explosive Ordnance Risk Education," *The Journal of Conventional Weapons Destruction*, 2022, https://www.jmu.edu/news/cisr/2022/10/261-2/11-261-toal.shtml

Finally, Journal authors agree that a hybrid approach to digital EORE is best—utilizing both online and in-person risk education sessions. As stated by Kryvova, "current EORE-sector thinking is that digital EORE campaigns seem to be most effective when complementing, not replacing, other EORE activities at an interpersonal or face-to-face level."[23]

As reported by the United Nations Commissioner for Refugees (UNHCR), as of 24 February 2023, 8.1 million people have been displaced from Ukraine into Europe, which equates to roughly twenty percent of the population. A recorded 19.3 million people have left Ukraine while 10.8 million people have since returned to the country.[24] These figures along with the significant EO contamination affecting Ukraine, makes EORE a vital component of current and future mine action operations in Ukraine.

Victim Assistance

The NGO European Disability Forum estimates there to be at least 2.7 million disabled people living in Ukraine.[25] As noted by a *Times* article published in April 2022, many disabled Ukrainians are "at greater risk of abandonment, violence, and discrimination within their own communities" due to the stigma that continues to surround disability in the country, leading to "a humanitarian crisis within a crisis" according to the chair of the International Disability Alliance.[26] "In a 2020 report on disability rights in Ukraine, the pan-European human rights NGO Council of Europe found that disabled people are often excluded from Ukrainian society because of negative stereotypes, legal and workplace discrimination, and high levels of institutionalization. The war has exacerbated these issues …"[27]

23 Kryvova, Olena, "Saving Lives in Eastern Ukraine: Alternative EORE Approaches," *The Journal of Conventional Weapons* Destruction, 2021, https://commons.lib.jmu.edu/cisr-journal/vol25/iss1/10/

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25 "Ukraine: 2.7 Million People with Disabilities at Risk UN Committee Warns," UNHCR, 14 April 2022, https://www.ohchr.org/en/statements/2022/04/ukraine-27-million-people-disabilities-risk-un-committee-warns

26 "The Informal International Network Getting Disabled Ukrainians Out of the War Zone," *Time*, 31 March 2022, https://time.com/6161800/disabled-refugees-ukraine/

27 ibid

In the December 2020 Journal article, "Assessing Ukraine's Victim Assistance Capacities," authors Kateryna Mashchenko, Tetiana Shymanchuk, Oleh Stoiev, and Nick Vovk (Danish Refugee Council-Danish Demining Group, DRC-DDG) published an article detailing their findings from the in-depth report, "Mine Victim Assistance Needs in Ukraine," (UNICEF, DRC-DDG), identifying the situations of child EO survivors and their families in eastern Ukraine.[28]

Using various international policies and guidelines, the report identified gaps in six key areas in Ukrainian victim assistance capacities:

Laws and policies: Although the Mine Action Law adopted in 2018 provides services for EO survivors—including rights to medical, psychological, professional, and social assistance—the authors highlight challenges in the Ukrainian legal framework that hamper its implementation. At the time of the report's publication, there was no system or protocol in place for the provision of victim assistance at the state level. Furthermore, certain gaps, such as the lack of data collection, undermine Ukraine's VA capabilities.

Data collection: At the time of the report, there was no systematic data collection of EO victims in Ukraine, nor is it mentioned in the Mine Action Law. This further impedes identifying EO survivors, assessing their needs, and prevents aid from reaching those who need it.

Emergency and medical care: While emergency care to EO survivors is provided at the local level, long-term medical care is severely lacking, affected by the shortage of specialists and equipment, which further leads to errors in treatment. Furthermore, "the biggest deficiencies have been identified in rural areas due to the long distances that need to be traveled…"[29]

28 Maschenko, Kateryna, Tetiana Shymanchuk, Oleh Stoiev, and Nick Vovk, "Assessing Ukraine's Victim Assistance Capacities," *The Journal of Conventional Weapons Destruction*," 2020, https://commons.lib.jmu.edu/cisr-journal/vol24/iss2/13/

29 ibid

Rehabilitation: The authors identified numerous gaps in the provision of rehabilitation care to EO survivors, citing that "no interviewed EO victim has availed the full cycle of prostheses: preparation, adjustments, maintenance, and replacement … as a result, prostheses provided to children are exclusively cosmetic rather than functional."[30] The authors also identified a reluctance from officials to fully inform EO survivors of their rehabilitation services due to lack of funding.

Psychological and psycho-social support: As noted by the authors: "Ukrainian child EO victims are not supported by an established system of psychological aid or qualified professionals, with distrust for such services prevalent among the population."[31] Psychological support of survivors is not seen as a priority and is made even further inaccessible due to high cost and lack of state-supported funding for psychological and social support for EO survivors.

Socioeconomic inclusion: Focusing on the gaps in educational opportunities for child EO survivors, the study found that those with more severe injuries could not attend school for six months or more due to inaccessible schools, and "teachers from conflict-affected areas still reported a lack of knowledge, skills, and information on working with children with disabilities and no relevant training on inclusion in schools. Consequently, teaching staff and administrators are sometimes not ready or unwilling to include children with disabilities in their classes."[32]

At the time of publication, the DRC-DDG and UNICEF study was the only review of national Ukrainian victim assistance capacities. This reflects what the executive summary of the report identified in 2019, citing that a key area of mine action in Ukraine that continues to be overlooked by the Ukrainian government and international donor community is victim assistance. As the invasion continues and contamination continually increases, more needs to be done now by the mine action and donor community to address long-term and sustainable victim assistance in Ukraine.

30 ibid
31 ibid
32 ibid

Capacity Building, Sustainable Development

Capacity building and sustainable development are crucial for ensuring the lasting safety, security, and socio-economic progress of communities affected by conflict. The presence of landmines and ERW in Ukraine poses a constant threat to civilian life, infrastructure, and the country's economy.

The development of Ukraine's mine action sector and its approach to landmine clearance is ongoing, and the sector is confronting the reality of extensive contamination resulting from the Russia-Ukraine war. To establish a multifaceted, sustainable, and independent mine action sector that can effectively address current and future challenges, capacity building is essential. In their article "Developing National Landmine Clearance Capacity in Ukraine," Tobias Hewitt and Ronan Shenhav explore HALO's involvement with helping Ukraine strengthen its mine action practices and procedures with the goal of ensuring that both can stand the test of time and future contamination clearance.[33]

Following the 2014 conflict, HALO conducted non-technical surveys, trained deminers, and worked to build its capacity for future clearance operations. Through the process of training deminers in Ukraine, HALO gained a better understanding of "how to overcome obstacles and improve operational efficiency," garnering invaluable knowledge for the future of Ukraine's clearance teams.[34] Additionally, the authors addressed sustainability in training programs and future operations in mine action clearance in Ukraine, proposing that "in order to deal with the scale and nature of the mine contamination in Ukraine, future national mine clearance training will need to focus on a set of approaches that address all operational challenges in the country." Lastly, the authors stress that capacity development efforts will need to be coordinated with other actors in the sector, and that "increased experience with conducting humanitarian clearance that goes beyond reactive, targeted EOD [explosive ordnance disposal] spot tasks will lead to an increased national capacity that is capable of independently addressing challenges and obstacles in Ukraine."[35]

33 Hewitt, Tobias and Ronan Shenhav, "Developing National Landmine Clearance Capacity in Ukraine," *The Journal of Conventional Weapons Destruction*, 2021, https://commons.lib.jmu.edu/cisr-journal/vol25/iss1/9/
34 Ibid.
35 Ibid.

A year later in 2022, authors Linsey Cottrell (Conflict and Environment Observatory), Eoghan Darbyshire (Conflict and Environment Observatory), and Kristin Holme Obrestad (NPA) address the impact of contamination on Ukraine's environment, stressing the impact that explosive weapons have on civilian and industrial infrastructure.[36] In their article, "Explosive Weapons Use and the Environmental Consequences: Mapping Environmental Incidents in Ukraine," the authors underscore the impact of contamination on civilian life, as well as deminers in conflict-affected areas, and how monitoring the conflict pollution, which "describes the contamination caused by the direct damage to infrastructure," will play a critical role in remediation and sustainable clearance operations for years to come. Given Ukraine's "extensive and diverse industrialized economy, including heavy manufacturing and nuclear facilities," those who live in the country are at an increased risk of exposure to landmines, as well as air, soil, and water pollution. Collaborative support among all actors in mine clearance operations is the only way that land will safely and sustainably be returned to its people, the authors suggest.[37]

A push for capacity building and sustainable development in Ukraine is critical as the war presses on, depositing more hazardous materials and explosive contamination. However, the challenges of contamination caused by the war in Ukraine and the impact on the environment require ongoing collaboration and innovation among all actors in the sector to ensure lasting remediation and clearance efforts. The development of sustainable methodologies and ongoing capacity-building efforts will play a key role in Ukraine's progress toward a safer, more secure future.

36 Cottrell, Linsey, Eoghan Darbyshire, and Kristin Holme Obrestad, "Explosive Weapons Use and the Environmental Consequences: Mapping Environmental Incidents in Ukraine," *The Journal of Conventional Weapons Destruction*, 2022, https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/4/

37 Ibid.

Conclusion

Based on his visit to Ukraine in April 2022, Sean Sutton (MAG) published a photo essay in the Fall 2022 issue of *The Journal*, documenting the reality of life in Ukraine shortly after the February 2022 invasion began. Sutton's images reflect on the people he met and are poignant reminders of the humanitarian aspect and the utter devastation of war, and captures the personal stories of civilians living in Lviv as families fled on trains; Andriivka, which was occupied by Russian forces for thirty-five days and for which its citizens walk past unexploded projectiles on a daily basis; mass grave sites and contaminated mine fields in Irpin; and destroyed buildings resulting from sustained bombardments in Bodoryanka and Kyiv Oblasts. At the end of his photo essay, Sutton reflects on his experience, "Just days after the Russian troops had been pushed out, villages were being cleared by groups of volunteers traveling amidst the devastation. This is but a brief snapshot of what I saw and offers only a glimpse of the enormity of the work that the mine action sector will face in the years to come,"[38] something Greg Crowther (MAG) reflects on in his editorial "Ukraine: Coordinating the Response" in *The Journal's* 2022 summer edition.[39]

In an editorial published four months after the February 2022 invasion, Crowther looks at the road ahead for the mine action sector in Ukraine. Crowther notes the scale and nature of the conflict in Ukraine poses immense challenges for the current and future mine action response, one that cannot be delivered in isolation but must be coordinated by donors, UN agencies, national actors, civil society groups, as well as experienced mine action operators.

38 Sutton, Sean, "Ukraine: Through the Eyes of the People," *The Journal of Conventional Weapons Destruction*, 2022, https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/2/

39 Crowther, Greg, "Ukraine: Coordinating the Response," *The Journal of Conventional Weapons Destruction*, https://commons.lib.jmu.edu/cisr-journal/vol25/iss3/3/

Crowther discusses the most urgent responses—emergency risk education and tracking of reported explosive impacts is already underway—but asks if the mine action sector and international donor community is prepared for the sustained and long-term response required by Ukraine? In looking at challenges and lessons learned from previous conflicts, Crowther discusses the long-term effects of the second Gulf War in Iraq, noting that as "fresh conflict dominates the international consciousness, even support to the more recent crisis is beginning to dissipate."[40]

As the mine action sector looks forward, Crowther insists that the "lessons learned from Iraq and from other major conflicts in places like Syria, Myanmar, and South Sudan must be learned in Ukraine: the international donor community, working in partnership, has to put in the right mechanisms for an effective mine action response."[41]

The Journal, 23.1, Spring 2019.
Image courtesy of CISR.

The Journal, Issue 26.1, Fall 2022.
Image courtesy of CISR.

40 ibid
41 ibid

WITHIN

R&D AND NEW TECHNOLOGIES MINE ACTION

YOLO – deep learning model for UXO detection in thermal video

Milan Bajić jr.[1]

ABSTRACT

Deep learning is widespread and thoroughly researched in autonomous vehicles, face recognition, and other similar domains. It is rare in land mine (LM) clearance and other explosive objects clearance domains in the non-military application. This text presents follow thru of previous research using the YOLO algorithm for UXO detection in thermal images by applying it to near real-time detection of annotated explosive objects in a thermal video sequence. The research was conducted on UXOTi_NPA dataset with 11 different explosive targets and original thermal video of very high ground sampling distance taken from an altitude of 3m. YOLO is a fast and accurate model that can achieve detections in more than 40 frames per second (FPS) thus giving viable solutions for 25FPS or 30 FPS thermal videos. Up to date, no automated solutions exist for surface UXO detection by using thermal video that enables large area survey and this research will be a step in that direction.

Introduction

Thermal imaging is a non-contact approach that translates the radiation pattern of an object into a visual representation, referred to as a thermal image or thermogram. Everything above absolute zero temperature emits infrared radiation, which can be detected by Thermal Infrared (TIR) remote sensors deployed on air and space-borne platforms [1]. These sensors do not require an external source of infrared radiation, making them appropriate for field applications.

Explosive remnants of war have been a constant presence since World War I, with landmines contaminating 64 countries [2]. While some countries maintain databases of explosive devices [3], others are still in the process of developing such information. Removing these mines is a slow and arduous process, taking around 100 times longer to clear each mine than to plant it. These remnants are typically well-known by their physical dimensions, weight, type of fuse, and cover material.

There are various deep learning algorithms that perform very precise object detection in images or videos. Some of them lean more towards speed measured in frames per second for inference, others are more precise, and precision is measured in values mAP@0.5, and stricter are those of mAP@0.5-0.95. For real-time or near real-time detection algorithm should have a speed of at least 30 frames per second with acceptable precision, more information and an in-depth comparison of speed and model performance can be found in [4]. Another parameter very important for edge device applications is model size as this can help evaluate needed resources.

The most widespread edge computing device is Raspberry Pi even though it has very limited capabilities, it is used for very specific tasks as it uses little energy. More powerful with a complete software ecosystem for the development of applications is NVIDIA Jetson [5], small enough for placement on UAV but fast and energy efficient up to autonomous vehicle complexity, which includes parallel multiple sensor data processing, with as many as 7-8 video cameras, LIDAR, time of flight devices and thermal imaging cameras. Video considered in this text and computer sciences is treated as a sequence of images with frame rates from 25 up to a few hundred frames per second. The thermal video used in this work has a resolution of 720x480 pixels and 30 FPS, it is grayscale and was taken at 3m high, so it has a very small ground sampling distance with a pixel size of less than 1cm. The video is about 30 seconds long; in every image, there is at least one UXO or landmine. There are 11 different types of objects of variable size smallest is a hand grenade and the largest one is an 82mm mortar mine. The least number of occurrences is of PMA 3 in 79 frames and in 161 frames occurs tromblone mine TTM RP and fuse of 125mm mortar mine.

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Materials and methods

The video used in this work was provided to the author by Norwegian Peoples Aid and was used in previous work by Bajić jr. and Potočnik [6] where YOLOv5 was researched as a possible detector and publicly available UXOTi_NPA dataset was created and the paper at ROSUS conference in March 2023 [7] where results were complemented with YOLOv7 at that time most recent version on this one pass object detection algorithm. As the precision and speed achieved by these two algorithms were satisfying in this work it will be compared inference time for both of those algorithms in YOLOv5 five models of various complexity and YOLOv7 two models previously trained and tested. Training of these models was made on previously pretrained models on COCO dataset which is one of the benchmarking models often used for comparison by using these model checkpoints and is a way to go according to [8]. This saved time used for retraining but also helped achieve higher precision on a custom dataset. All the training and inference were done on the Google Colab platform where one can buy resources on demand and for a relatively small amount can tap into very complex computing power for a limited time. In Table 1. results are given when all the objects are treated as one class. In this case, the model is a little bit smaller, and detection is faster but, in most situations, gives enough information that a threat is present and which area should be checked. The model size is defined as the number of free parameters in Millions and Inference time is given for the whole video sequence, of 917frames (approximately 30 seconds), precision was not given as it is already available for all mentioned models in [7] and is for smallest models YOLOv5n (mAP@0.5-0.95) 87.9% and YOLOv7tiny (mAP@0.5-0.95) 86.8%.

Table 1. Inference time of seven YOLO models

Model	Model Size	Inference time (s)
YOLOv5n	1,8	8,253
YOLOv5s	7,1	8,345
YOLOv5m	21,1	11,921
YOLOv5l	46,4	19,074
YOLOv5xl	86,6	36,863
YOLOv7tiny	6,1	17,438
YOLOv7	36,8	22,730

The results of the inference are video sequences with a number of class, in this case, it is always 1, and the probability of detection that varies from frame to frame.

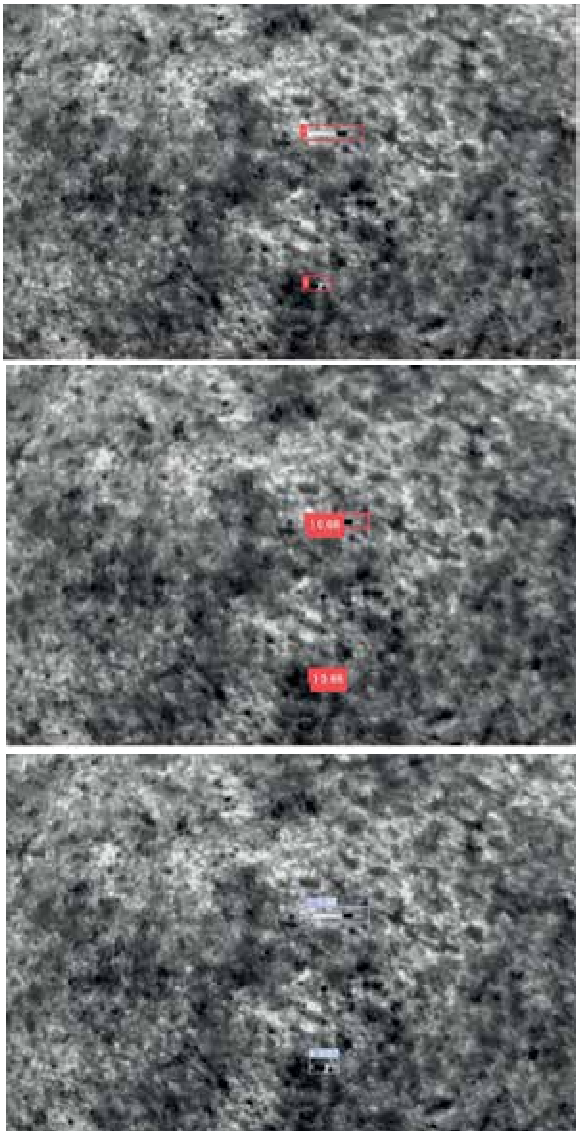

Figure 1. The qualitative results of one class problem: The thermal image at the top was annotated by experts, while the bounding boxes in the middle and bottom show the UXOs detected using YOLOv5n and YOLOv7 tiny. Each bounding box is accompanied by a single class index of 1 and the corresponding detection probability.

Discussion

This study aimed to detect Unexploded Ordnances (UXOs) using state-of-the-art Deep Learning and Convolutional Neural Network approaches applied to thermal video materials. UXO detection is crucial for neutralizing explosive remnants of war, and our automated solution allows terrain examination from the air (e.g., by using Unmanned Aerial Vehicles) to identify potentially dangerous areas in advance.

One of the innovative aspects of the study is the utilization of thermal video for UXO detection. Thermal imaging provides valuable information about the environment and its changes that are not detectable in the visible spectrum. Different materials, including UXOs, leave unique thermal signatures in the image, making it possible to identify them accurately. It is compared the performance of YOLOv7 with that of YOLOv5 on the NPA thermal video sequence. YOLOv5 is an established architecture thoroughly tested on various datasets, while YOLOv7 is a newer model still in the development phase. Based on standardized metrics mAP@0.5-0.95 and inference time, we found that YOLOv5 has a better trade-off between model size and detection effectiveness than YOLOv7. This conclusion is mainly due to the higher number of false positive detections by YOLOv7. It can be noted that YOLOv7 requires more processing time and resources than YOLOv5, and this increase was not justified by the results, possibly due to the small UXOTi_NPA dataset on which models were trained. A similar discussion on this topic can also be found in [9]. In this study, it is demonstrated that the combination of deep Convolutional Neural Networks and thermal imaging can effectively detect UXOs in a real environment. Based on the inference time and complexity of the model given in Table 1. the same conclusions can be made as YOLOv5s is bigger than YOLOv7tiny and has an inference time of just 8.345s which is just half of the inference time of the smaller model. Instead of a conclusion Figure 2. is given in which one can see why thermal imaging could be a better solution for a survey of a large suspect area.

Figure 2. The image shows a land mine with a green metal casing placed on green grass. The top image represents the terrain as seen in the visible spectrum, while the bottom image shows the same terrain in the thermal spectrum.

Models of smaller size, YOLOv5n, YOLOv5s, and YOLOv5m should be considered as a solution for near real-time object detection in a thermal video sequence as their inference time is less than half of sequence length and when applied on the edge computing device that can perform well on UAV [5] it is possible to have results on the screen during a flight. These optimistic results presented here have limitations as the UXOTi_NPA dataset is very small, it was created on limited objects and from a very low altitude of 3m. Higher altitudes would mean a possibility for larger areas to survey but at the same time would lead to another set of questions because of smaller target sizes. The future direction of this research is an expansion of the UXOTi_NPA dataset with various altitudes, times of day, and terrains.

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Test and evaluation of a UAV mounted 3D Ground Penetrating Radar system for mine detection

Ståle Fjeldstad[1], Evgeniya Shelavina[1], Jacopo Sala[1], Milan Bajić[2]

Abstract: 3D Ground Penetrating Radar (3D GPR) systems uses electromagnetic waves to generate 3 dimensional volumetric images of the subsurface, for object detection and identification. A 3D GPR based object detection system has the potential to detect both low and non-metallic buried objects and has the capability to generate volumetric images unveiling the shape of the object.

Kontur has developed a UAV deployed 3D GPR system based on a heavy lift drone platform and an ultra-wideband 3D GPR system for high-resolution synthetic aperture imaging of the subsurface. The system has been evaluated in collaboration with HCR-CTRO, based on field testing at the Benkovac outdoor tes t facility in May 2022.

The paper describes the test setup together with data acquisition, processing and interpretation. It further addresses some challenges and method limitations related to the execution of the survey, local conditions and different types of landmines. The detection results were analyzed in collaboration with HCR-CTRO. The evaluation shows that the Kontur 3D GPR system detected 80% of the AT mines, while improvements in positioning and lateral resolution is required for imaging of AP types of mines.

Based on this initial test, potential improvements and future developments are discussed.

Introduction

Kontur AS has developed a 3D GPR system that is possible to mount on a UAV, Figure 1. Despite of the smaller size it has all the capabilities of an industrial muti-channel GPR system. The usage of UAV is well suited for demining as it eliminates danger for its operator. A full-scale trial has been performed at the Benkovac outdoor test facility, which is a complex case for GPR performance evaluation due to variable soil properties and local terrain variations. The ground surface is rough and uneven and the presence of irregularities such as stones and vegetation, makes this a challenging GPR test environment.

Figure 1:UAV 3D GPR system from Kontur during operation

The Benkovac test facility includes a public area with only anti-personnel mines (AP) and confidential area with both anti-personnel and anti-tank mines (AT). Kontur AS has performed a blind test in the confidential area without prior knowledge of the target location. The data collection covered 38 lines, each 44 m long with over 600 mines buried beneath the ground.

System description

The Benkovac test and evaluation study utilized a lightweight version of the Kontur Air GPR system, an air-launched antenna array that is designed for high-speed three-dimensional subsurface assessment. Data collection was done with a DX1617 GPR array, 160cm wide, 17 channels, 75mm channel spacing. Effective scan width 98cm. Operational bandwidth 30MHz to 3000MHz. Total system weight 19kg.

The UAV used for the test was a custom-built multirotor drone developed in collaboration with Nordic Unmanned, Norway. The size of the UAV is 220cm between motor centers, 300cm including propellers. Total weight exclusive payload 25kg. Total battery capacity 2000Wh. UAV has dual RTK GNSS receivers, redundant inertial

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measurement units (IMU) with separate compass for improved heading accuracy. To ensure stable low-altitude flight the UAV was equipped with a laser distance sensor.

Survey setup and execution

A command-and-control ground station was set up with a redundant telemetry link controlling the UAV and GPR sensor. A high-end GNSS receiver was used as the local GNSS base station ensuring millimeter RTK GNSS precision. High resolution areal image map with multiple ground reference points was generated for the mission planning and data analysis phase.

A GPS guided flight pattern was defined by the start/stop position for each of the test lanes, together with flight height and speed. Flight height was set to 100cm from the ground to the bottom of the antenna, speed 1m/s. To ensure a safe distance from the fence the first and last meter of each test lane was excluded from the survey. The last lane, lane number 47, was also excluded from the survey due to the proximity to the fence.

The GPR system was configured to have a trigger rate of 50 triggers per second, giving a lateral resolution of 20mm in the direction of flight.

The total flight time per battery change was around 15 minutes, 5 minutes shorter than initial tests. The main reason for the shorter flight time was the high ambient temperature affecting the battery performance.

Results and discussion

Raw GPR data can be affected by noise, interference, and scattering due to heterogeneities and artefacts caused by proximity to metal objects (e.g. fence). Post processing of the GPR data helps to reduce these issues. Kontur AS uses Examiner™ software that provides a three-dimensional georeferenced view of the GPR data together with processing and interpretation. It also allows to annotate specific features linked to the buried objects.

Figure 2 shows the georeferenced view for 5 adjacent lanes in the confidential section. GPR data is visualized at a depth of 9cm. As illustrated in the overview, potential targets can be observed as circular patterns. The overview shows a minor deviation between the straight line of the lane and the flight path, an anomaly caused by varying wind conditions.

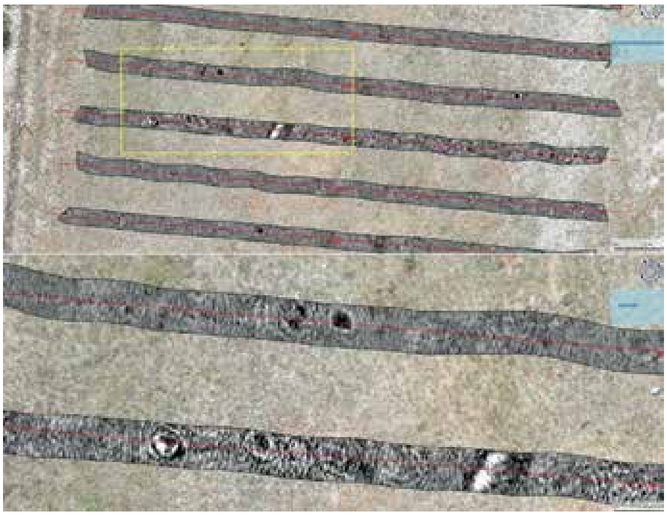

Figure 2: View from Examiner showing GPR data from multiple lines (top). Zoomed in region showing selected targets (bottom)

Objects are expected to create a hyperbolic reflection in the GPR data that looks like a circle in the horizontal plane (Figure 3 and Figure 4). Over 200 such features of various strengths have been identified and reported back to HCR-CTRO. According to their comparison with ground truth information the method works well on the anti-tank (AT) mines (Figure 3) with 80% of probability of detection (POD). The mines could be detected up to depths more than 20 cm. Anti-personnel (AP) mines located above the ground and hidden in the high grass can also be easily detected including tripwire (Figure 4).

Initial experiments indicated that AP mines can be imaged and detected under ideal conditions (dry sand). Results from the Benkovac evaluation indicated limited detection capabilities for AP mines, where further work is required to improve lateral resolution and position accuracy. The dynamic behavior of the UAV (e.g. tilt, yaw and pitch), also causes a small-target blurring effect making it difficult isolate the smaller targets in the GPR data.

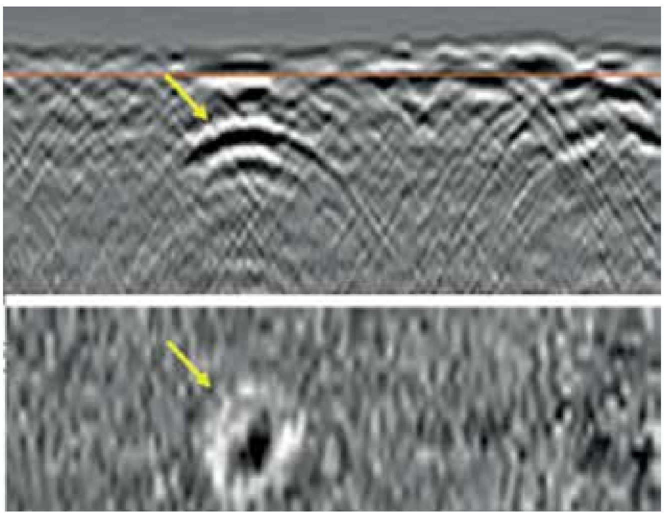

Figure 3: GPR response for a TMA-1A mine (315 mm diameter, 18 cm depth). Vertical cross-section (B scan) above, and horizontal view (C scan below). Yellow arrows indicate the position of TMA-1A mine.

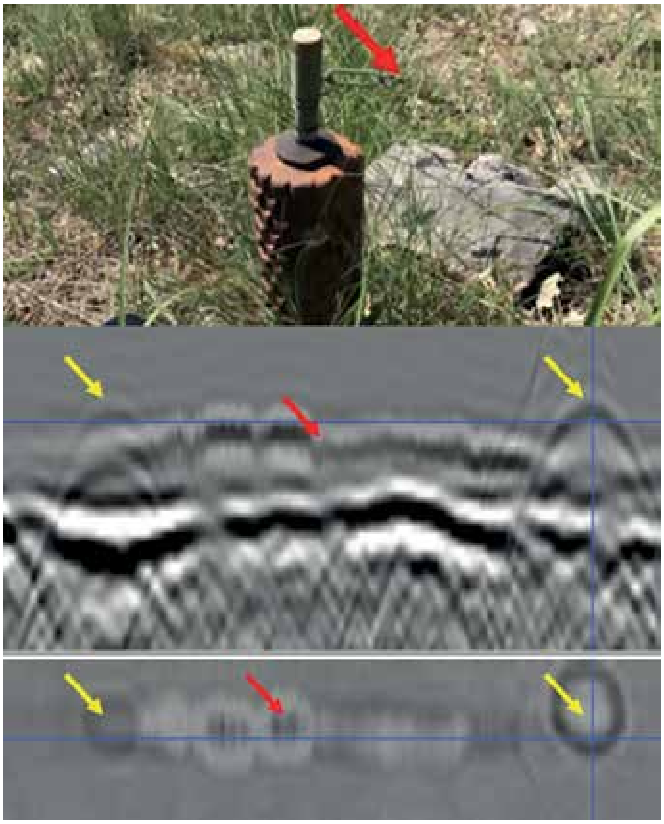

Figure 4: PRM-2AS mine with tripwire above with corresponding GPR response below. Yellow arrows indicate mine, red arrows tripwire.

Conclusion and way forward

The main conclusion from the Benkovac test and evaluation survey is that the Kontur UAV deployed 3D GPR systems is a viable alternative for detection of anti-tank mines. Study demonstrates that heavy-lift UAV platforms can be used as instrument platforms for low-altitude near surface surveying. For the Kontur air-coupled 3D GPR systems the height above ground has limited impact on the quality of the data, and it is no noticeable difference in the detection capability when the antenna is operated at 70cm or 100cm.

Although heavy-lift drone platforms now are becoming widely available, operations of heavy-lift drones still impose significant operational risk and complexity. The UAV uses large Lithium Polymer batteries which are inherently flammable and sensitive to high temperatures and has a limited lifespan between 300 and 500 charge cycles. A heavy-lift drone can cause life threatening or serious injuries and requires high alertness and dedicated safety personnel to be present during operations.

Kontur will continue the development of the UAV GPR system with a focus on enhanced operational efficiency and small-target detection capabilities. A new UAV GPR system will be released with improved vertical and lateral resolution, integrating the dynamics of the UAV to refine the positioning of the GPR data during post-processing.

Multi-agent system and AI for Explosive Ordnance Disposal

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Abstract—**Artificial Intelligence for the detection of explosive devices (AIDED) is a European project aiming to research and integrate cutting-edge technologies to; i) Identify both unconventional and conventional explosive devices, such as buried mines and IEDs; ii) Plan missions both offline and in real-time. To achieve this, the system uses AI-machine learning techniques, including deep learning, to train on simulated and real datasets from various sensors such as Ground Penetrating Radar (GPR), Electromagnetic Arrays, infraredand thermal cameras, and Laser Induced Breakdown Spectroscopy (LIBS). The project has developed customdeep learning models for each different sensor workingon its own type of input, whilst facing challenges, such as imbalanced data and a limited number of samples for training. Data fusion strategies have also been explored with the aim of improving the detection and classification of EOs compared to their individual baselines,namely by mitigating the number of false positives and outliers, and ensuring adaptability to different environments. Additionally, AIDED proposes a cooperationstrategy between centralized and decentralized missionplanning algorithms, which have been developed basedon different AI architectures. This strategy aims toprovide a conflict-free distribution of tasks among the agents, along with optimal path planning. The Multi- Robot System (MRS) of AIDED is composed of two UGVs of different sizes and a single UAV to detectExplosive Ordnance (EO) that are visible, buried, or hidden. The system also uses AI-machine learning techniques for positioning, navigation, and mapping to achieve robustness and independent operation, even in GNSS-denied environments.**

Introduction

In recent conflicts like those in Ukraine, Afghanistan, Iraq, and Syria, the use of Explosive Ordnance (EO) like Improvised Explosive Devices (IEDs) and landmines has become more prevalent, leading to increased casualties among EU and NATO member and partner states. IEDs alone account for around half of all soldier deaths in action. To addressthis issue, the European Defense Agency (EDA) has funded a consortium to work on the AIDED project, which seeks to develop AI systems aiming at the detection and classification of explosive devices by means of heterogeneous robotic platforms (UAVsand UGVs).

Multi-agent systems have the potential to increase the efficiency and effectiveness of IED detectionoperations, as they can cover a larger area and share information to make more informed decisions. Furthermore, using robots can reduce the risk of harm to human operators, as robots can be remotely operated or even work autonomously. The use of multi-agent systems for demining has already been assessed on a previous NATO project [1].

The methods and technologies applied in demining had to adapt to the evolution of the mines used in conflicts. While the use of a metal detector alone was effective for the detection of traditional industrial mines, plastic mines and IEDs that contain no orlow levels of metal made it insufficient. This is why the most recent applications have proposed to couplethe use of the metal detector with a Ground Penetrating Radar (GPR) [2]. This not only allows the detection of non-metallic objects, but also reduces the number of false detections [3] by differentiating any metallic object from a potential IED. The use of Laser Induced Breakdown Spectroscopy (LIBS) has also proven its efficiency to detect EOD [4] [5].

The AIDED system demonstrates the potential of multi-agent robot systems for IED detection and provides insights into the challenges and opportunities of using robotics for counter-IED operations. Furthermore,

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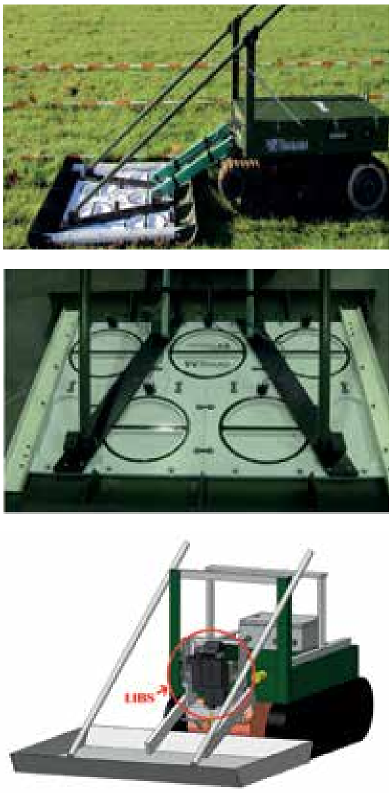
it explores the development of artificial intelligence (AI) solutions based on advanced machine learning (ML) techniques, such as deep learning (DL), able to detect and classify explosive devices in a meaningful deployment scenario. The targeted AI-based detectors are tailored to use a mix of sensors comprised of electromagnetic induction (EMI) arrays, GPRs, and LIBS sensors. The project targets the development of state-of-the-art detection models for each modality, but also the potential for multimodal data fusion and its effect on the performance of autonomous explosive detection.

Systems and architecture

A. Platforms

The Large Unmanned Ground Vehicle (LUGV) used in the project is a tEODor (telerob Explosive Ordnance Disposal and observation robot), designed by the company Telerob. The robot has been modified by the researchers of RMA [6] to use the middleware ROS [7] and be more modular than the original robot. In addition, different sensors needed for localization and navigation have been added to make the robot autonomous. The purpose of the LUGV is to embed all the sensors used in the project for EOD detection in order to provide the most accurate and reliable detection possible while limiting false positives by fusing all sensors with an AI.

Fig. 1:



a) LUGV

b) EMI sensor integrated on the LUGV

c) 3D model on LIBS integration on the LUGV

Fig. 2:
a) SUGV with sensors
b) EMI sensor integrated on the SUGV

A Small Unmanned Ground Vehicle (SUGV) is exploited for fast recognition and maneuverability. Despite the size, the robot needs to be able to carrya considerable amount of sensors to perform all the activities expected in the project. For this reason, a Husky A200™ model from Clearpath Robotics, shown in Figure 2, was ultimately chosen. The SUGV is equipped with an electromagnetic induction (EMI) sensor manufactured by the same company ofthe LUGV's array, Vallon. Considering the reduced dimensions, the choice of the sensor fell on a single coil of 25 cm of diameter, the VS25, shown in Figure 2. This choice seemed to be the best tradeoff between dimensions and detection capabilities.
A smaller coil has a better sensitivity to smaller metallic pieces, such as cables, allowing to extend the global range of detection to different objects. In particular the VS25 is coupled with the fourth-generation metal detector VMC4 as seen in Figure 2. The design is optimized for both use in urban environment as for dense vegetation, with a sensitivity ideal for all types of soils and shallow water.

The UAV for AIDED, shown in Figure 3, contains perception and navigation systems for a fixed height scan of the terrain using a RadSys Zond GPR. The UAV also has onboard processing similar to the UGVs such as the Zed stereo camera, IMUs, GNSS and a radar altimeter, as well as a thermal camerathat is used to detect temperature variations caused by the presence of IEDs.

Fig. 3: UAV with GPR.

B. Control Center and Offline Planner

The Supervisory Control Center (SCC) is a technological ecosystem with the objective to connecta Mission Control Team (MCT) to a group of Unmanned Vehicles (UxVs) active in a distant location.In our case, this toolchain will allow to connect multiple UxVs like drones and ground robots. The Mission Control Team will be able to perform supervision tasks, such as; Monitor the state of the UxVs (Online or Offline); Visualize and analyze all the data received from the different robots; and configuremissions with their goals.

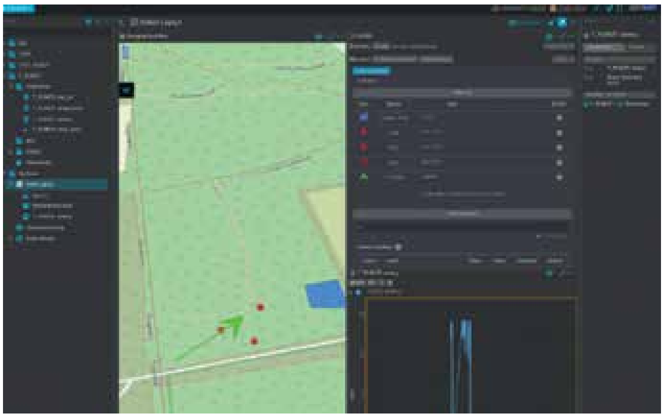


Fig. 4: SCC with telemetry, map and robot data.

A mission is composed of assets and actions to perform. To plan a mission, we need to define a problem with these assets and actions. A graphical user interface (GUI) to configure a mission is necessary to easily plan a mission. An operator can easily plan a mission with all the assets at hand. Using an offline planner provides an optimal planfor the deployment of the robots. The offline planneroptimizes the use of the robots based on time and positions of the robots. Thus, the cooperation is decided by the offline planner. The chosen approach is a tradeoff between the absolute state of the art andwell established methods for mission planning.

Explosive ordnance detection

The selection of the architectures for each sensor's AI-based EO detector is the first step in the design process. Under the same conditions to ensure fairness, each candidate produces a score, linked to the detection performance, and the best one is considered the winner. Once the architectures are selected, further experiments are exploitative in nature, with the objective of fine-tuning the base model to achieve even better scores. In the case of DL, this includes carefully adjusting the number of network layers or neurons, or in the particular case of convolutional neural networks (CNNs), for example, the size of receptive fields. Advanced ML techniques such as Bayesian optimisation [8] will be adopted for this model calibration step.

The training and validation of models are achieved with datasets collected under the scope of the project, featuring measurements of actual improvised explosive device (IED) mock-ups acquired with real sensors. Nevertheless, due to the inherent costs of such acquisitions campaigns and the nature of the data itself, the collected samples for training will be limited in number. AIDED will as such be a case study for dealing with limited resources to train a classifier when a high-stakes objective like maximising the number of detected explosives is at stake.

The problem at hand means that the available data is too valuable to sacrifice for a separate testset, as the traditional ML frameworks dictate. To work around this, AIDED employs nested crossvalidation [9] techniques, which cleverly consist in the nesting of two distinct cross-validation loops: an inner one is responsible for model hyperparameter tuning, whereas an outer one is responsible for the estimation of the generalisation error. The procedurehas been stated to provide a practically unbiasedestimate of the true error for the model. On the other hand, nested cross-validation dramatically increases the computation time relative to standard data splits. To mitigate this, the project will take advantage of City, University of London's high performance computing facility, Hyperion, consisting of 72 computing nodes, as well as three NVIDIA® Quadro RTX 800048 Gb VRAM cards.

A. GPR

GPR B-scan data can be represented as a single channel image, making the basis for the GPR-based EO detection prototypes a CNN. These are a typeof deep neural network specialised in taking input data arranged in a grid via the convolution operator. Consisting in a two-dimensional arrangement of pixels, images are an example of such grid-like input, and CNNs have had immense success in practical applications dealing with them [10]. Existing works employing CNNs for buried object detection using B-scan data [11] [12] employ similar-style architectures.

B. EMI

Metal detection has traditionally been applied to manual use of landmine clearance. In this scenario, the deminer's expertise takes on the key role in differentiating between the emitted sounds due to the presence of a landmine or metallic background clutter. As such, it is a technique marked by high false alarm rates and is often fused with GPR data rather than used as a standalone sensor. Notwithstanding, there have been research efforts towards investigating the former case coupled with ML for decision-making. The project will explore the applicability of long-short term memory (LSTM, [13]) cells to capturing the temporal correlations between EMI signals, and compare them to traditional feed- forward architectures, namely the multi-layer perceptron (MLP).

C. LIBS

LIBS for the detection and discrimination of landmines has been the target of several studies. In these, casings of a wide selection of landmines are measured using LIBS and analysed using various multivariate statistics techniques [14]. AIDED will explore the usage of small scale MLP networks, to avoid overfitting on reduced-sample LIBS datasets, coupled with feature extraction techniques such as principal component analysis (PCA) to deal with the wide spectra typically imaged by this sensor.

Mission planning

A. Distributed online planner for Multi-Robot Task allocation

The primary scenario of the project consists mainly of scanning a map of the environment within which the AIDED system will operate. The operator selects the area to be mapped, and the three robots (SUGV, LUGV and UAV) plan their motions to visitall the required places in order to scan the entirearea. The task allocation algorithm seeks to find a globally feasible assignment

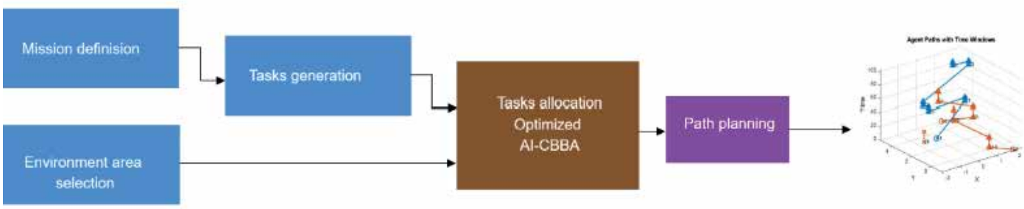


Fig. 5: Distributed online mission planner

of tasks to agents while optimizing one or more objectives. Distributed consensus-based task allocation algorithms, such as the Consensus-Based Bundle Algorithm (CBBA), can address task allocation challenges without a centralized controller, as agents participate in a two-phase cooperative planning process. CBBA is designed based on AI algorithms, enabling online adaptation and optimization according to the given scenario. The goal is to leverage the concept of learning a prediction function and adopting a strategy-switching behavior, allowing agents to independentlyadjust task allocation strategies in response to changing environmental factors and scenarios, thereby enhancing performance. The learned function serves as an effective prediction mechanism for selecting the task allocation strategy that yields the optimal global task allocation. Figure 5 shows the essential modules of the proposed algorithm.

B. Design and Prototyping of Multi Agent Position- ing, Navigation, and Mapping (PN&M)

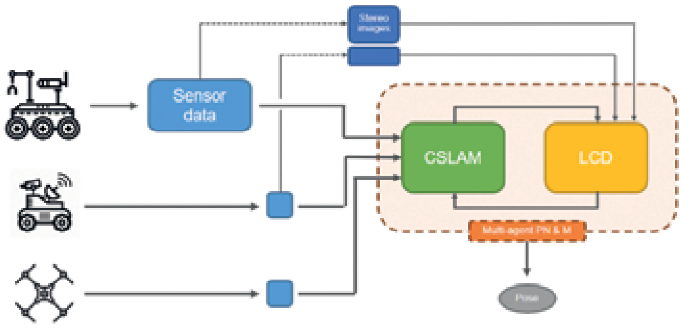


Fig. 6: Design and Prototyping of Multi-agent PN & M

During this task we designed the multi-agent PN&M architecture module which is responsible for the navigation-based cooperation of the three robotic vehicles established in AIDED: SUGV, LUGV and UAV. The architecture was divided into two sub- modules: the loop closure detection (LCD); and the optimization. The former is responsible for taking sensor and processed localization information from each of the robots to detect when one is in a location previously visited by another. Specifically, it makes use of images, which are fed to pre-trained DL- based pipelines, to yield global image descriptors and then combined with in-house developed heuristic algorithms to close loops. The latter, on the other hand, is triggered once a loop closure is detected and, based on that, is responsible for refining the poses/maps provided by the individual agents.

Conclusion

The objective of AIDED is to demonstrate thepossibilities offered by the use of heterogeneous multi-agent systems on demining activities to reduce false positive detections. If the first measurementcampaigns and the data collected have provided encouraging results, the next test activities carried out in collaboration with the Demining Group ofthe Belgian Army (DOVO) will demonstrate all the capabilities of the system.

Acknowledgement

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Humanitarian Demining Using Data Observatories and Data Lakes

Marko Horvat[1], Andrija Krtalić[2], Amila Akagić[3], Klara Krmpotić[1], Sven Skender[1]

Abstract: Humanitarian demining is an indispensable part of any post-conflict reconstruction and rehabilitation efforts, as landmines and other unexploded ordnance (UXO) continue to pose a significant threat to civilians and infrastructure. Traditional non-technical survey demining methods are typically time-consuming, labor-intensive, and require professional familiarity with a number of different complex tools and involved procedures. The emergence of the latest artificial intelligence (AI) technologies for deep learning (DL) and data analysis techniques presents an opportunity to transform humanitarian demining by significantly improving its efficiency, speed, accuracy, and safety. One such approach is the development of a data observatory that implements data ingestion pipelines into a data lake using data transformation to improve the usability of unstructured data about a mine scene. This paper addresses the key characteristics and benefits of such a system and its potential to improve humanitarian demining.

Keywords: data transformation, data observatory, big data, non-technical survey, mine scene analysis, artificial intelligence

Introduction

Humanitarian demining is an indispensable part of post-conflict reconstruction and rehabilitation efforts, as millions of landmines and unexploded ordnance (UXO) continue to pose a significant threat to civilians, infrastructure, and socio-economic development [1]. Non-technical survey is an interdisciplinary process that allows to identify, understand, and prioritize the areas where UXO pose the greatest threat and to create mine presence probability maps, thus enabling a more organized, safe, targeted and efficient approach to mine action [2]. It typically involves the collection of relevant data from a variety of sources, such as remote sensing, mine action expert knowledge, formal and informal historical records, and interviews with local residents, former combatants, and eyewitnesses [3]. As new information becomes available, or as the situation on the ground evolves, the survey findings may need to be updated and refined. This adaptive approach ensures that mine action efforts remain responsive to changing circumstances and that resources are correctly redirected. It can be said that non-technical survey provides a comprehensive understanding of the complex and multifaceted problem of landmine and explosive remnants of war (ERW) contamination and is an indispensable part of any mine action process as a crucial foundation for the subsequent phases of clearance. However, traditional approach to non-technical survey is time-consuming, labor-intensive, and requires experienced mine action domain professionals. The emergence of new artificial intelligence (AI) technologies and data analysis techniques presents an opportunity to revolutionize the overall humanitarian demining process by significantly improving its efficiency, accuracy, and speed [4]. This paper explores the potential of using a data observatory and data lake-based approach to non-technical survey for humanitarian demining, discussing the benefits and implications of such a system.

The reminder of the paper is organized as follows: The next section explains the proposal of data observatories and data lakes for the purpose of non-technical survey and humanitarian demining, including the description of the modules of such a concept. Section 3 details the data pipeline implemented as part of the proposed data observatory, including data input, management, analysis, and data sharing. Section 4 highlights the advantages of using blockchain technology in data lakes for humanitarian demining, such as immutability, transparency, and trustworthiness. Section 5 lists all benefits of developing a data observatory for humanitarian demining. Finally, the last section summarizes the proposed approach and emphasizes the potential impact of the proposed solution on improving the efficiency, speed, accessibility, and overall cost of humanitarian demining.

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Data Observatories and Data Lakes: A New Approach to Humanitarian Demining

A data observatory is an organized, centralized platform designed to collect, store, process and analyze vast amounts of data from multiple sources [5]. The underlying premise of any data observatory is to provide stakeholders with access to comprehensive, up-to-date, and actionable information that can be used to enhance decision-making processes, help in data mining and discovery of new hidden information in existing datasets, and improve overall efficiency in various domains, including humanitarian demining [6]. The data observatory ingests the collected data into a data lake. Data lakes are large-scale, scalable and centralized repositories that can accommodate vast amounts of structured and unstructured data in native formats [7]. They are particularly well-suited for storing and processing diverse data types, such as textual descriptions, document scans, satellite or drone multispectral and hyperspectral images, and geospatial information. By implementing a data ingestion pipeline into a data lake, humanitarian demining efforts can leverage this scalable, cost-effective storage solution to accommodate the ever-increasing volume and variety of data.

In the proposal outlined in this paper, within the context of non-technical survey for humanitarian demining, a data observatory would gather information from various sources, such as satellite imagery, drone footage, ground sensors, and historical records, to create a comprehensive picture of a mine-affected area. This structure not only enhances decision-making processes but also drives innovation in humanitarian demining. By combining the power of data lakes with advanced data transformation techniques, the data observatory approach significantly could improve the usability and value of unstructured data for demining operations, ultimately contributing to more efficient and effective clearance of landmines and unexploded ordnance.

Unstructured data about a Suspected Hazardous Area (SHA), such as different satellite, aerial drone images or field reports, can be challenging to process and analyze due to its inherent complexity and lack of standardization. Data transformation techniques, including natural language processing (NLP), computer vision, and machine learning (ML) algorithms, are essential for converting this raw data into a more structured and usable format [4]. In the context of non-technical survey and humanitarian demining, data transformation techniques can facilitate the extraction of valuable information from diverse data sources. For example, different computer vision and deep learning algorithms can be applied to satellite imagery to identify potential mine-contaminated areas, while computer vision object classification and NLP together can help process and analyze textual data from hand-drawn minefield records, historical records and expert reports [4]. These techniques can be employed to automatically identify and categorize essential information within the data, such as the types of landmines or UXO, their locations, and potential hazards [4].

The Mine Action Data Observatory (MADO) concept consists of four main components (as depicted in Figure 1):

1. A component for ingestion, processing, and transformation of unstructured, non-technical survey data about mine scene.
2. A knowledge base component with a formal vocabulary for describing mine scene semantics using ontologies and knowledge graphs.
3. A component with a service for automatic inference from the knowledge base, exploratory search of the knowledge base, and generation of new knowledge.
4. An image processing component for localization and classification of mine scene objects using DL models.

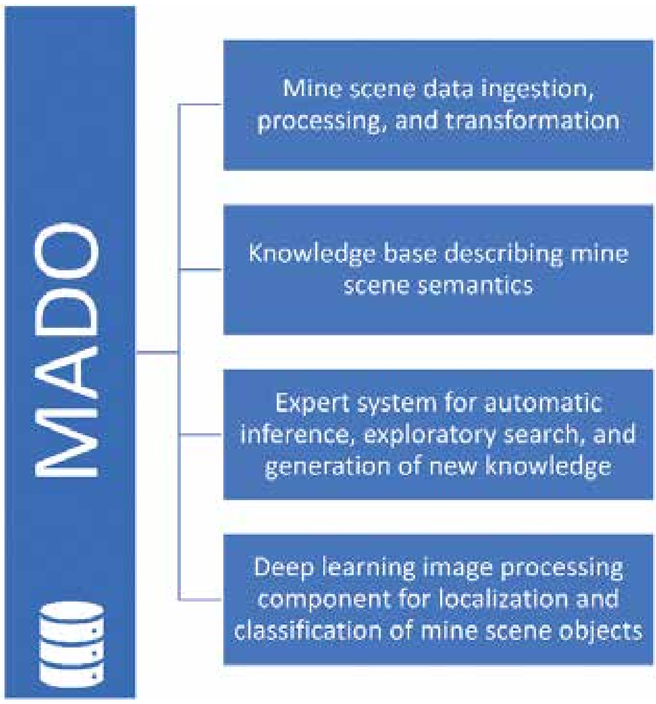

Figure 1. Four components of Mine Action Data Observatory (MADO).

The proposed data platform will leverage existing best practices in humanitarian demining and the knowledge base will include partially structured data on UXO obtained from any available sensor or through sensor fusion. Examples of such data include: Records of interviews with populations living near SHA, mine logs from completed mining or demining operations, mine accident logs, aerial and satellite imagery, scans of military maps, GIS mine explosive device data, and the results of analyzes of any other available data.

Currently, these data sources are not linked and there is no model that offers the possibility of integrated search, analysis, and discovery of new knowledge in the field of humanitarian demining.

Non-technical Survey Data Input, Management, Analysis, and Sharing Pipeline

A data observatory typically consists of several key components that work in concert to facilitate data input, management, analysis, and sharing. In [5], the components of a typical data observatory are identified as:

1) data ingestion,
2) data storage,
3) data transformation,
4) data analysis and visualization, and
5) data sharing and collaboration.

The data ingestion pipeline, as illustrated in Figure 2, is the first component of a mine action data observatory, and involves collecting raw data from various sources, such as aerial and ground-based sensors, satellite imagery, historical records, and expert knowledge.

A data ingestion pipeline is a series of processes that facilitate the collection, preprocessing, and storage of raw data from disparate sources. In the context of humanitarian demining, this may include data from aerial and ground-based sensors, satellite imagery, historical records, and expert knowledge. Data ingestion pipelines streamline the process of acquiring and integrating data, ensuring that it is readily available for analysis. Data ingestion pipelines are designed to streamline the acquisition and integration of data, ensuring that it is readily available for subsequent analysis.

Unstructured data, such as satellite images or field reports, can be challenging to process and analyze due to its inherent complexity and lack of standardization. Data transformation techniques, including natural language processing, computer vision, and machine learning algorithms, are essential for converting this raw data into a more structured and usable format. One such study was proposed in [9], where an approach for automatic detection of mine presence indicators in hazardous areas from aerial surveying images in a safe and explainable manner was presented.

As technology continues to advance and new data sources and formats emerge, the synergy between data ingestion pipelines and data lakes will only become more critical to the success of data observatories in humanitarian demining. The integration of emerging technologies, such as IoT devices, AI, and ML algorithms, will further enhance the capabilities of these components, enabling more sophisticated data collection, advanced data transformation techniques, real-time data processing, enhanced data integration and interoperability, data analysis, as well as security and data governance.

The ongoing development of AI and ML algorithms will facilitate more advanced data transformation techniques, allowing stakeholders to extract even greater insights from the diverse data sources collected by the data ingestion pipeline. This can help identify patterns, trends,

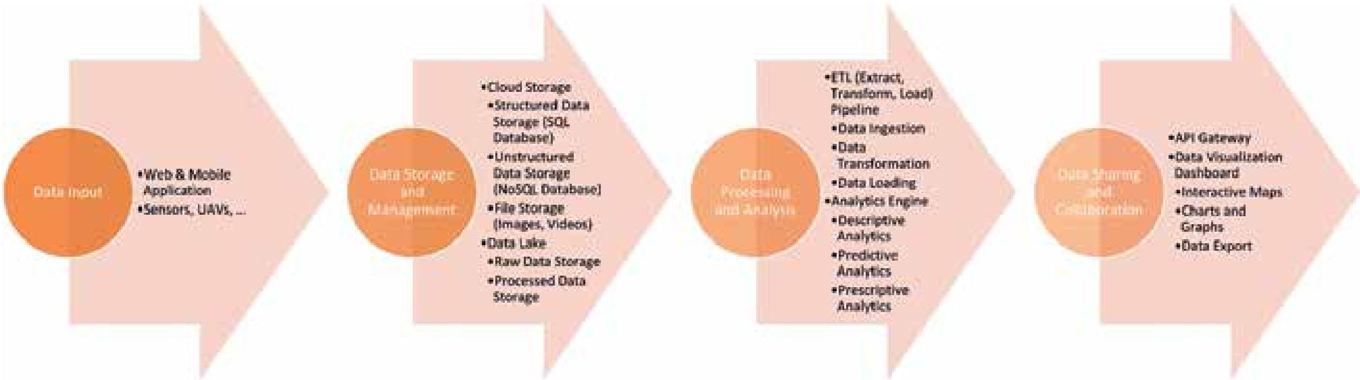

Figure 2. Data architecture pipeline of cloud-based software platform for data input, storage and management, processing and analysis, sharing and collaboration in non-technical survey.

and relationships that might otherwise be overlooked, contributing to more effective demining strategies.

In the context of real-time data processing, the integration of IoT devices and real-time data processing tools into the data ingestion pipeline will enable the continuous collection and analysis of data from mine-affected areas. This can provide stakeholders with up-to-date information about mine scenes, allowing them to respond more quickly and effectively to emerging risks and opportunities.

As new data sources and formats become available, the integration capabilities of data ingestion pipelines and data lakes will need to evolve to accommodate these developments. This will ensure that data observatories remain a valuable resource for humanitarian demining efforts, promoting reporting, visualization, as well as collaboration, enhanced data integration and interoperability among different stakeholders, e.g., national Mine Action Centers (MACs) such as CROMAC, in the humanitarian demining operations.

In this regard, in our previous work we have developed a new core ontology called MINEONT (MINE-action ONTology) for formal knowledge representation and automated reasoning in demining [4]. This approach allows expressive representation of concepts in mine action, high-level semantics, geospatial metadata, and information obtained through various mine action surveys including multimodal data sources, such as aerial and satellite imagery, mine presence indicators, contextual data, and expert knowledge from humanitarian demining specialists [4]. The purpose of MINEONT is to be used to build a specialized AI-based decision support system that integrates large amounts of data and facilitates interpretation and decision-making processes as a data observatory for mine action [3][8].

Enhancing Mine Scene Description and Collaboration through Blockchain Technology

With the growing volume and variety of data associated with humanitarian demining, ensuring the security and proper data governance of data stored in data lakes will become increasingly important. Implementing robust data security measures and developing comprehensive data governance policies will be essential to safeguard sensitive information and maintain the trust of stakeholders involved in demining efforts.

To this regard we envision the use of blockchain technology to describe a mine scene. This approach has several significant benefits and could improve the overall efficiency and trustworthiness of humanitarian demining [10].

Blockchain technology ensures data integrity and reliability by securely storing geolocations, types, and other metadata of landmines and unexploded ordnance in an immutable and transparent ledger. By providing a shared, trustworthy source of information, the decentralized nature of blockchain facilitates collaboration among stakeholders such as governments, MACs, and international organizations. This allows for more efficient resource allocation, less duplication of effort, and better decision-making in demining operations. In addition, the verifiability provided by the blockchain enables stakeholders to trace the origin and history of mine scene data, which can aid in the establishment of trust in the information and the identification of potential inconsistencies in the landmine detection process.

Benefits of Developing a Data Observatory for Humanitarian Demining

In summary, the use of a data observatory and data lake system for non-technical survey in humanitarian demining, as proposed in the paper, offers several key benefits compared to the traditional approach:

1. Improved operational Efficiency: By automating the data collection, storage, and processing tasks, the mine action data observatory can significantly reduce the time and resources required to analyze and act upon mine-related data, leading to more efficient demining operations.

2. Enhanced decision-making: A data observatory provides mine action centers and other stakeholders with access to comprehensive, up-to-date information about mine scenes, enabling them to make more informed decisions regarding demining priorities and resource allocation.

3. Enhanced Accuracy: Advanced data analysis techniques and AI algorithms can help detect landmines and UXO with greater precision, thereby reducing the risk of false positives or negatives.

4. Increased Safety: Advanced data transformation techniques can help identify high-risk areas provide demining teams with real-time, accurate information about mine locations and potential hazards, allowing them to prioritize and execute their operations more safely.
5. Scalability and Flexibility: The data lake architecture is highly scalable and can accommodate the growing volume and variety of data sources, facilitating the integration of new technologies and methodologies in humanitarian demining as they become available.
6. Interoperability and collaboration: The centralized data observatory can serve as a central hub facilitating data sharing and joint analysis efforts as well as sharing best practices among various stakeholders, including governments, non-governmental organizations, and research institutions.

Conclusion

The integration of data observatories, data lakes, and advanced data analysis techniques has the potential to revolutionize humanitarian demining by offering a more efficient, accurate, and safer alternative to traditional methods. The design, development and deployment of Mine Action Data Observatory (MADO) can significantly contribute to the broader goals of post-conflict reconstruction and rehabilitation, ultimately saving lives and paving the way for sustainable development in mine-affected regions.

The development of a data observatory that implements data ingestion pipelines into a data lake and employs data transformation techniques to improve the usability of unstructured data about a mine scene is a promising approach for enhancing humanitarian demining efforts. By leveraging the power of data lakes, advanced data transformation techniques, and the centralization offered by a data observatory, stakeholders can unlock valuable insights, streamline operations, and ultimately save lives.

The integration of emerging technologies, such as artificial intelligence, machine learning, and computer vision, will only serve to further refine the capabilities of data observatories in the field of humanitarian demining. As these technologies advance, the potential for more accurate, efficient, and safer demining operations increases, paving the way for a future where the threat of landmines and unexploded ordnance is effectively mitigated.

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Real-Time Geo-Localization of Unexploded Ordnance

Harald Lampesberger[1], Eckehard Hermann[2]

Abstract. **Many areas in conflict zones are still contaminated by UXOs, landmines and improvised explosives, posing hardship for the local population. Given the recent advances in consumer electronics, such as smartphones and drones, a potential research direction is to improve how the civilian population can report locations of remnants of war, so experts can assess the provided data and eventually react. Ideally, computing the location of a potential explosive on a digital map must be possible from a safe distance to the object in question with the equipment at hand. Our prototypical solution relies on global positioning and attitude sensors for calculating a geographic point of an object, e.g., a potential explosive, visible on a recorded image. This process is purely optical and neither a laser range finder nor digital elevation model are required. The technique is based on an optimization algorithm for the geometric ray intersection problem. This can be done independently from ground elevation data, which could be outdated because of ground disturbances or natural disasters. The computation of a location is done in real time, which enables rapid dissemination for better situational awareness. Furthermore, the prototype supports collaboration, so that images from different positions and cameras can increase the precision of a point. The presented prototype uses an unmodified Parrot Anafi drone as capturing device and the concept is currently ported to a smartphone app. In addition, real-time object detection is currently being worked on.**

Keywords: geo-localization, real time, ray intersection, consumer hardware, UAV

Introduction

We assume that reporting of locations of unexploded ordnance (UXO), landmines and improvised explosive devices (IEDs) by civilians is essential for clearing operations in conflict areas. This also coincides with the personal experiences of the authors, where remnants of WW2 are still found today by relatives in agriculture and construction. From this problem setting, we conclude that a tool for reporting of potential explosives could support the clearance process when the following requirements are met:

1. The tool should run as a software application on consumer devices, such as smartphones or consumer drones (unmanned aerial vehicles - UAVs), so it can be easily distributed and deployed.

2. Determining the location of a potential explosive must be possible from a safe distance and sufficiently accurate using the on-board optical capabilities of the consumer device without reliance on special hardware (e.g., laser range finder).

3. A location should be provided in three dimensions (i.e., latitude, longitude, altitude), such that locations below ground or on different levels of a building can be expressed.

4. The computation process of a reported location should be in (near) real time for quick dissemination, to support clearing teams in the field.

5. Determining a location should be independent from specialized maps (e.g., digital elevation models) to account for recent terrain changes, e.g., from a natural disaster.

In this paper, we explore this direction and discuss a software prototype for the listed requirements. The determination of ground positions from aerial photography is also known as geo-localization [1] and applications are found in the military domain, such as aerial reconnaissance, and in the civilian domain, such as search-and-rescue and agriculture.

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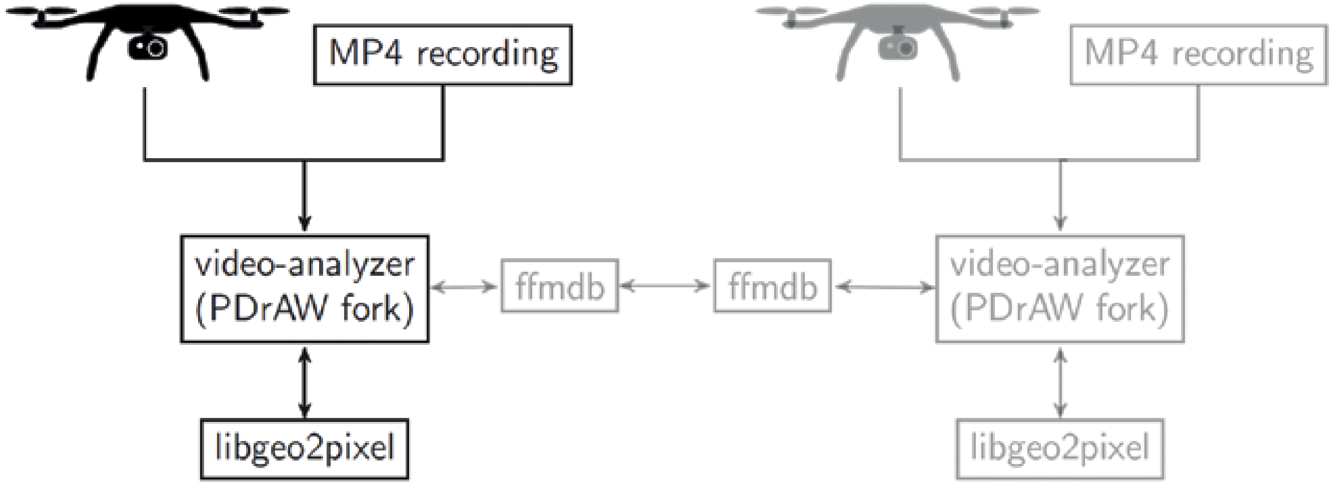

Figure 1 Software architecture

State of the art

Geo-localization is well established in avionics [1] and there are several research projects based on UAVs, e.g., locating ground objects [2], tracking the actions of persons [3] and cattle counting [4]. On the commercial side, solutions like *DJI PinPoint* [5] for professional UAVs or the software *SmartCam3D* [6] by Rapid Imaging, enable geo-localization capabilities, but their price range is typically beyond consumer devices. With respect to the reporting process of potential explosives, the Bosnia and Herzegovina Mine Action Centre [7] has developed an App for Android and Apple smartphones that integrates a digital map of suspected areas and reporting functionality using the device's camera.

Hardware selection

For selecting a capturing device, the UAV models *Parrot Anafi* and *DJI Mavic Mini* were compared because of their pricing and availability. *Parrot Anafi* was selected because it is a European company that provides open-source software, and for ease of use, the UAV's telemetry data is embedded as metadata in the live stream and in recordings. Furthermore, comparative experiments in an early stage of the project have shown that the *Parrot Anafi's* flight altitude is more accurate than that of the *DJI Mavic Mini*. From DJI's *MobileSDK* [8] development documentation, it can be assumed that DJI primarily uses barometers to measure altitude for their consumer models, which is too inaccurate.

Software concept

The architecture of our software prototype is shown in Figure 1. We consider both the real-time and the offline case. The following components have been developed or are currently under development.

The *video-analyzer* is the central application that reads a video stream in real time from the UAV or a previous recording, extracts telemetry metadata, and implements a rudimentary user interface as an augmented reality overlay. The application is based on the open-source *Parrot PDrAW* [9]. Telemetry data in a video stream includes global positioning, altitude, and attitude of the UAV and its camera with respect to the North-East-Down reference frame. From this data, the *libgeo2pixel* component tracks the geographic state of the UAV and implements two geo-localization algorithms that are initiated from mouse clicks in the user interface. Measured points are immediately exported in CSV format. The *ffmdb* component is work-in-progress and implements an in-memory database optimized for sharing location data.

The *libgeo2pixel* component is an independent development of the authors, implemented outside of the current project, and has been provided for this academic research. The library is written in C and implements various coordinate system transformations, rotations and camera projections based on the WGS84 geoid [10]. Two geo-localization methods are currently available.

When a digital elevation model is available, a single measurement (i.e., a mouse click in the video stream) computes the intersection of a virtual ray, emerging from

Figure 2 Example of ray intersection and point coordinates on Google Maps

the camera, with the ground level. This measurement is only accurate if the object or potential explosive is on the ground and the digital elevation model is up to date. Some elevation models are freely available, e.g., from the EU project COPERNICUS [11].

The second method is based on ray intersection and requires at least two measurements of the same object from different perspectives. These measurements could be from different capturing devices, e.g., two UAVs. An optimization algorithm estimates a point in space from two or more virtual rays without the need for a digital elevation model. This method is therefore applicable when digital elevation models are outdated or unavailable for the region.

An example is given in Figure 2. The left and center image are screenshots from a recording, replayed in *video-analyzer*, where the UAV approached piles of wood from the North. For this test flight, a suspicious object was placed between the piles. The left image shows the result of a mouse click on the object. The first location estimation is based on a digital elevation model. The displayed number is the distance in meters from the UAV to the computed point. In the second image, the UAV has proceeded towards South, and the suspicious object is seen from a different perspective. A second mouse click (measurement) on the object initiates the ray intersection method and the previous point is updated. The right image shows the point coordinates on Google Maps.

Preliminary results

Between 2021-2022, test flights with two Parrot Anafi UAVs were conducted in the greater area of Upper Austria. For estimating the accuracy of the described approach, identifiable landmarks were randomly selected in recordings and the XY error of a computed location was determined in a corresponding digital map. In accordance with Nuske et al. [12], preliminary results indicate that the magnetic heading of the UAV introduces the largest error. This error manifests in an XY deviation proportionally up to 10% of the distance between UAV and true location in the worst case. We therefore implemented a manual calibration routine in *video-analyzer*, where a ground elevation grid can be aligned visually with the video stream. When calibrated, the XY error was reduced to 1-2% of the distance between UAV and true location in our test cases.

Conclusion

Based on the *Parrot Anafi* UAV, we have shown that current consumer devices have sufficiently accurate sensors for geo-localization of objects in visual data and we see a particular use case in the UXO clearance and demining community. There are various ways of improvement and further development. We see two possible directions. On the one hand, our system is planned to be integrated with deep learning algorithms, such as Bajić and Potočnik [13], for real-time UXO detection in the field. On the other hand, *video-analyzer* software has been designed for Linux-based systems and ported to MacOS so far, and as a next step, we are currently working on an iOS app that implements *libgeo2pixel* using the smartphone sensors and camera.

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New Techniques for Optical Sensing of Explosives

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Abstract: **Optical sensing of explosives has emerged in recent years as a promising tool for detecting explosive vapours emitted from landmines, unexploded ordnances (UXOs), and improvised explosives devices (IEDs). Light-emitting thin films made from special conducting plastics have been shown to detect trace explosive molecules, including in the field in Croatia and in a swabbing configuration for testing objects. In this paper, we discuss recent advances in this technology, including thermal control of the fluorescent polymer for reusable sensors and time-resolved fluorescence measurements to help identify explosive hazards.**

Introduction

The humanitarian impact of landmines, UXOs, and IEDs can remain severe for years even after the end of a military conflict because the mines and failed explosive ordnances used during military conflicts are left behind, posing a life-threatening danger to civilians. More worrisome is that booby traps using explosive ordnances and IEDs are equally left behind after military operations, and civilians are the common victims. So, mine clearance and detecting explosives contamination is still critical, considering the recent military conflicts in Ukraine.

Sniffer dogs can detect explosive hazards effectively [1] and are widely used in humanitarian demining; however, they are expensive to maintain, and their efficiency is affected when they get tired. Honeybees have been used as a bio-accumulator in conjunction with fluorescent polymers to confirm the presence of explosives in a minefield in Croatia [2]. Unlike using sniffer dogs, honeybees minimise the risk posed to deminers and explosive ordnance disposal (EOD) personnel because human presence is not required to be on the field during sweeping or surveying a minefield.

Honeybees have been shown to effectively collect trace explosives molecules and other contaminants via their body hairs while foraging. The trace explosives molecules are then collected from the bees' body hair using a preconcentrator [3], then thermally desorbed onto some highly sensitive organic fluorescent sensors for detection.

The presence of explosives or other contaminants is indicated by the reduction of the light emitted by the sensors.

One of the limitations of using organic fluorescent sensors is the inability to effectively discriminate between explosives molecules and common distractants, which may result in false detection. Methods to analyse "fingerprints" of explosives would be a significant advance in real-world explosives detection.
Here we present recent advances in using organic fluorescent polymer sensors for enhanced detection of trace molecules of explosives, including thermal control of the sensors to resolve the challenge of false detection and additionally reset the sensors for multiple usages, thereby limiting the number of sensors that would be required for military or security operations. We also discuss our recent work on advancing the selective detection of explosives using array sensors and time-resolved fluorescence measurements.

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Explosives hazard identification via preconcentration techniques

Explosives detection in field conditions is challenging because of the low vapour pressure of most explosives 4, and other environmental factors such as temperature and humidity, and consequently, the amount of explosives molecules in the vapour plume around concealed explosives weapons or mines are small, which impacts the limit of detection or require ultra-sensitive explosives vapour detectors to confirm the presence of explosives hazards.

To increase the amount of explosives molecules available for detection in field conditions, preconcentration techniques are commonly used to accumulate explosives molecules, and are thermally desorbed to a sensor, thereby increasing the sensitivity. This is a common method in analytical chemistry. Our preconcentators, which are polymers that can sorb and retain trace explosive molecules, were also used in swabbing surfaces of objects contaminated with real explosives and IEDs at the Swedish EOD and Demining Centre (SWEDEC) as shown in figure 1.

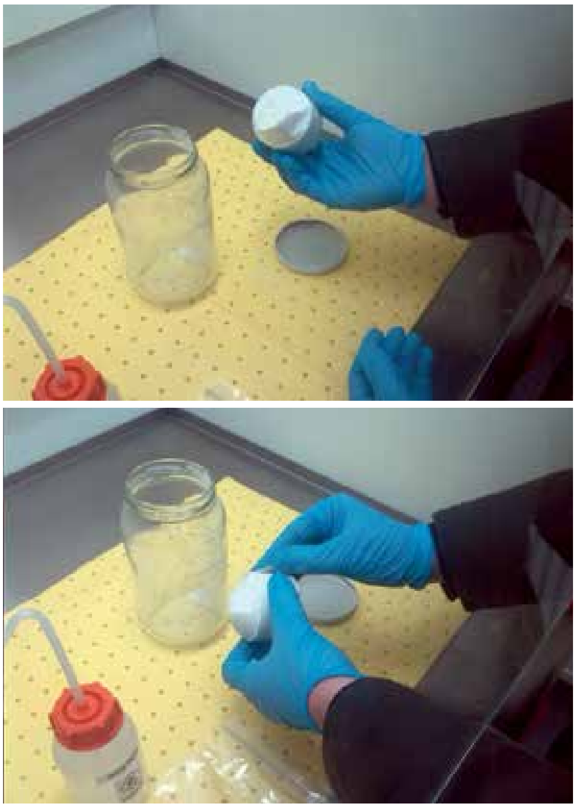

Figure 1 - Using preconcentrator at Swedish EOD and Demining Centre (SWEDEC) to swab objects for identification of objects with trace explosives contamination.

The preconcentrators were also used in conjunction with honeybees to survey the Benkovac mined field in Croatia, which has 1,000 mines of different compositions.

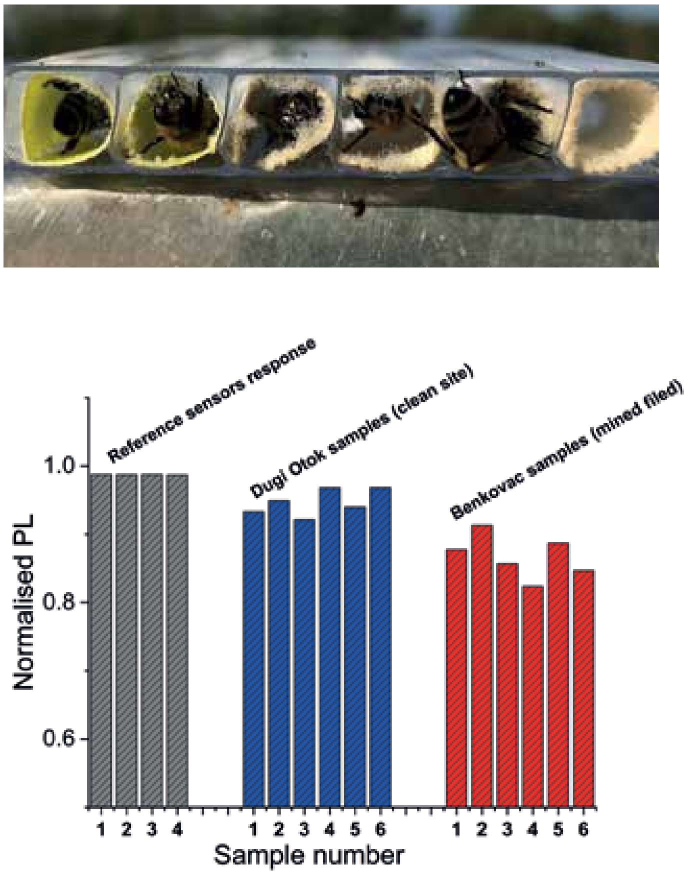

Figure 2 - (a) Preconcentrators inserted in tunnels, and honeybees passing through the tunnels, thereby depositing analytes. (b) Field results from Benkovac minefield (red bars), mined free site (blue bars), and sensors response for reference.

Figure 2(a) shows tunnels housing the preconcentrators placed at the entrance of bee hives and honeybees passing through tunnels. Any analytes on their body hair may be deposited and sorbed into the preconcentrators. Figure 2(b) shows the results from the Benkovac minefield (red bars), with about 20% loss in light emission of our sensors, indicating that explosives molecules may be present on the preconcentrators collected from the test minefield. The samples collected from a clean site, Dugi Otok (blue bars), show slight losses in light emission, which may be attributed to chemicals, likely local pesticides, in contrast to the responses from our sensors (grey bars), whose light emission is relatively stable.

Thermal desorption as a route for selective detection and reusable organic fluorescent sensors

The sensors were optimised to minimise false positive detections by controlling the sensors' temperature. Different explosives molecules have different strengths of binding interactions with the sensor material [5] and hence should exhibit different temperatures at which the explosives are desorbed from the sensor. The combination of the degree of loss of light emission and the desorption temperature may be used to discriminate analytes and hence screen out false positives.

Also, by controlling the sensors' temperature, the sensors can be reused multiple times. Figure 3 shows a laboratory result of our sensor responses to multiple exposures of 2,4-DNT and resetting cycles. DNT vapour at significantly lower concentration than the saturated vapour pressure was generated and exposed to the sensor for 60 seconds, followed by thermal desorption of the sorbed DNT to reset the sensor. The resetting step involves increasing the sensors' temperature from room temperature to 90 ºC, with DNT desorbing from the sensor at 57 ºC, thus making the sensors reusable.

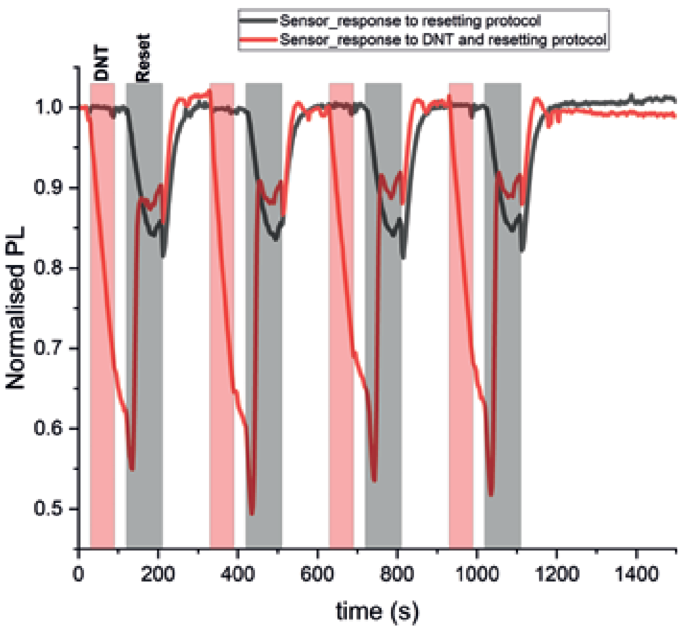

Figure 3 - Response of SY sensor to 2,4-DNT, and thermal desorption for multiple uses (red curve). The black curve shows the response of the sensor to temperature only. The red and grey rectangular bars show the period of DNT exposure and thermal cycling respectively.

Selective detection via Fingerprinting

In addition to using the amount of light loss and desorption temperature as a route to screen out false detections, we explore using an array sensor made of four different organic fluorescent polymers in a 2 x 2 matrix, as shown in figure 4.

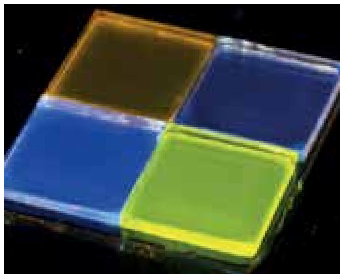

Figure 4 - Fluorescent array

The various polymers used in the array have different responses to analytes, and the collective responses from the array can give a fingerprint to discriminate analytes. Array sensors using organic materials have been explored for detecting explosives [6]; the sensing mechanism was based on the amount of light loss of the various fluorescent materials in the array. An alternative approach is to measure the fluorescent lifetime of the sensors, which gives information on the process involved in the loss of light of the sensor, and it is not affected by the fluctuations of the excitation intensity.

We measure the sensor array's fluorescent intensity and lifetime imaging using our custom-made Endocam image sensor device. The Endocam device is a 120 X 128-pixel time-gated SPAD array originally developed for biological applications [7], capable of < 400 ps time resolution. This enables simultaneous measurement of four films reacting to explosive vapours, leading to a unique fingerprint of individual explosives.

Conclusion and outlook

Organic fluorescent sensors, made with special plastics that can conduct electricity and emit light, have emerged as a promising tool for detecting explosives vapour emitted from landmines, UXOs, and IEDs in recent years. These special plastics have been used with preconcentrators and honeybees to detect trace explosives molecules in a mined field in Croatia. Using our preconcentrator to swab suspected objects has shown to be effective in detecting concealed explosives.

We explore temperature control of the sensors as a route to minimise false positives, using the degree of light loss of the sensor and the temperature at which the analytes are released from the sensor to discriminate between analytes. This additionally allows the sensor to be reset for multiple uses.

Finally, we used a 2 x 2 array sensor and an Endocam image sensor device to measure the fluorescent intensity and lifetime of the 2x2 array for detecting fingerprint of explosives molecules, thereby identifying explosives hazards.

Future work will focus on optimising the preconcentrators, expanding the library of measurements for both the thermal control and fluorescent lifetime measurements, and using machine learning to enhance sensitivity and screen out false positives while identifying explosives hazards.

Acknowledgements

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Humanitarian Demining Activities in Ukraine and Bosnia and Herzegovina with the ALIS dual-sensor detector

Motoyuki Sato[1,4], Arnold Schoolderman[2], Sead Vrana[3], Muamer Husilović[3]

Introduction

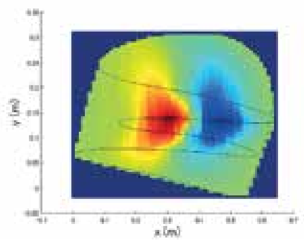
One year has passed since the outbreak of the Ukrainian War, there have been reports of damage caused by landmines left behind after the Russian army withdrew [1]. Since the 1990s, humanitarian demining activities against landmines that cause damage to civilians unrelated to combat have been carried out worldwide in post-conflict landmine-affected countries such as Cambodia and the former Yugoslavian countries. We have developed a landmine detection dual sensor ALIS: Advanced Landmine Imaging System, and are using it for actual demining activities. A technical overview of ALIS was introduced in [2][3].

ALIS has been tested in Cambodia, and we are conducting a NATO SPS project for ALIS in Bosnia and Herzegovina since 2021. As one of Japan's assistances to Ukraine, a project to introduce ALIS was started by JICA [4] in 2023. We will summarize the technical advantages of ALIS and its scientific approach to introduce into demining activities to mine affected countries including Ukraine.

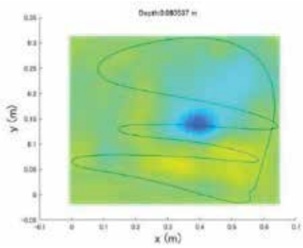
Dual sensors for mine detection

Electromagnetic induction sensors (metal detectors) have been mainly used to detect landmines. Although metal detectors are highly reliable, they also react to metals other than those contained in landmines, so excavating and removing them takes an enormous amount of time. As a means to solve this problem, around the year 2000, the development of a «dual sensor» combining a ground penetrating radar (GPR) with a metal detector was promoted worldwide. We started development of dual-sensor ALIS in 2002 [2][3]. The most important feature of ALIS is the ability to identify clutter by imaging buried objects by synthetic aperture radar processing (SAR, migration) of GPR signals.

GPR of ALIS adopts 800MHz-2.6GHz step frequency-continuous wave (SF-CW) radar system, and utilizes circular polarization with cavity-back spiral antennas. It is also characterized by acquiring GPR data while tracking the antenna position with a 3-axis accelerometer and imaging buried objects by 3D migration. In landmine detection by ALIS, the presence of metal objects is first confirmed using a metal detector. Then, we use GPR for confirmation of the objects. One data acquisition is performed on an area of about 50 cm x 50 cm, but it is completed within 1 minute. After the data acquisition, the data is processed almost instantly, and the two images shown in Fig. 1 will be displayed on the tablet terminal screen, at which a deminer can check the object.



(a) Metal detector



b) GPR

Fig.1 ALIS

1 Tohoku University, Japan
2 TNO, Netherlands
3 FACP, Bosnia and Herzegovina,
4 ALISys Co. Ltd.

Activities in Cambodia

Cambodian Mine Action Center (CMAC) started test of ALIS in 2018. From January 2019, it was approved for use in minefields in Cambodia, and full-scale operation began. Based on the results of the field operation test of ALIS, 12 ALIS were provided to CMAC in February 2023 as ODA(Official Development Assistance) by the Japanese government. At the same time, CMAC established a training course of ALIS operation for deminers.

Activities in Bosnia and Herzegovina

ALIS has the equivalent metal detector performance as conventional metal detectors, but the dual sensor performance and operating method are significantly different. Therefore, in Bosnia and Herzegovina, the Bosnian Federal Demining Organization, Tohoku University, and the Netherlands Institute for Applied Sciences (TNO) jointly working under the NATO SPS (G5607 project) 'Accelerating mine clearance by introducing a user-friendly and cost-effective dual-sensor detector in humanitarian demining operations [5] during 2021-2023. In this project, we aim at accelerating mine clearance (mine detection) by introducing (including tuning to user requirements) of the ALIS dual-sensor detector. In order to achieve this task, we need Software fine-tuning, training protocols, and establishment of SOP.

We expect that use of the ALIS detector in demining in BiH will speed up mine clearance. The project is conducted in close collaboration with an end user, and we aim for direct implementation of the results in humanitarian demining activities. In this project, we have conducted the following activities:

1. Familiarization with current mine detection methods used in BiH, including soil types and landmines in BiH
2. Set-up of training (and test) lanes, establishment of a training plan and training of operators (train-the-trainer)
3. Small scale operational assessment with ALIS in BiH
4. Draft Standard Operational Procedure (SOP) for ALIS
5. Large(r) scale operational assessment according to SOP
6. Reporting with conclusions on added value of ALIS

Due to COVID-19, local activities were restricted, but from 2022, we started training on ALIS operation methods for local deminers. In May 2022, we started fundamental training in Sarajevo, and in September 2022, we conducted intensive training of ALIS operation to FACP deminers. We lectured fundamental properties of ALIS detector, which include assembling, starting up, basic operation, scan pattern. Then training on the GPR scanning pattern and detection of metal parts and plastic body in a controlled condition. Then we started operational training at a training site prepared in the outskirts of Sarajevo. In that site, we used TDR for soil moisture measurement for ALIS software tuning, and several different mine simulants including defused PMA-2 and PMA-3 mines were used for training. In October 2022, the use of ALIS started in mine fields near Sarajevo, and a few explosives were detected, as shown in Fig.4. We can analyze the data by using a software prepared for ALIS.

Fig.2 ALIS basic training in Sarajevo

Fig.3 ALIS operational training in Sarajevo

Activities and Prospects for Ukraine

In Ukraine, the annexation of the Crimean Peninsula by Russia in March 2014 and the conflict with the Russian military in the eastern Donbass region have been occurring for more than 10 years, and the problem of landmines by the Russian military has already become apparent [6]. After the Russian army invaded Ukraine in February 2022, new problems caused by landmines planted by the Russian army became apparent, and Ukraine requested Japan's assistance in countermeasures against mines. The landmine problem in war-torn Ukraine is different from landmine-affected countries in

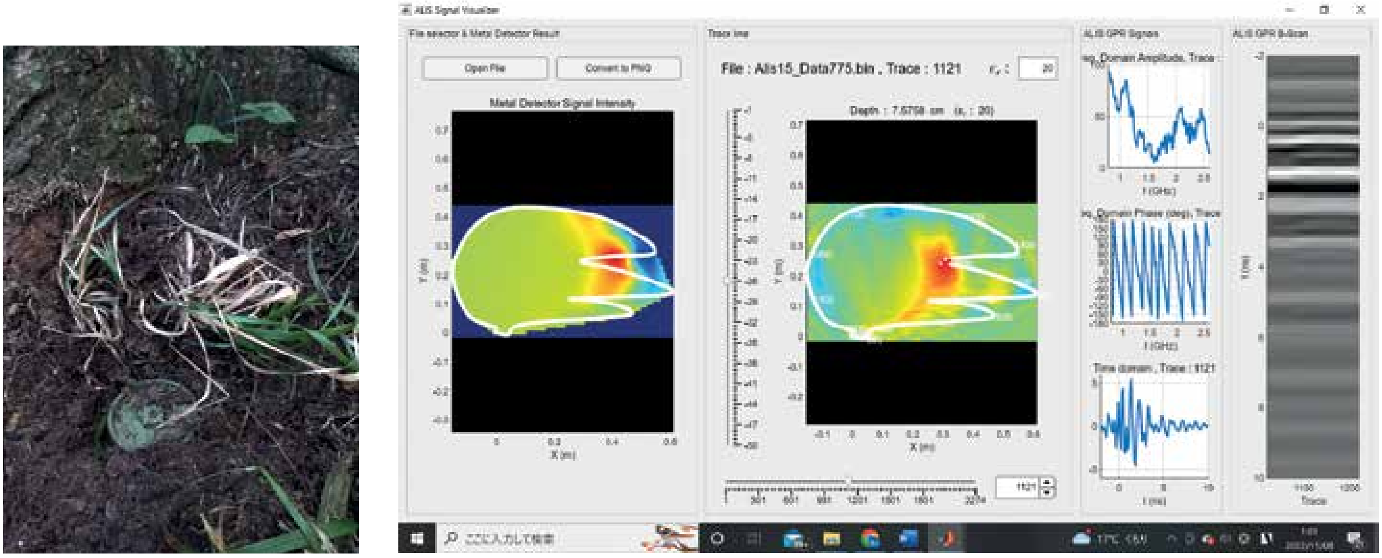


Fig.4 AP mine detected by ALIS in Sarajevo in October 2022.

the past. It has been reported that Russian troops who have invaded urban areas will bury landmines inside buildings or in the destroyed concrete debris. ALIS can visualize objects behind concrete, including rebar as well as soil. ALIS can be expected to be used even in situations where conventional metal detectors react to reinforcing bars and are useless.

For Japan, by the governmental policy, which finds it difficult to provide military assistance to Ukraine, contributing to humanitarian demining, which is a non-military activity, is extremely important. Against this background, JICA (Japan International Cooperation Agency) started a pilot project to introduce ALIS to Ukraine in cooperation with the Ministry of Foreign Affairs [4]. Since it is difficult to carry out activities in Ukraine, 8 deminers of the Ministry of Emergency Situations of Ukraine (SESU) were invited to Cambodia, and in January 2023, ALIS operation training was conducted.

Fig. 5 ALIS operational training for SESU personnel
(Photo: Courtesy of JICA)
(January 2023 Cambodia CMAC facility)

Based on the experience of operation of ALIS in Cambodia by CMAC, CMAC itself had a system in place to train ALIS operators. Therefore, we explained the significance and technical features of the introduction of ALIS to the Ukrainian deminers in Cambodia, and then conducted ALIS operation training for the Ukrainian deminers together with CMAC instructors.

As of March 2023, visit of Japanese to Ukraine is severely restricted by the Japanese government, so we cannot currently plan to go there. Therefore, Dr. G. Pochanin of the Ukrainian Academy of Sciences, who has been conducting research on GPR for landmine detection in Ukraine, was invited to Cambodia to provide technical information on soil moisture measurement by TDR and parameter settings for ALIS migration processing. We entrusted technical guidance for ALIS operation in Japan. Dr. A. Schoolderman of the Netherlands Organization for Applied Sciences (TNO) is also participating in developing an effective demining operation method using ALIS.

For the time being, several ALIS units will be operated in Ukraine, and based on the results, the number will be increased from the spring of 2023 with the aim of full-scale operation.

Activities in Colombia

Effective utilization of ALIS is currently being conducted on a trial basis in Columbia, from 2022 with grants-in-aid for scientific research. In Colombia, we are conducting experiments with the local Colombian NGO CCCM to verify the effectiveness of ALIS in detecting different types of Colombian soil and unique explosives created by guerrillas. We have also gained experience in ALIS training for NGO deminers.

Summary

The operation of ALIS is expected to be effective in clearing landmines in difficult situations with conventional metal detectors alone. Also, by working on multiple projects, we will be able to accumulate experience in a variety of situations.

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Detection of ferromagnetic landmines with a UAV-based magnetometer, demonstration, and verification

Markus Schikorra[1], Milan Bajić[2]

Abstract. The project aimed to test the capabilities of Sensys MagDrone R4 for the detection of ferromagnetic mines. The MagDroneR4 is equipped with five three-axis FGM3D/75 fluxgate sensors at 0.5 m spacing, which allows the coverage of a 2.5 m wide swath within one flight pass. A radar sensor controlled the constant flight height of the UAV over the surface. The 200 Hz sampling rate of the FGM3D/75 sensors allow easy filtering of interferences generated by the UAV and external disturbances like power lines or infrastructure. The survey speed can be chosen between 1m/s to 7m/s according to the terrain relief. The result of the survey is always a geo-referenced color-coded map and text file, with the magnetic anomalies in nT. To compensate for the background earth's magnetic field and calculate the intensity of the anomalies, a median filtering need to be applied to the total intensity raw data. Due to the significant influence of the distance from the sensor to the object, it is essential to get as close as possible to the ground. To demonstrate the capabilities of the system to a wider group of interested people, a test will be conducted on May 4 2023 to show the recording and processing of survey data in the field. Detection of unexploded ordnance (UXO) with a magnetometer on a UAV is developed, tested, and operationally accepted technology. Although there are minefields with ferromagnetic landmines, the application of a magnetometer on a UAV for this purpose has not yet been developed, there are only two or three public references. In the joint project, SENSYS and HCR-CTRO demonstrate the operational features of ferromagnetic mine surveys with a magnetometer on a UAV but also test and verify the detection potentials. Testing is carried out at the Benkovac test site, on 90 ferromagnetic mines, which are buried at depths of up to 25 cm, and several of them are on the surface of the ground. The outcome will be an awareness of the technology of magnetometric detection of landmines and an understanding and compliance with the conditions, and procedures that guarantee success, as is done with metal detectors.

Magnetometer system onboard UAV, Sensys MagDrone R4

The compact Sensys MagDrone R4 that will be used for the test survey is equipped with five three-axis FGM3D/75 fluxgate sensors at 0.5-m spacing, allowing the coverage of a 2.5-m-wide swath within one flight pass (Figure 1, left) and a spatial measurement resolution of 0.1 m (flight/measurement direction) x 0.5 m (traverse distance).

According to the manufacturer's specifications, the sensitivity of the sensors is ±0.15 nT. The entire set-up weighs 8.1 kg, whereas the MagDrone R4 without the UAV itself is very lightweight at 1.4 kg.

Under real conditions and at a speed of about 1-5 m/s, the system can be in use for up to 30 min per battery set. Due to the quite flat terrain of the test site, the R4 could be operated at a fixed flight height of just 1 m above the surface (Figure 1, right). A radar sensor (Nanoradar NRA24) controlled the constant flight height of the drone.

The 200 Hz sampling rate of the FGM3D/75 sensors allows the easy filtering of interference generated by the UAV and external disturbances like power lines or infrastructure (MagDrone R4 – Sensys Magnetometer, 2022).

The post-processing included filtering and compensation of the raw data in Sensys MagDrone DataTool. To filter out the drone's high-frequency noise, the smoothing filter (Hodrick – Prescott LP) can be used. For compensation and calculation of the intensity of anomalies, a 10 to

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25- moving median is recommended to be applied to the three-axis fluxgate data. The post-processed data can be converted into any GIS-compatible ASCII format in the Sensys MagDroneDataTool software. Finally, geo-referenced color-coded maps with a spatial resolution of up to 5 cm per pixel can be produced by the Sensys post-processing software Magneto and visualized in a GIS tool like QGIS.

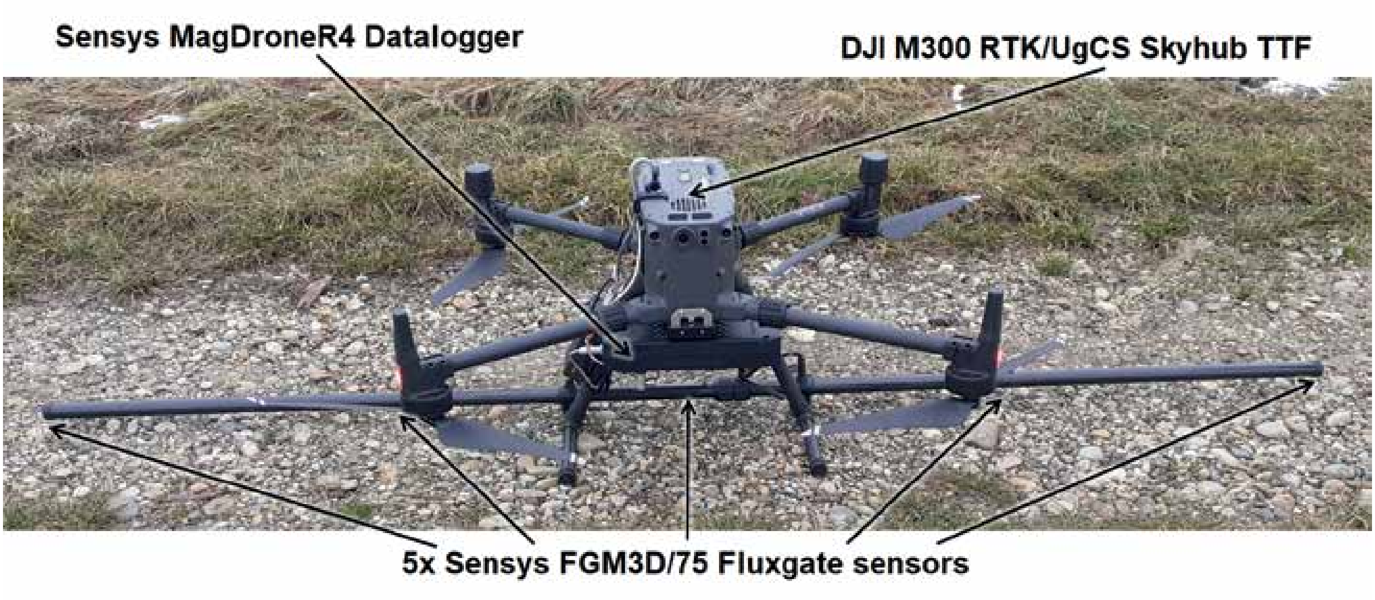

Figure 1 The compact setup of the Sensys MagDroneR4 magnetometer system

Preliminary tests

So far several preliminary tests were conducted to prove the concept itself. The development site is the GEOMIL test range from Sensys. It is a 100m by 15m large area with 56 different UXO and other remains of war-buried objects. The magnetic properties, depth, position, and orientation of the objects are well-known and documented. The test area was excavated 8m deep and filled with non-magnetic pea gravel to ensure a magnetic clean environment.

The test was conducted at different heights with different speeds. The results presented in Fig.2 are very competitive to land-based systems. Nevertheless is the greater distance to the surface the main drawback.

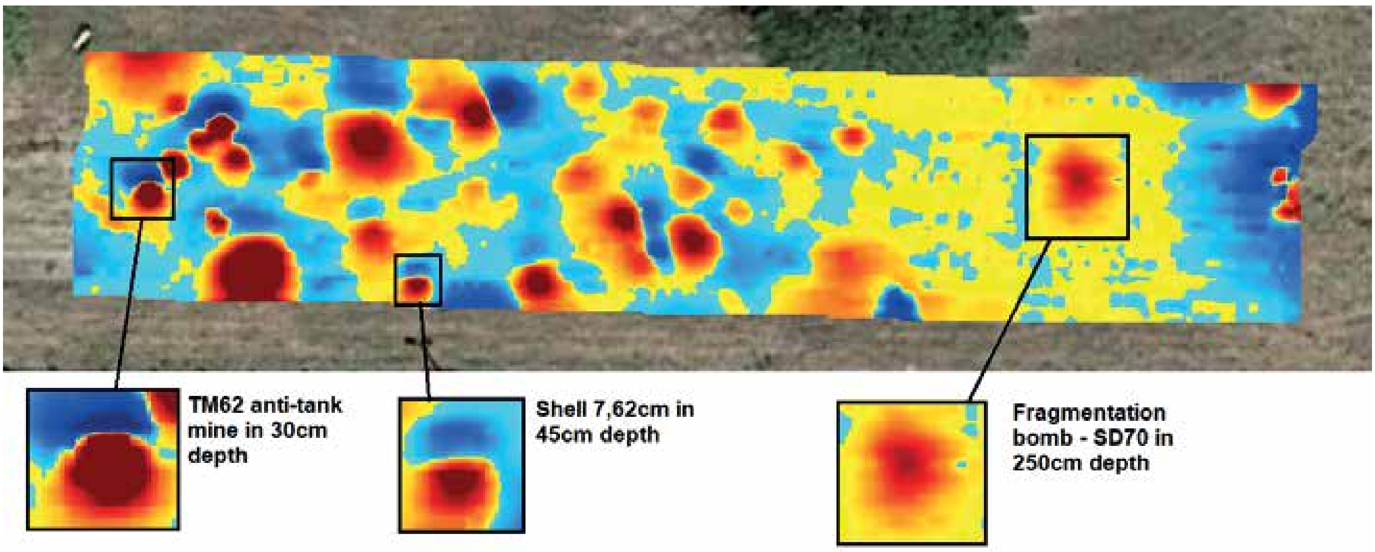

Figure 2 Result of GEOMIL test range with MagDroneR4 in 50cm flight height

Testing and verification of detection of ferromagnetic mines by magnetometer on UAV

The use of magnetometers onboard UAVs for the detection of unexploded ordnance (UXO) is highly developed both in the military and in the humanitarian mine action domain. Conversely, magnetometer systems are not used so far to detect landmines in humanitarian mine action. Only two or three published works refer to the detection of landmines with a UAV magnetometer, [1], [2]. Since there are significant amounts of ferromagnetic landmines, in the minefields in the world, this project tests an advanced magnetometer system on a UAV to gain a well-founded understanding of this technology. The system will be demonstrated in the Benkovac test site, Fig. 3, and the results of the testing will be presented at the Mine Action 2023 symposium.

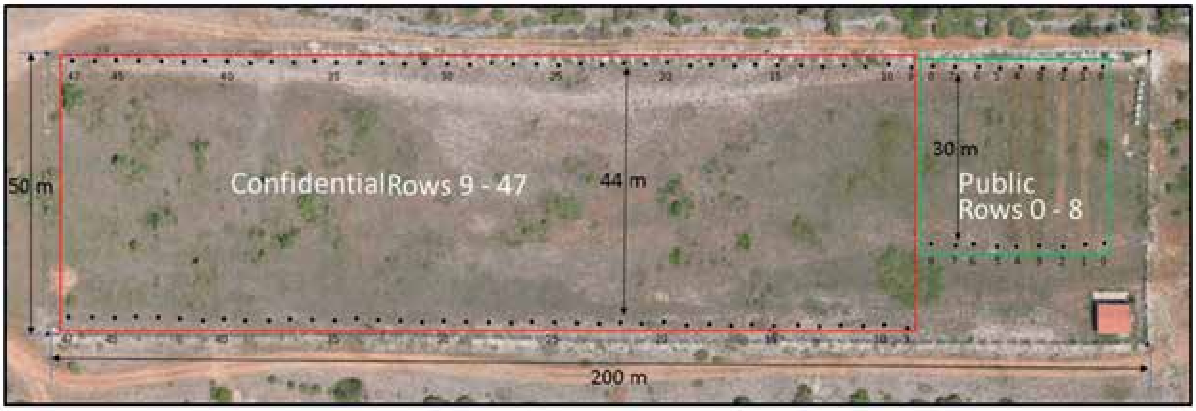

Figure 3. Benkovac test site of HCR-CTRO

There are many countries in the world where there are minefields with ferromagnetic, anti-personnel (AP), and anti-armor (AT) mines. In Croatia, too, there are such minefields, Tab.1, in which deminers are still dying, so detection from UAVs without entering the minefield is still extremely necessary.

Table 1. Confirmed hazardous areas with ferromagnetic landmines, the typical example from Croatia, 2022.

Minefield record	landmine	pieces
MEZ-4715	PROM-1	80
MEZ-4716	PMR-2A	20
MEZ-4917	TMRP-6	100
MEZ-4719	PMR-2A	142

Based on the described need, SENSYS and HCR-CTRO decided to implement a joint action in three steps: the a) blind test of the detection of ferromagnetic mines with the Sensys MagDrone R4 system, b) Processing and interpretation of recordings, presentation of results at the Symposium. c) Demonstration of the system and process on May 4, 2023.

The parent material (ground) of the Benkovac test site: Tertiary limestone. Pedological description of the soil in the Benkovac test site (Confidential part). Soil type Skeletic Chromic Cambisol, Soil depth: 35 cm (on average). Texture: Clay to silty clay. Humus content: 1 - 2 %. Soil color: reddish brown and brownish grey. Lime content: 5 %. Stone content: 60 - 80 %, limestone, slightly rounded angles. Rock outcrop on a surface: 80 - 90 %.

Although there are hundreds of mines in the Benkovac test site, only ferromagnetic ones are used in the planned tests, tab.2

Table 2 Ferromagnetic mines in Benkovac

Landmine	pieces
PROM-1	65
PMR-2A	3
PMR-3	11
TMM-1	7
TPRP-6	5

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Detection of Buried Landmines Using Fusion of Nuclear and Acoustic Techniques

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***Abstract*:** In order to detect and locate buried landmines, a vehicle-mounted system is proposed that fuses the complementary detection methods of thermal neutron activation (TNA) and acoustic detection. The TNA system uses an electronic neutron generator to interrogate the ground, with the presence of explosives being confirmed via detection of characteristic gamma rays associated with the decay of nitrogen, which is commonly found in explosives. The TNA components are based on years of design using state-of-the art radiation transport codes, judicious choice of specialized shielding materials, and development of pulse processing electronics that operate at extremely high count rates. The TNA method has been deployed in field trials with military user groups, demonstrating detection of landmines at realistic burial depths. The acoustic detection system uses a sound source to insonify the ground surface, with vibration sensors being used to detect the vibrational energy of buried landmines. The fused system combines the strengths of TNA and acoustic detection, and is expected to provide improved capabilities to end users working in the landmine detection mission. Potential improvements include increased success rate for detecting mines, reduced inspection times, and improved coverage for a range of field types containing landmines of various types and construction.

Introduction and Background

The principle of the thermal neutron activation (TNA) method [1] is illustrated in Figure 1. A source of high-energy (fast) neutrons, typically an isotopic fission source (e.g., ^{252}Cf) or an electronic neutron generator, irradiates the ground. The fast neutrons (with typical energies from a few MeV to 15 MeV) interact in soil and other materials, and may become lower-energy thermal neutrons (with energies less than 1 eV). These thermal neutrons have high probabilities for capture reactions in certain materials, including nitrogen, which is common in landmines. When nitrogen captures a thermal neutron, a characteristic 10.8 MeV gamma ray is emitted, which can be detected using gamma detectors co-located with the neutron source. The method, therefore, provides a means to detect the explosive materials in landmines, as opposed to detecting metallic material, which is commonly found in other underground objects.

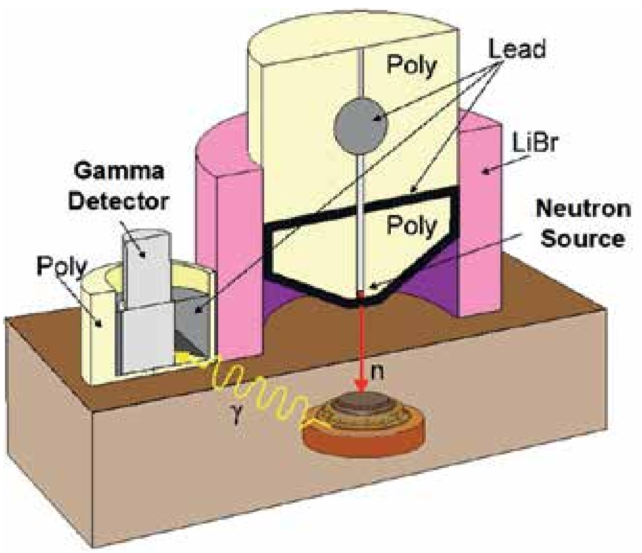

Figure 1: Schematic representation of the thermal neutron activation (TNA) method; taken from Ref. [1]

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2 International Aerospace Engineering Corporation, Washington, DC, USA

Working with the Canadian Department of Defence and other project partners, Bubble Technology Industries (BTI) developed a TNA system in the late 1990s, which was developed for and tested on a remote-controlled robotic vehicular system called the Improved Landmine Detection System (ILDS). The ILDS [2] used custom sensor fusion algorithms to combine information from a downward-looking electromagnetic induction (EMI) detector array, a downward-looking ground-probing radar (GPR) array, and a forward-looking infrared camera, to determine a suspicious region of the ground. These sensor systems operated while the vehicle was in motion. The TNA system was then deployed over the region of interest, with the vehicle stationary, to confirm the presence of nitrogenous explosives. The ILDS was intended for large anti-tank mines buried in roads and tracks. A small number of ILDS prototypes (Figure 2) were manufactured for the Canadian Forces and successfully demonstrated detection of anti-tank mines at realistic burial depths.

Figure 2: ILDS developed by BTI with the Canadian Department of Defence

By 2013, BTI and its Canadian military partners had developed a significantly improved prototype of the TNA system. It used six $LaBr_3$ scintillation detectors in place of the four NaI detectors used in the earlier prototypes, thus providing improved energy resolution and detection efficiency, which in turn yielded faster and more accurate detection of mines. The updated prototype also included significantly advanced signal-processing electronics, based on field-programmable gate array (FPGA) technology, with improved performance for the high count rates encountered in the TNA method. Importantly, the revised system substituted a compact, pulsed D-T (deuterium–tritium) neutron generator in place of the original ^{252}Cf source. The D-T generator (an example is shown in Figure 3) provides higher-energy, more penetrating neutrons than ^{252}Cf, and has the significant advantage that it can be turned off when not in use.

Figure 3: Commercial-off-the-shelf Thermo P 385 (D-D or D-T) neutron generator

Other methods of detecting landmines using neutron interrogation have been investigated by BTI and other research groups worldwide. The development of the ILDS prototype included an assessment of fast neutron analysis (FNA) with an associated particle imaging (API) system [3]. The FNA technique involves the measurement of characteristic gamma rays following interactions of fast neutrons in the ground. It may be coupled to the API method, which identifies the direction of the cone into which each fast neutron is emitted. This provides the ability to select the soil volume contributing to the measured gamma-ray spectrum, thus improving the sensitivity of the FNA method. A neutron albedo system [4] was also developed by BTI, which worked by irradiating the ground with fast neutrons, then detecting the thermalized neutrons that return using a position-sensitive thermal neutron detector. While the FNA and albedo systems did not develop into advanced prototypes, the research work demonstrated that these techniques may provide advantages in some scenarios.

Acoustic techniques have also been investigated as potential solutions for the detection of buried landmines. The phenomenon of an acoustic wave striking the ground surface and coupling its energy into seismic motion in the subsurface of the ground is well understood [5]. Two decades ago, an experimental study on the feasibility of using this phenomenon to detect landmines was conducted using a couple of different seismic motion sensing methods [6]. The seismic-landmine coupling occurs when a mine is buried several centimetres below the ground surface. A few different sensor technologies were considered in this study, including radar, laser, and ultrasound Doppler velocimeters. In order to complement the neutron-based methods discussed above, implementation of laser Doppler velocimeters is planned, which will enhance and increase the efficiency of detecting landmines in various seismic and ground configurations.

Proposed System

Since the time of the ILDS and neutron albedo developments, BTI has continued to improve its signal processing electronics and data analysis techniques, which are now deployed in a range of products for passive radiation detection in homeland security and law enforcement operations. Prototype systems for cargo inspection using neutron beams have also been developed, some of which are based on detection of nitrogenous explosives using the TNA method. These recent developments position BTI well to further advance demining efforts using its neutron interrogation methods.

A new, multi-sensor system for landmine detection is proposed, which couples BTI's nuclear techniques to acoustic methods being developed by International Aerospace Engineering Corporation (IAEC). The acoustic detection system uses a sound source to insonify the ground surface. Vibration sensors, such as laser Doppler velocimeters, subsequently detect the vibrational energy of the coupled seismic and buried landmine system; this method is depicted in Figure 4.

Figure 4: Schematic representation of the seismic-acoustic landmine detection system

The seismic-acoustic system under development utilizes the linear and non-linear vibrational coupling to detect landmines buried under the ground. Advancements in acoustic sources, laser Doppler velocimetry (LDV), and signal processing are being made in order to increase the efficiency of discriminating different types of landmines from the existence of other objects within the seismic columns.

In the proposed system, the seismic-acoustic methods will be coupled to a modern TNA system based on BTI's latest technologies. A compact neutron generator will be coupled to multiple scintillator detectors, processed by high-speed electronics and advanced data analysis algorithms. A combination of shielding materials will be developed to enable the gamma-ray detectors to operate in the vicinity of the neutron generator. The fused system combines the strengths of TNA and acoustic detection, and is expected to provide improved capabilities to end users working in the landmine detection mission.

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A one-system approach for information management in mine action

Torsten Vikström, Stefan Kallin[1]

Abstract: Mines and unexploded ordnance all over the world are still taking its toll as lifelong suffering or death. It strikes blindly and affects innocent civilians. The European Union has, by the project TIRAMISU during the years 2012 – 2015, taken on the task to boost clearing of the deadly legacy left in countries plagued by war.

T-IMS, The SITE Information Management System, is a GIS centric stand-alone software application that was developed in the TIRAMISU-project. T-IMS, which is built for mobile use, fully supports data collection within the processes of Mine Action/Humanitarian Demining:

Non-Technical Survey (NTS), Technical Survey (TS) and Clearance operations, as well as Quality Assurance/Quality Control (QA/QC) activities and final Reporting.

T-IMS improves the general survey processes with significantly increased finalization of activities directly through field work – without additional office work. The recording of the path of the surveyors and geospatial positioning significantly improves safety of field activities.

T-IMS combines easy-to-use computer software with the use of standards for information storage, data exchange and increased interoperability. By following and adapting to widely accepted and used standards, for instance International and National Mine Action Standards (IMAS/NMAS), standards developed and maintained by the Open Geospatial Consortium (OGC) and the Geneva International Centre for Humanitarian Demining (GICHD), organizations using T-IMS have the ability to connect, integrate and exchange information and reports with other systems and tools commonly used by the Mine Action Community, such as IMSMA Core.

T-IMS has been operationally validated by CTDT and CROMAC.

Post the TIRAMISU-project T-IMS has been used mainly in Cambodia and Lebanon. T-IMS has been selected for a pilot project in Syria/Iraq supporting urban survey and building clearance.

Introduction

"*There is an emergent consensus that an excessive use of clearance resources in areas that may not contain landmines and/or explosive remnants of war (ERW) represents an error in miscalculation rather than justifiable prudence. Tens of millions of dollars have been invested in survey since 2009. At large, the global survey efforts did not yield any conclusive data and could have been applied differently. This is a concern which continues to be the single biggest obstacle to faster and better aimed mine clearance. This has increased the inability to establish a clear baseline of the remaining hazard, time and resources needed, which are fundamental for the eradication of this global threat. To treat this problem a solid information management system is required.*"

M. Bold

Technology Development

The technology developments at the turn of the 21st century now offer a broad range of new technical breakthroughs within the areas of information technology, artificial intelligence (AI)/deep learning and telecommunications. Yesterday's powerful desktops are being transformed to sensory input and output devices merging intelligent software and extensive connectivity. We are getting more reliant on current existing multifaceted network connections and adapting to "smart environments" that are changing the ways we operate and interact. Easy access to interactive global networks with further simplification of computer use, can improve the ways we gather, analyze, monitor and evaluate information.

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Mine action would benefit immensely allowing it to shift away from the traditional hierarchical command and control structures and hence opening up for horizontal networks and co-operative teams. Consequently, this would enhance the ability in decision-making, monitoring and evaluation in parallel with continuous improvement. In consequence, this will increase efficiency but at the same time will also provide scope for growing transparency along with the national capability to bridge mine action with human security.

Mine action needs to embrace a culture of creativity, experimentation and openness for change. Nonetheless, technological advances in themselves provide no conclusion as to the extent and manner in which they can be used unless resources are freed to allow creativity.

The importance of standards

By combining easy-to-use computer software with the use of standards for information storage, data exchange etc. increased interoperability is enabled. By following and adapting to widely accepted and used standards, such as International and National Mine Action Standards (IMAS/NMAS) and standards developed and maintained by the Open Geospatial Consortium (OGC) and the Geneva International Centre for Humanitarian Demining (GICHD), organizations using T-IMS have the ability to connect, integrate and exchange information and reports with other systems and tools commonly used by the Mine Action Community, such as IMSMA NG/Core.

Mobile Technologies in Mine Action

Photos from a minefield in the Battambang province, Cambodia. © SITE.

Still as of today, a lot of the information collected in the field by surveyors and deminers is captured by hand with the use of pen & paper, separate GPS-units and hand drawn maps over the current area and situation. Over time, this is a very time and effort consuming way – often combined with high risk – to collect sensitive information. Information that often need to be passed several steps by hand to finally end up in an IM-system, where it is consolidated and make basis for new and improved manual maps to be drawn.

By using modern mobile technology tools for field data collection, such as T-IMS, this approach and process will be vastly improved in many areas:

- All captured information in the field – what, when and by whom – is accessible for reporting and communication in native form, which means that no further modification of data need to be done.
- Everyone involved in survey, clearance and QA/QC could and should be able to contribute & report.
- No more human errors and errors from manual handling.
- Situation awareness. Digital up-to-date maps with historical information, also showing the carriers' current position substantially improves safety in the field.
- Standardized map symbology – for the whole process of land release – minimizes the risk of misunderstanding and misinterpretation.
- Collected and captured information over larger areas can be compiled periodically and shared – in a common and standardized way – with donors and others of interest.
- Provides a basis for making the right priorities for action: Put action where action is needed.

T-IMS – The SITE Information Management System

T-IMS is a stand-alone very user-friendly system. It is for use in the early stages of Non-Technical Surveys through the phases of Technical Survey and Mine Clearance as well as the following Quality Assurance and reporting. With T-IMS, hazardous areas (SHA/CHA), indicators of mines or UXOs, GPS-trackings etc. can easily be defined and positioned in the map module.

With T-IMS' intuitive search engine, findings such as UXOs or landmines will easily be identified and can likewise be positioned with high accuracy in the map. T-IMS can on request be equipped with an off-line ordnance database. Any type of attachment – such as geo-referenced photos, voice recordings, videos, images and documents – may be attached to any activity.

T-IMS is built for use under rough conditions as well as in extreme environments. It runs with 100% of its functionality off-line. The overall concept, design and usability have been evolved by deminers with many years of use and great experience from earlier generations of like applications. It is built for use in the field and its user interface is completely adapted to touch technology. T-IMS is fully usable without a touchpad or a mouse.

The TIRAMISU project

The European Union has, by the Project TIRAMISU, taken on the task to boost clearing of the deadly legacy left in countries plagued by war. The project, funded by the European Union's Seventh Framework Program (FP7), aimed to provide the Mine Action community with a global toolbox to assist in addressing the many issues related to Humanitarian Demining, thus promoting peace, national and regional security, conflict prevention, social and economic rehabilitation and post-conflict reconstruction. This toolbox cover the main mine action activities, from the survey of large areas to the actual disposal of explosive hazards, including mine risk education. To reach the level of expertise needed the TIRAMISU team included organizations that were involved in some of the most important European and international research projects in mine action of the last fifteen years. The TIRAMISU consortium consisted of 26 partners from 12 different countries, with a total budget of approx. EUR 20 million. The TIRAMISU project started up in 2012 and was ended by December 2015.

The SITE Information Management System T-IMS is an outcome of the TIRAMISU project.

Acknowledgement

The research leading to these results and information has received funding from the European Union's Seventh Framework Programme for 2007-2013 under grant agreement n° 284747, project TIRAMISU.

T-IMS has been operationally validated by CROMAC/CTDT within the TIRAMISU project.

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Energy as binding force

JANAF

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RASTRUCTURE
TY IN RELATION
TO ERW

Challenges and needs in underwater demining faced by the Republic of Serbia

Bojan Glamočlija[1] , Aleksandar Milić[2], Jovica Milićević[3]

Abstract: During the previous century, the territory of the Republic of Serbia was the scene of various types of armed conflicts, starting with the Balkan Wars, the First and the Second World War, to bombing and conflicts in 1999 and 2000. All this contributed to the fact that the watercourses of Serbia and the main waterways on the largest rivers are contaminated with various types of explosive remnants of war. The consequences for the local population and infrastructure development are multiple. Million losses due to the impossibility of using the entire Danube waterway near Prahovo, temporarily suspended reconstruction of the port in Novi Sad, difficulty in building bridges over the Danube, almost daily ERW findings in gravel pits on the rivers, are just some of the examples of the consequences of the residual explosive remnants of war. Although in recent years there has been a progress in the technology of underwater survey and locating underwater ERW, due to the specifics of carrying out underwater works, it is of crucial importance that the personnel must be adequately trained, with the necessary experience and qualifications.

Keywords: Underwater demining, infrastructure, explosive remnants of war.

Introduction

Underwater explosive remnants of war (ERW), scattered throughout the waters of Europe, pose a huge threat to human safety, aquatic ecosystems and the environment in general. During World War II alone, more than a million tons of ammunition were dumped into the waterways of Europe.

The Republic of Serbia is not exempt, so it still struggles with the legacy of wars fought during the 20th century, in the form of explosive remnants of war. Inland waterways of the Republic of Serbia are contaminated by various types of ERW (air bombs, grenades, underwater mines, mined sunken ships, etc.)

The safety of the waterways of the Republic of Serbia is of vital importance for the safety of people, economic and infrastructural development, transport, tourism and environmental protection. Taking into account the fact that the Mine Action Centre of the Republic of Serbia, have over 12 locations on inland waters, which are suspected of being contaminated by various types of ERW, the focus is slowly shifting to the clearance of inland waterways, in order to achieve the aforementioned condition.

So far, the Mine Action Centre has developed and successfully implemented 6 ERW clearance projects on water surfaces. The applied ERW detection methodology and the experience gained during the implementation of these projects will be presented in this paper, through a case study on the „Port of Novi Sad“.

Case study «Port of Novi Sad construction and reconstruction project»

The port in Novi Sad, on the Danube river, plays an important role in the commercial and economic life of Serbia, as one of the most important transport waterway. The planned project of modernization and reconstruction of this port, worth several million euros, was stopped due to the existence of underwater explosive remnants of war. Due to the fact that the reconstruction of the port included works carried out on the water surface, which the Mine Action Centre kept in database as an suspected hazardous area of being contaminated by explosive remnants of war, a project for ERW clearance was developed.

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Photo 1: Location for technical survey within the port of Novi Sad
Source: Technical report - Port of Novi Sad

The Project included a technical survey of the water surface in order to define the possible contamination by ERW. The first step included historical research of the conflicts fought on the territory of Novi Sad, which served as a starting point for the following activities:

- Bathymetric survey - as the first stage, a bathymetric measurement of the river bed was carried out using a single-beam ultrasonic depth sensor, in order to completely survey the required area and create an adequate terrain model. The terrain model obtained was a necessary basis for the further phases of the research and presentation of the results.
- Survey with a magnetometer - magnetometric measurement records the gradient of the magnetic field in real time, precisely identifies magnetic targets on the river bed or buried under the river bed;
- Ultrasonic Depth Probe with Side Scan Sonar - Side scan sonar is an acoustic system used as an imaging technique to visualize objects located on the river bottom;
- Investigation with a sub-bottom profiler - the application of the acoustic depth profiler system enables the creation of a suitable image of everything that is located below the river bed.

After identifying the anomalies by carrying out the mentioned activities, based on a series of set criteria (such as total mass, slope, depth below the river bed, etc.) it is determined how likely it is, that an anomaly is an explosive remnant of war. Taking into account the given criteria, the identified anomalies are evaluated as follows:

- **1** - High probability that the anomaly is not an ERW;
- **2** - It is unlikely that the anomaly is ERW;
- **3** - The possibility that the anomaly is an ERW cannot be excluded;
- **4** - High probability that the anomaly is ERW;
- **5** - Anomaly determined to be an ERW;

In the case of the „Port of Novi Sad" project, a total of 188 anomalies were identified, of which 12 were determined to have high probability to be ERW. The project, as a separate phase, defined the engagement of underwater EOD divers for visual search of the river bed. A visual inspection of the riverbed involved the engagement of specially trained underwater EOD divers in order to confirm whether identified anomalies ERW. Out of a total of 21 anomalies for investigation, defined by the project, one 155mm artillery shell was found by the engagement of underwater EOD divers.

Photo 2: 155mm artillery shell
Source: Mine Action Centre of Republic of Serbia

In addition to this project, the Mine Action Centre has developed projects for clearance waterways as part of the construction of vital infrastructure throughout the Republic of Serbia (construction of a bridge within the Fruškogorski corridor, reconstruction of several railway bridges, construction of gas pipelines over water surfaces, construction of a bridge over the Danube River, etc.)

The sunken fleet on the Danube near Prahovo

At the bottom of the Danube river, on the border between Serbia and Romania, near the port of Prahovo, there is a sunken Black Sea fleet of Germany. During World War II, while retreating from Romania, German army sank, according to some estimates, over 40 ships on this part of the Danube, in order to slow down the advance of the Soviet Union.

There are a number of risks and consequences that a sunken fleet carries with it, including dangers to the safety of people and tourists, economic losses due to the narrowed waterway of the Danube and environmental damage.

Photo 3: Sunken ships visible when the water level of the Danube drops
Source: Technical report - Prahovo

One of the challenges is the fact that most sunken ships were carrying a large amount of explosives, torpedoes and other weapons. During the sinking of the ships, due to detonations, part of the explosives ended up next to the sunken ships. During the previous survey carried out in 2006, ammunition of different calibers, as well as explosive charges (TNT/RDX), each weighing over 125 kg, were identified. All of this represents a serious security risk, when carrying out the activities of retrieving sunken ships.

A complex, multi-stage, geophysical survey of the Danube riverbed in the area of interest was carried out again in 2021, and was to reveal the presence and precisely locate the shipwrecks and scattered ERW on the riverbed.

As in previous cases, the first step in this process was the collection and analysis of available historical data, including information from previously conducted survey projects for this location. Based on the collected information, a technical survey of the water surface was conducted, which included the following activities:

- Field survey;
- Bathymetric survey;
- Survey using Side-scan sonar;
- Investigation with sub-bottom profiler;
- Magnetometric survey;
- Visual inspection;
- Development of a technical report as the end result.

The preliminary analysis of the technical survey showed where the sunken vessels are located, as well as the morphology of the riverbed, providing essential information about the available water depth in the Project area. As a result, 14 additional sunken vessels (large objects) were identified compared to the 21 identified by the previous survey in 2006. In addition to this, a total of 603 anomalies - magnetic targets - were identified, of which 246 were determined to have high probability to be ERW.

During the visual inspection, one of the biggest risks and challenges, in addition to the presence of ERW, was related to the hydrological and hydraulic conditions, which affected the visual inspection by divers. Namely, depending on the water level and weather conditions, the visibility of the Danube can be very low. Visibility up to a depth of 5 m is estimated at a maximum of 30 cm. With a further increase in depth, already between 5-6 meters, a sudden loss of light and visibility was observed.

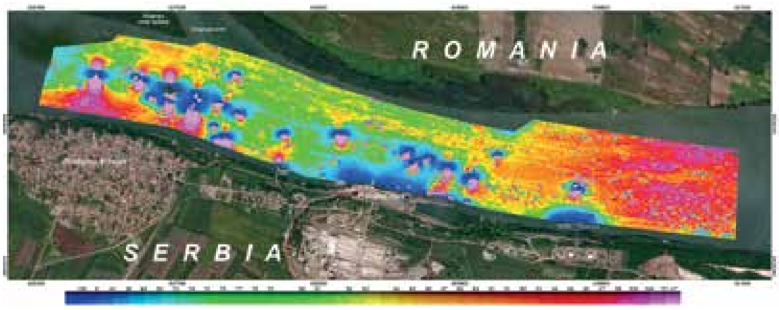


Photo 4: Map of total magnetic field intensity
Source: Technical Report on UXO presence on German sunken vessels in the area of Prahovo[4]

Conclusion

In addition to the advanced technology that facilitates the detection of underwater anomalies, there are a number of challenges that the problem of the existence of underwater ERW brings with it. Countries, generally do not have defined standards and protocols for conducting underwater ERW clearance activities. The absence of precise data on all water surfaces that are contaminated by ERW requires additional resources to be spent on their identification. Also, if the identified ERW is not removed within a certain period of time, its location may change, due to the natural action of waves, tides, but also due to the human factor. Depending on the weather

4 Technical Report on UXO presence on German sunken vessels in the area of Prahovo, developed under the auspices of the Ministry of Construction, Transport and Infrastructure of Republic of Serbia and European Union

conditions, visibility under water also changes, which can greatly complicate and increase the risk of injuries to underwater EOD divers.

However, in addition to the aforementioned challenges that underwater demining brings, the biggest challenge remains the training and adequate qualifications that divers must have in order to engage in activities related to the clearance of underwater ERW. The fact is that there are not enough underwater EOD divers trained in the Balkan region. According to the Study on Underwater Unexploded Ordnance conducted by the European Commission, which included public authorities, around 40 divers are trained each year to full EOD certification[5]. If we consider that, due to the physical demands of diving, divers years of service does not exceed 15-20 years, this is certainly not a sufficient number. All of the above indicates the necessity of further development and improvement of capacities for underwater demining.

As the implementation of a large number of infrastructure projects, on and underwater, is planned in the Republic of Serbia, commercial, industrial, business and recreational diving is becoming an important economic activity. In order to improve this area in the Republic of Serbia, the workshop «Potential for the development and improvement of the commercial diving sector» was organized in cooperation with the Chamber of Commerce and Industry of Serbia and the Mine Action Centre. Diving experts from the United States of America presented to the diving units of the Ministry of the Interior and the Ministry of Defense, international standards and new regulations in the field of diving and underwater demining, as well as the development of new methodologies and systems for diving, which will contribute to raising awareness and strengthening and growing this sector in the Republic of Serbia.

5 Study on underwater unexploded munition by European Commission

Infrastructure safety in relation to ERW

Oleksandr Lobov[1]

Background and Situation Analysis

The war in Ukraine has already resulted in significant loss of life, unprecedented displacement, internally and towards neighbouring countries, and devastating destruction of homes and critical infrastructure. The security situation and the overall operational environment have deteriorated rapidly over the last two months. The 2022 UN Ukraine Flash Appeal[2] shows that at least 15.7 million people are in immediate need of emergency assistance and protection.

According to the latest estimates[3], over 8 million people have already left Ukraine as refugees and over 5 million have been internally displaced persons (IDP), largely to the western regions of the country. Many of those displaced are women and children.

They leave behind shattered landscapes: as of today, over 2,528 education facilities, 859 medical institutions, 154 factories and enterprises, 68 administrative buildings, and 115 cultural buildings were damaged or destroyed[4]. The total amount of direct documented infrastructure damages is $84.8 billion, while the overall economic losses from the war exceed $564 billion.

The wide-scale, often urban, damage to the built environment, with the associated risk from explosives ordnance (EO), is proving a real and present hazard and hindrance to the first steps of recovery. Coupled with the widespread presence of landmines, sub-munitions, and other explosive remnants of war (ERW) in Ukraine, debris and military waste are the first and most significant threat to first responders as well as residents in war-affected areas. These threats also impede access for humanitarian actors, human rights investigators, and specialised services seeking to assess, contain or remediate other priority threats to public health and safety. In addition, the extensive presence of unstable and damaged buildings presents a considerable danger from uncontrolled collapse.

When combined with risks from unexploded ordnances (according to expert opinion, an estimated 10-30% of ordnance may not detonate as intended) removal and processing of debris poses a significant challenge, while their safe management is a precondition for in-country emergency assistance and the initiation of early recovery efforts.

1 United Nations Development Programme in Ukraine, oleksandr.lobov@undp.org
2 Ukraine Flash Appeal (March to December 2022) | United Nations in Ukraine
3 Ukraine Data Explorer (humdata.org)
4 Building Damage Assessment Overview Maps, UNOSAT, https://www.unitar.org/maps/latest-maps

Due to disruptions to the system of waste management, debris and other forms of waste are currently being piled up roadside, with potential for negative impact on human health, particularly in the hot summer months, as well as possibilities for detonation of unseen EO hazards.

Notwithstanding the large needs, the national agencies (such as the State Emergency Services of Ukraine) tasked with clearing EO, debris and damaged buildings are significantly limited in both their resources as well as capacity to provide this service. This includes lack of EO related tools and equipment and debris clearance capabilities.

Damage to Essential Services and Utilities

Wide-scale damage to the energy and water networks is crippling essential public functions required to enable the Government's support for the first responders and humanitarian actors in war-affected areas of Ukraine. This includes hospitals, clinics, fire stations and police stations not being able to operate due to a lack of electricity, gas, or water. Initiation of early recovery efforts is hindered by this lack of critical services and utilities. Needs include the restoration water and electricity facilities, solid waste collection and appropriate disposal facilities since uncontrolled and uncollected wastes in the streets and open public spaces lead to serious negative public health and environmental risks.

Due to the damaged infrastructure, chemicals and hazardous substances are leaking into the natural environment impacting on land, water, and air resources. This contamination of water supplies, agricultural land and air results in human health issues associated with environmental risk factors. These environmental risks can be acute, for example where burning fuel supplies or leaking chemical tanks cause direct and immediate negative health impact on humans.

The government agencies responsible for the monitoring of these risks are seriously under-resourced with a lack of environmental monitoring stations and capabilities

to deal with the most acute environmental risks, often in industrial settings. This results in compounding negative human health risks to first responders, residents, returning IDPs/refugees as well as the humanitarian sector. These critical environmental and social/community health risks and impacts need immediate attention to reduce further risks.

Essential utilities and services must therefore be restored quickly, both to facilitate emergency assistance and humanitarian response, and to provide the foundation for safe return and gender-responsive reconstruction efforts.

UNDP's response

Within the context of the situation analysis presented above, and the framework of its newly launched comprehensive Resilience Building and Recovery Programme for Ukraine[5], UNDP is already engaged in a number of integrated activities directly relevant to the work outlined in the request by the Government.

UNDP has been implementing a series of projects to ensure safe human mobility and access to essential goods and services for humanitarian support. One of projects' interventions are focused on EO survey and clearance to support demolition of damaged structures / buildings and debris removal works.

As of March 2023, the first project on demolition and debris removal has been completed in Kyiv region, Bucha sub-region where heavy fighting took place.

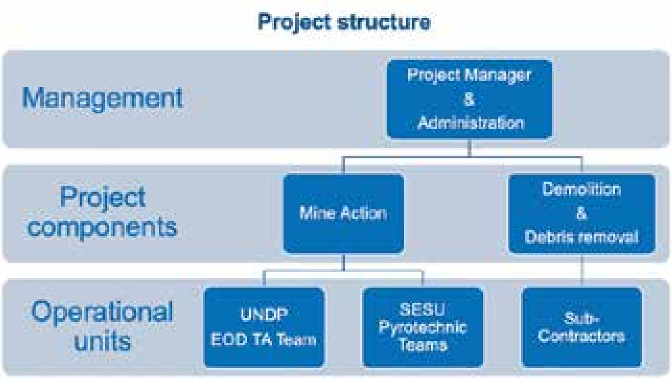
In the Kyiv region, the Russian invaders destroyed and damaged about 26,000 objects, of which almost 5,000 private houses and about 170 high-rise buildings were completely destroyed.

Now the area of implementation of similar projects is being expanded in the recently liberated territories. The priority regions are Kharkiv, Mykolaiv and Kherson regions.

5 https://www.ua.undp.org/content/ukraine/en/home/presscenter/pressreleases/2022/undp-launches-new-programme-to-address-the-socio-economic-impact.html

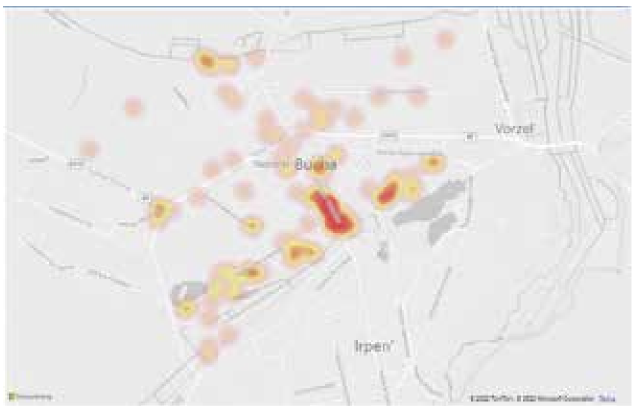
The challenges of working inside structures in conflict-affected areas that are intact or damaged, require a different operational framework and distinct methodologies from those for clearance of open areas.

A typical project structure has a project administration and two executive components. One is Mine Action, second – Demolition & Debris Removal. Mine Action component serves as operational support for demolition of unstable structures and building and further debris removal. The component involves UNDP Explosive Ordnance Disposal (EOD) technical advisory group and pyrotechnic teams of State Emergency Service of Ukraine (SESU). SESU is a beneficiary for the provision of technical support in the provision of up-to-date demining equipment and acts as an implementing partner within frame work of signed memorandum of understanding.



Provision of the safety of demolition and debris removal around EO is organized in several stages.

Initial stage – desk assessment with UNOSAT that provides satellite image analysis identifying location and degree of destruction of buildings and infrastructure. Such information gives an understanding of potentially EO contaminated areas.



At this stage, in parallel, the UNDP mine action specialists also conduct EO risk education trainings around with the personal of sub-contracting companies hired for demolition and debris removal. The training program is built taking into account the implementation of various types of work activities, for drivers of vehicles, operators of engineering machines, welders, as well as for those who are directly involved in the manual dismantling of construction debris.

The following step is on the ground date collection and analysis, without the use of technical interventions, as part of the Non-Technical Survey methodology, which is an evidence-based approach which contributes to decision-making for land release or identification as to whether further technical interventions for technical survey and/or clearance are required.


a)


b)


c)

To date, through partnership with SESU and local authorities, UNDP has contributed to the demolition over 340 buildings and removed 65,000 tons of construction debris, benefiting approximately 1,700 people in need.


d)

a) SESU pyrotechnic staff remove EO
b) Destroyed building in Moshchun village, Kiev region
c) A rocket part stuck in the wall of a building
d) Demolition and debris removal in Moshchun village, Kiev region

Fire fighting in areas contaminated by unexploded ordnance (UXO)

Aljaž Leban[1], Andrej Sekli [1]

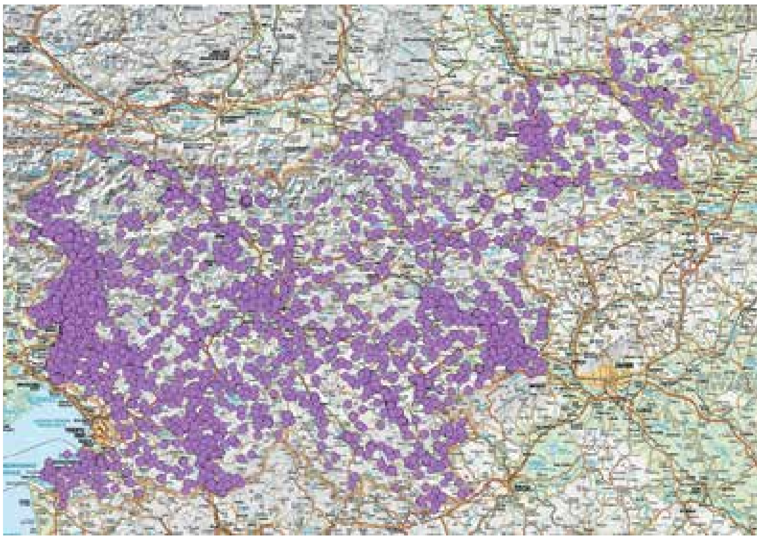
Due to past wars (WW I, WW II, and the War of Independence) unknown quantities of unexploded ordnance (UXO) remain in Slovenia and are removed on an almost daily basis by members of the Slovenian EOD state unit. The UXO most commonly recovered on Slovenian territory are dominated by canon grenades, mortar mines, hand bombs, and ammunition for infantry weapons. The experience and individual assessments of the members of the Slovenian EOD state unit as well as the statistics of the finds indicate that the threat of UXO to the Slovenian territory is considerable.

The specific geographical location of Slovenia brings with itself distinctive climatic conditions bound to a very small area, which necessarily translates to several different climates – a circumstance that additionally affects the fire risk. In general, the natural environment of Slovenia is not a high-risk fire zone, except during prolonged periods of drought. Western Slovenia, however, with its typical sub-Mediterranean climate and vast karst zones, is subject to a slightly higher fire risk throughout the year, especially compared to the continental part of the country.

It was in this area that the so-called Isonzo front was positioned during WW I and where the Italian and Austro-Hungarian armies fought each other for almost four years. As the frontline did not really move from the area of the Isonzo valley and the western part of Karst, the years of fighting here accumulated a huge amount of UXO in a very small area. During the WW II, several new hazardous remains accumulated in this region. Thus a considerable amount of UXO is lying on the surface or just below, which would threatened the local population for quite some years to come. In the rest of Slovenia, the WW I did not leave the same mark as in the western part of the country, though there it was of course the WW II that would leave its indelible, although luckily a considerably less palpable, mark. The UXO protection measures in the Republic of Slovenia are implemented by the Slovenian EOD state unit, which is composed of 32 members divided into 6 divisions (country-wide), including specialists for underwater operations and interventions in mountainous areas as well as karstic and other caves.

The unit is activated by the Regional Information Centre (ReCO - 112) on a direct call of the finder of a UXO.

Geographically speaking, Slovenia has a rather diverse distribution of UXO. One of the most important tasks therefore remains to record and keep statistics on the UXO found in each area. The map presented here roughly outlines the areas of contamination divided into four categories from the lowest to the highest level of threat:



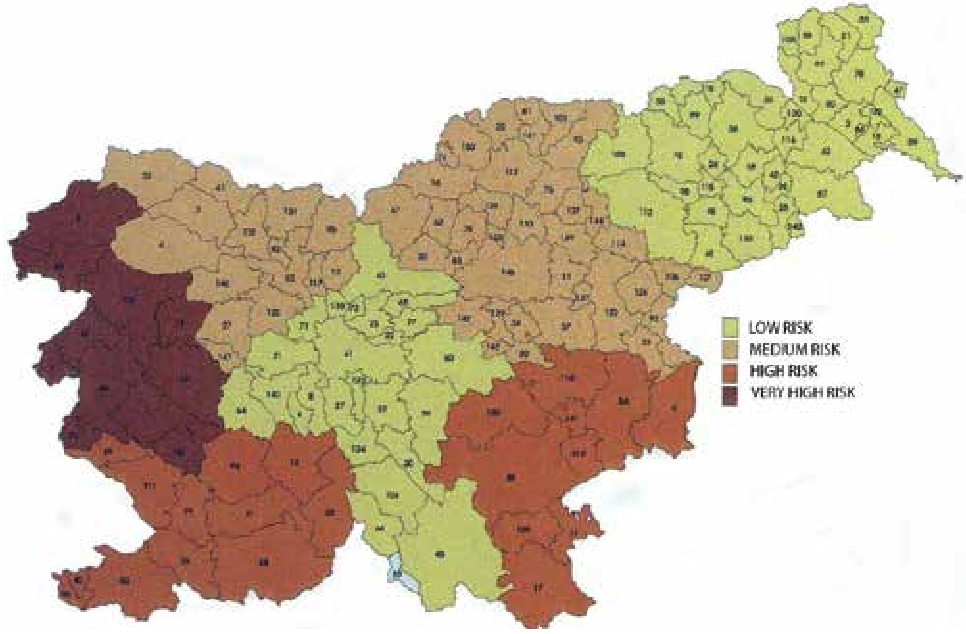
A distribution map of the recorded locations of UXO in Slovenia

Based on the statistics of removed UXO and the development of a threat map, the document "*Outlines for fire fighting in natural environments in areas contaminated by UXO*" was adopted in 2013. The document carefully sets out all the procedures to be followed in the event of a fire.

The Slovenian territory is divided into zones in terms of the threat posed by the probable presence of UXO, namely:

- low-risk zones,
- medium-risk zones,
- high-risk zones,
- very high-risk zones.

1 Ministry of Defence, Administration for civil protection and disaster relief of the Republic of Slovenia



The map of UXO threat level

The level of threat is very high in the Isonzo Valley and partly in the Karst region of Primorska (the Littoral). This of course is due to the static frontline warfare during the WW I.

High-threat zones typically translate into areas where major Italian or German offensives took place during the WW II. German troops retreated through these areas even at the end of WW II, holding a line of defence that also left a considerable amount of unexploded remnants.

The medium-threat zone will normally be an area where sporadic military conflicts have taken place and through which German troops and their allies have been withdrawing. Such events are equally likely responsible for UXO contamination but in this case we can more or less speak of geographically limited areas.

Low-threat zones are generally characterised by isolated, locally limited conflicts, which have not marked the environment by a particularly large amount of explosive residue, seeing that the use of only lighter infantry weapons was typically involved. The most commonly found items in such areas are, in addition to ammunition, hand bombs and mortar mines, much less frequently also small calibre cannon shells.

The second section of the afore-mentioned document defines the information and activation procedures (in the event of threat, it is always the commander of the Slovenian EOD state unit who deploys a member to the fire site to advise the intervention leader in terms of the safety measures to be undertaken during wildfire supression). The third and final section of the document describes the specific procedures and measures to be taken during fire suppression (firefighting restriction, prohibition of movement in a certain area, road closure, evacuation of people, etc.).

When it comes to wildfires in areas contaminated by UXO it is necessary to be aware of the danger posed by woody material and undergrowth and also what this translates into in relation to the free-lying and buried explosive remnants of war.

The UXO left over from war conflicts are located in areas covered with forests, low undergrowth and grass. The fuel element here is mostly wood and wood residues, so that the type of combustion we are dealing with is in fact pyrolysis. A good knowledge of pyrolysis and its conditions is therefore essential in assessing and ordering safety measures directly at the fire site.

Pyrolysis is the chemical decomposition of a substance, in this case wood, by heat.

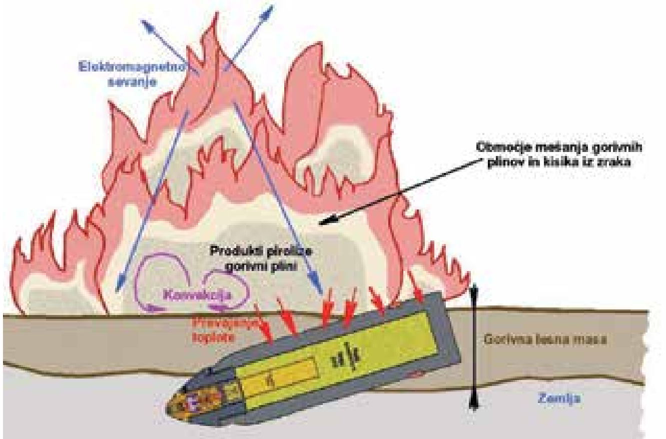
The cell structure of hardwood is denser, while that of softer wood is thinner, so that the latter evaporates moisture at lower temperatures. Softer wood also tends to contain resin, which evaporates very quickly when heated, thus additionally accelerating combustion. After the gas phase of the combustion process what is left over is glowing charred fuel. Why is knowledge of this particular combustion process actually important in relation to UXO?

- The higher the fuel mass in a given area, the more likely it is that even explosions of UXO with thicker casings will occur, rather than just ammunition and UXO with thinner casings (in the case, e.g., of a dense spruce or pine forest fire, or whenever the area is covered with an old forest where a lot of dry wood is involved).

- Thinner soft wood, dry grass and undergrowth burn faster and will consequently also release heat into the environment faster, the result of which is the short-time thermal effect (in such scenarios UXO with thinner casings will typically explode).

- Charcoal as glowing wood mass produced in the solid phase of the combustion process actually presents a higher risk factor for the potential explosion of UXO than the initial burning, seeing that the heat is transferred deeper into the ground where the UXO is usually located (the time delay for an explosion can therefore be quite substantial and may easily occur after the main fire has already died down).

In connection with the above some other aspects are important that describe the spread of fire in space and consequently can also affect the state of the UXO in the relevant environment. Basically, fire spreads in two distinct ways, by flame and by heat transfer. Flame spread by flame front propagation is only due to the presence of flammable gas vapours, which are formed by pyrolysis at the surface of combustible material and then mix with air and ignite. UXO are usually located on the surface or slightly deeper in the ground and very rarely have open combustible components, so that they cannot normally be ignited or activated by a flame. Unshielded clean explosives, gunpowder, pyrotechnic elements on the surface of the ground, or some broken unshielded UXO may, however, be directly ignited by flame.



The combustion process and its effects on UXO

A significantly greater impact on UXO, however, is exerted by heat transfer. There are basically three modes of heat transfer: electromagnetic radiation, heat conduction and convection, all of which can have the effect of activating the UXO over time (the condition of course being that the fuel mass is large enough).

Conduction

The commonest effect that can lead to ignition or activation of UXO is conduction, i.e. the transfer of heat through material. As is known, materials conduct heat differently. Metals are known to conduct heat well, which means that the most likely way to activate a UXO is indeed by conduction of heat through the casing to the internal explosive components, which then overheat, which may, depending on the state of the detonator booster, ultimately result in their deflagration or detonation.

Convection

Convection is the natural movement of a warmer gas through a cooler, denser gas in its surroundings. This circulates the warm gases and further heats the surface, which in turn is a prerequisite for increased heat transfer to the adjacent layers, resulting in increased pyrolysis and hence combustion. The combustion process becomes self- sustained and, depending on the type and quantity of the fuel mass involved, rather aggressive, which in turn increases the heat and the circulation of the warm gases. The surface is thus intensely heated and heat conduction increases.

Radiation

Radiation is the transfer of heat energy by electromagnetic waves. This radiation does not heat gases but only solids in its path of propagation. The energy decreases with the square of the distance, but in developed combustion it is usually sufficient to ignite combustible material in its surroundings. Like convection, radiation also hits the surface further, helping to transfer heat to adjacent layers. Metals receive these electromagnetic waves very well and consequently heat up very quickly, which in turn causes them to quickly start radiating heat. In the case of UXO, the massive metal body passes the received energy onto the explosive charge.

Eksplozivi	Topi pri °C	Vžge pri °C	Učinek
TNT	80,8	300	Gori – deflagrira
Pikrinska kislina	122	320	Gori – deflagrira
Amonij nitrat	170	210	Gori – deflagrira
Nitroceluloza	-	180	Gori – deflagrira/detonira
Pentrit	-	220	Gori – deflagrira
Tetryl	130	195	Gori – deflagrira
Heksogen	204	260	Gori – deflagrira

Temperature sensitivity of explosives

All these facts have been taken into account in the preparation of the present guidance document.

In the event of major wildfires, the commander of the Slovenian EOD state unit is permanently present. Their task is to advise and guide the intervention leader on safety distances for fire suppression, determine and supervise firefighter positions, collect up-to-date information on UXO (localisation, removal), determine the distribution of firefighters on a fire site, inspect the terrain, and provide assistance to other units.

The 2022 Karst wildfire took place in an area of very high risk, seeing that it coincided with the site interspersed with WW I frontlines, so that the most stringent measures had to be taken to ensure safety in the process of fire suppression.

The area of the 2022 wildfire and WW I frontlines.

Several smaller fires on the Slovenian and the Italian sides of the border merged into a larger fire, which burnt about 3705 ha, including 2900 ha of sheer forest. The fire lasted from July 15th to August 1st 2022, during which time 979 pieces of UXO with a total weight of 2742 kilos were successfully removed. Due to the stricter safety measures taken there were no injuries in spite of more than 500 explosions!

An example of UXO on a fire site

When the fire was finally suppressed, the members of the Slovenian EOD state unit initiated post wildfire inspection measures, such as surveying the fire area, prioritising locations for inspection, removing visible UXO, forming teams for the identification and inspection of the individual locations, setting inspection dates, etc. The aim and purpose of these activities was to clear the fire site of UXO remains and UXO debris as much as possible, especially along main roads and routes, as well as to ensure safe conditions for fire suppression in the possible event of a new fire.

An example of UXO on a fire site

In the period from the start of the fire until February 2023, the Slovenian EOD state unit carried out no less than 223 interventions, inspected approximately 190,000 m2 of terrain, and removed 2304 pieces of UXO with a total weight of 6873 kilos.

The Slovenian EOD State Unit

Minefields as a different kind of security risk

Alenko Vrđuka[1]

The mine suspected area (MSA) in the Republic of Croatia is the heritage of some past conflicts. The fear of death or injury was a discouraging element for those with the idea to enter such an area and it remained so to the present day. However, this rule is not universal. Sometimes there is an individual with an interest greater than the risk and fear of being injured by a mine.

The fear of being injured is directly related to the awareness of the risk of injury. If the risk of fatality is small and certain people are aware of it, then her fear is also lower. The risk of getting injured in MSA indicates several indicators. First of all, what is the number of victims in the specific MSA (which can be human, but also animals)? How much time since planting a mine has passed is also important. However, it is difficult to define the life span of mines because those that are not hermetically closed decay very quickly while those that are hermetically closed do not have the same duration, which depends on the material they are made from. The laps of time affect differently the mines that are buried and those that are placed above the ground. The latter, due to the way they are triggered, are far more exposed to the movements in the area, and thus, over time, the likelihood of being activated by animals is larger.

None of the above indicators is a guarantee that someone will not get hurt entering the MSA, but it can influence a person in a way that reduces his fear of getting hurt and decides to enter that area. If such a person enters the MSA and returns unharmed, there is a high probability that he will repeat it, and, at the same time, it reduces the feeling of fear in other people and can affect the chain involvement of more people in those who are no longer afraid of entering the MSA.

The way to suppress the phenomenon of illegal entry into the MSA is found in the legal regulations. According to the Mine Action Act, unauthorized persons are not allowed to enter the MSA until the Ministry of Internal Affairs issues a Certificate on the exclusion of that area or facilities from the MSA. The law stipulates a fine of €260 to €1,320 [1]. Although the prescribed penalty is high, this provision cannot be successful until it is certain that the perpetrator will be arrested.

The implementation of the law within the MSA is not as easy as outside it. Nor do the police enter such areas unless it is a specific event. In such a case, the procedure is significantly slowed by opening a safe passage (demining), giving the perpetrator enough time to escape. An additional aggravating circumstance is in cases where the MSA is located along the state border and when a person enters and leaves the MSA from the territory of a neighboring state. All these circumstances make this space interesting for people who see MSA as an opportunity for illegal activities.

Punishable actions that could be linked to a mine-suspected area are twofold. One is the actions that use the MSA as an area where they are protected from the police and other people, and the other is those that are aimed at obtaining explosives from the mines located there.

As an example, we will take the area of Sisak-Moslavina County, where 24.4 square kilometers are mine-suspected [2]. The largest part is located in the area of Dvor along the state border with Bosnia and Herzegovina. It is a genuine example of MSA as a safe space for perpetrators of illegal activities.

By analyzing and comparing the aerial photographs of the area taken in 2011 and in the period from 2014 to 2016 [3], it is possible to see several changes caused by human activity in the MSA (Figure 1).

1 Police Administration Sisak-Moslavina,
Ministry of the Interior, Croatia, avrduka@mup.hr

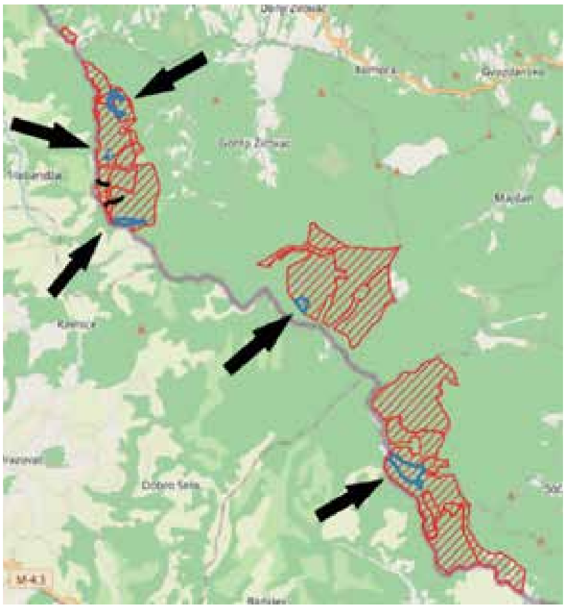


Figure 1 - Areas with visible human activity

Several types of illegal activities occur in the MSA. Figure 2 shows a clear representation of forest cutting.

Figure 2- Changes made in the MSA - woods

Figure 3 shows a road on the recordings from 2014-2016 that did not exist on the recordings from 2011. The road comes from the direction of Bosnia and Herzegovina and extends deep into the MSA. Considering the proximity of the roads to the locations where the forest was cut, it can be concluded that the roads were created so that the cut trees could be dragged to B&H, which was confirmed by the local police [4].

Figure 3 - Changes made in the MSA - roads

From the figures above, it is clear that there are human activities within the MSA and that the actors of these activities come from neighboring B&H. Identical cases were recorded in MSAs in other parts of the Republic of Croatia [5].

Such areas are also suitable for other types of punishable actions. Namely, several cases of illegal hunting have been recorded in the MSA. In the above-mentioned area of Sisak-Moslavina County, there have been incidents with B&H citizens illegally hunting in the Republic of Croatia [6] who do not hesitate to shoot at police officers [7].

Such areas provide criminals with ideal conditions for another type of criminal activity. Although it cannot be confirmed with certainty for the Dvor area analyzed above, plantations of Indian hemp were also found in mine-suspected areas. Planting such a plant, the cultivation of which is illegal, is possible only in a covert manner, in a location where the perpetrator will be unnoticed and undisturbed. It is the MSA that provides the perpetrators with such conditions. Two such cases were recorded in Croatia, one near Osijek in 2015 [8] and the other near Lipik in 2018 [9], and one case was recorded in neighboring B&H in 2013 [10].

Today, in the tick of the migration crisis, several migrant routes pass through the Republic of Croatia. MSAs are also recognized by migrants as ideal for illegal entry and passage through the Republic of Croatia [11]. Unfortunately, such cases have also been known to end with fatal consequences, such as the case from Karlovac County in 2021, when one migrant was killed and several others were injured [12].

In addition to illegal logging, illegal hunting, cannabis cultivation, and the movement of illegal migrants, the mine-suspected area could become interesting for another reason. Certain criminal activities require explosives for their implementation. And MSA can be the source of such a substance. First of all, terrorism is thought of, however, explosives can also be used for confrontation between criminal organizations, but also as a means of committing some property crimes [13]. It would not be the first time that an attempt was made to steal mines from the MSA [14]. Mines located in minefields can contain over 5 kg of explosives [15], which is more than enough to commit any of the above-mentioned punishable acts. Furthermore, it was determined that the market for explosives or explosive ordinance does not have to be the territory of the country where it was dug. It could also be the territory of the European Union [16].

The thesis that explosives from minefields can be used for terrorist activities is based on several elements. The previously mentioned MSA in the vicinity of Dvor is in the area of the former demarcation between the warring parties and in the vicinity of that area, on the B&H side lives a certain number of people who fought there. These people are trained to handle explosives, and at the same time they are familiar with the exact position of minefields, and sometimes the mines themselves. These people are active members or sympathizers of radical Islam since the time of the conflict in the territory of the former Yugoslavia. Now there are also new generations who have become radicalized through participation in the wars in Iraq and Syria [17].

The use of military explosives does not necessarily have to be related to terrorism. In these ex-Yugoslav areas, several cases of confrontations between criminal organizations in which military explosives were used [18] were recorded. Such cases did not bypass Croatia [19].

Some perpetrators of property crimes have also shown interest in military explosives. In the last few years, ATM break-ins with the use of explosive gases or explosives have become more common [20]. As the systems for the chemical protection of money have advanced, the use of gas is stopped and explosives are primarily used because they can disable the protection system [21].

Can something be done to discourage people from entering the MSA? Namely, there are two types of factors that influence the willingness of individuals to enter MSA. One is attractive and the other is repulsive factors. The attractive factors refer to everything that makes individuals decide to enter the MSA, and the repulsive factors are the fear of stepping on a mine and legal sanctions for illegally entering the MSA. It is the repulsive factors that represent the space where something can be done.

First of all, we need to break the illusion that mines are no longer dangerous after so much time. It should be seen in which areas and which groups of citizens enter the MSA. Accordingly, a territorially and content-oriented campaign should be made on the real danger of mines for target groups (primary and secondary schools, hunting clubs, etc.).

As for illegal entry into the MSA, we can say that the sanctions prescribed by law are appropriate, but not certain.

In order to find people who illegally enter the MSA, it is necessary to take several measures:

1. Detect entry points in the MSA,
2. Place MSA signs at these locations,
3. Place ramps, if it is about entering with vehicles,
4. Ramps should be placed under video surveillance.

The interior of the MSA can be monitored from the air in order to see any changes caused by human influence. There is a possibility of chronological comparison of satellite images, and nowadays an even better view can be obtained by recording the area with unmanned aerial vehicles. By using special cameras, the display can be even more specific.

There is still the problem of entering the MSA from the territory of neighboring countries. That part must be regulated through interstate cooperation.

By taking the mentioned measures, we would gain insight into the state of the MSA. Illegal entry would be sanctioned more often than before. This would certainly lead to fewer victims, and it would also significantly affect other security problems arising from this issue, which are described in this text.

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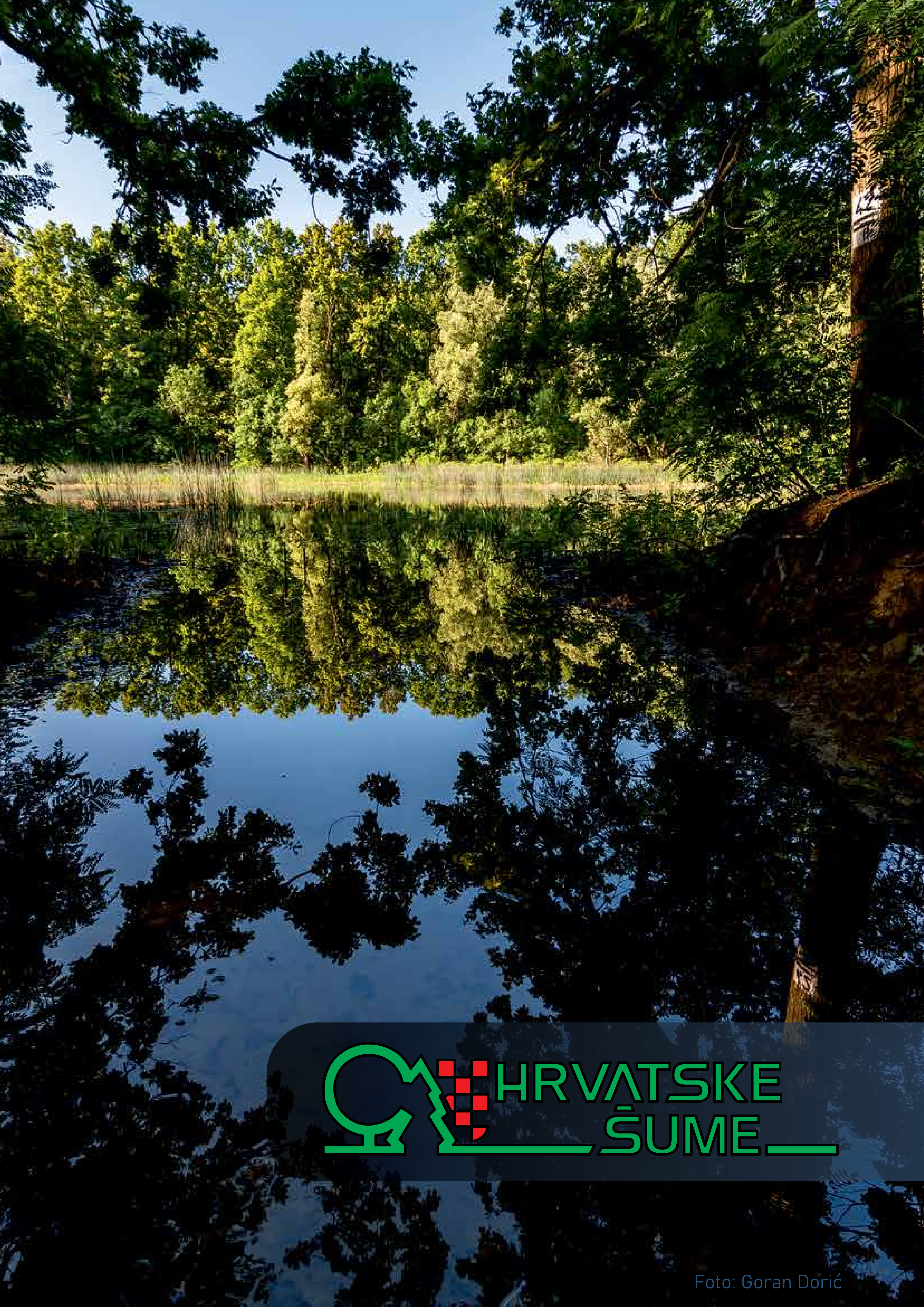

Foto: Goran Dorić

MINE VICTIMS

Safer Together - International cooperation of NGOs of Croatia and Ukraine

Adlešič, Đurđa[1]; Boltižar, Mihaela[2]

The cooperation between Croatian and Ukrainian NGO-s, „Croatia Helps“ and „Ukrainian Deminers Association“, started in 2021 with the planning and implementation of the project *Safe movement-mine prevention education for children and youth, Croatia and Ukraine*. During the implementation of the project, the aggression against Ukraine began, which increased the importance of the project activities, that, due to good partnership cooperation, were not stopped despite the war.

In 2021, the project team and lecturers visited Kyiv and Kharkiv and held lectures there for members of the partner association. The topics of the lectures were related to the Croatian experience of mine action and working methods in the last 20 years. As part of that visit, several meetings were held, and the result of one of them was the signing of an agreement between the Croatian Center for Testing, Development and Training and the State Emergency Service of Ukraine (SESU).

Picture 1-Kiev lecture

In the continuation of the project in the summer of 2022, psychosocial empowerment for Ukrainian children was organized. The first group of children consisted of girls and boys between the ages of 9 and 14 who, together with their parents, mostly mothers, found refuge in Croatia, in the city of Osijek and its surroundings. In June, they spent 10 days at the Red Cross resort of the City of Zagreb in Novi Vinodolski. Two months later, with the help of the Ministry of the Interior, the organization of the arrival of children from Ukraine, also between the ages of 9 and 14, children of Ukrainian veterans, firefighters, policemen and civil protection workers, was successfully implemented. A stay for them was also organized in Novi Vinodolski, and they were accommodated in the resort of the City of Bjelovar, which helped in the entire organization. During the stay, in addition to an active holiday, lectures on safety were also organized for the children: how to recognize explosive devices and how to react in case of danger.

The positive experience in the implementation of the Safe Movement project encouraged further cooperation between the two associations, which resulted in a new application to the tender of the Ministry of Foreign and European Affairs at the end of 2022. When creating the framework of the project, the current needs of the partner association were taken into account, which is the transfer of knowledge in the field of working with mine victims, the inclusion of veterans in the process of mine awareness education, and the continuation of the psychosocial empowerment of children. The Association Croatia Helps has many years of experience and a team of experts in the field of mine awareness education, and it is the only association that actively includes war veterans in this form of information.

Picture 2-anti-mine education, search dogs

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The idea of veteran-lecturers was created by combining the needs of different target groups: inclusion in society of war veterans and training and informing the civilian population about the dangers of mines and explosive devices. In this way, veterans who have theoretical and practical knowledge about explosive devices and their handling are strengthened psychosocially. At the same time, their lectures are alive, memorable and convincing to listeners of all age groups, precisely because of the fact that they had direct contact with mines and UXO. Croatian experience gained in the period from the Homeland War to today in the field of mine action issues is valuable to Ukrainian partners who can replicate Croatian methods on their soil.

Therefore, as part of the project *Safer Together*, the "know-how" of Croatian experts will be transferred to the members of the Ukrainian Deminers Association and their professional team. There will be six lecturers who will cover the following topics: inclusion of veterans as lecturers, methods of communication, teaching methodology, creation of a database on mine victims, ways of empowering mine victims.

The second part of the implementation is related to the continuation of the good practice of working with children from war-affected areas. Already at the beginning of the project, in February, the stay of the first group of children in Zagreb was organized. Support for the implementation of this activity was provided by the Police Academy "First Croatian Policeman" from Zagreb, where a group of 30 children and 4 educators were accommodated during their stay in Croatia. A rich educational, sports and cultural program has been prepared for the group. They spent part of their stay in Istria and visited Brijuni, the Pula amphitheatre and the observatory. They were received in Zagreb by the Speaker of the Croatian Parliament Gordan Jandroković and the Minister of Foreign and European Affairs Gordan Grlić Radman, and they were joined by the Ambassador of Ukraine to Croatia Vasilj Krilič. They had the opportunity to hang out with their peers from the nearby elementary school, visit the Neanderthal Museum in Krapina, and play sports. Daily activities provided the children with a break from the harsh reality in which they currently live. Children's reactions to the programs prepared for them are extremely positive.

Picture 3-February 2023, Ministry of Foreign and European Affairs

The arrival of the second group is currently being prepared, which is expected to arrive in June and will stay on the Adriatic coast, more precisely in Istria. The program will also include mine awareness education and introducing children to proper behaviour when dealing with explosive devices. All project activities are financed by the Ministry of Foreign and European Affairs of the Republic of Croatia.

The goal of this project is to reduce the possibility of casualties from mines and explosive devices of the entire population. That is why it is important to include as many people as possible in education, so that knowledge can be dispersed. The Croatian case shows a positive trend and correlation between the increased number of mine awareness education and the reduction of mine victims. The fact is that the danger does not end when the war ends, but there is still a very high possibility of casualties, especially for specific groups of society that move in suspected hazardous areas. The demining process will take a long time, and during that time it is important to work on the prevention of casualties.

MIS

SCELLANEOUS MINE ACTION TOPICS

Independent technical assessment of HCR – CTRO Test sites Benkovac and Cerovac

Branislav Jovanovic[1]

Abstract: The Independent technical assessment of HCR-CTRO test sites Benkovac and Cerovac was performed in the way to validate existing data and suggest possible improvements. When the focus is on marketing, the decision to make this assessment possible is sporadic in the explosive ordnance sector and, therefore, very significant.

In the last few years, we have witnessed the "booming" of new technologies and methodologies in the humanitarian demining and explosive ordnance sector. The lack of adequate test sites in the civilian sector presents a bottleneck to future development, especially in the assessment of application of developed solutions. These situations force most testing to occur in real (uncontrolled) conditions. These facts lead to the impossibility of standardisation of testing and the possibility of repeating the results. This independent technical assessment analysed the Test sites Benkovac and Cerovac and suggested future improvements.

Keywords: Humanitarian Demining, testing, training, explosive ordnance, landmines, independent, assessment.

Introduction

Croatian Mine Action Centre – Centre for Testing, Development and Training (HCR-CTRO) Ltd. was established as the first institution performing testing, research, development and education in the field of mine action in the Republic of Croatia.

The main aim is to conduct systematic trials, field tests, and evaluations of mine detection technologies and techniques, engage in R&D projects, and implement training courses in the field of mine action. Also, the primary purpose of establishing the Centre was to upgrade and improve mine action activities in Croatia and assist other mine-contaminated countries in organising and managing demining activities.

Among others, HCR-CTRO for this purpose uses two test sites:

Test Site Benkovac

Outdoor test facility intended to test and evaluate handheld mine detection systems, vehicle-mounted systems, robotic systems, UAV-mounted systems and biological detection methods.

Test Site Cerovac

The test site tests demining machines, mine detection dogs, metal detectors, PPE and new technologies.

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Independent Assessment

We had generous support from the HCR-CTRO at every stage of this assessment, but the views expressed herein are entirely EOKHUB's.

Although independent assessment is nothing new, the explosive ordnance sector is rare. The reasons are numerous and mainly personal.

About

An independent technical assessment (ITA) objectively evaluates a system, process, or product conducted by an independent third-party entity. An ITA aims to provide an unbiased assessment of the technical aspects of the system, process, or product to identify potential issues, risks, or opportunities for improvement.

The key benefits of an ITA include identifying technical issues before they become problems, providing an objective evaluation of a system or product, and improving the quality and performance of the system or product. ITAs can also provide stakeholders with confidence that the system or product is functioning as intended and is secure.

Overall, an independent technical assessment can be a valuable tool for organisations to ensure the technical integrity of their systems, processes, and products.

This type of assessment is essential for sector development, and we hope that time will show up.

HCR-CTRO Test sites

In communications with HCR-CTRO management, we point to the Test site as one of the uniqueness of the organisations in the civilian explosive ordnance sector. The agreed time frame was 6 months for the entire assessment. The biggest challenge was not to interfere with day – by day activities of the organisation and keep this activity below the radar to get as much as possible realistic results.
Both sites are specifically built with the purpose.

Test Site Benkovac

Test area (m^2): 10.000 m2
Office facility: Size: 35 m2

Figure 1: Test Site Benkovac

Outdoor test facility intended to test and evaluate hand-held mine detection systems, vehicle-mounted systems, robotic systems, UAV-mounted systems, and biological detection methods.

Three different soil types:

- original soil – uncooperative soil
- soil from the continental part of Croatia – cooperative-neutral soil
- local soil from the test site – uncooperative and heterogeneous

1000 landmine targets were buried in 2000.

Use of explosives: Using explosives is allowed, but activation is not allowed. Use of ignition devices and live mine fuses is not permitted.

Test lanes/areas

The test site is divided into 47 lanes.

- 39 lanes - blind test
- 47 m long and 1 m wide, landmines are buried at 5-27 cm deep. The distance between the lanes is 3 m. The lanes are divided into 1×1 m squares, their furthermost points are marked. There is a 3 m wide area along the fence, and an 8 m wide area at the entrance, where the office facility is placed and where preparation and training are conducted.
- 8 lanes - training and testing lanes with publicly known locations of landmines
- three types of soil:
- 2 lanes: – neighbouring area soil – uncooperative soil
- 2 lanes: – soil from the continental part of Croatia – cooperative-neutral soil
- 4 lanes: – local soil from the test site – uncooperative and heterogeneous

Weather conditions enable the use of the test site all year round. There is almost no snow or frost, and the rains are rare.

Targets

In the area intended for blind tests, there are 810 mines, 449 false alarm objects and 457 empty spaces.

Figure 2: AP landmine (Yugoslav PMA-3)

The following types of mines are buried:

- AT landmines: TMM-1, TMA-1A, TMA-2A, TMA-3, TMA-4, TMA-5, TMRP-6
- - AP landmines: PMA-1A, PMA-2, PMA-3, PMR-2A/2AS, PMR-3, PROM-1

The following types of mines are provided for training and testing:

- AT landmines: TMM-1, TMA-3, TMA-4, TMRP-6.
- AP landmines: PMA-1A, PMA-2, PMA-3, PROM-1

Supporting equipment

There is a weather station at the test site.

Year	Activities	Beneficiary
2003-2005	Reliability tests of metal detectors	BAM (Federal Institute for Materials Research and Testing – Germany)
2003	Demonstration of the work of CEIA metal detectors	AKD Mungos
2003	testing of technical performance of metal detectors	CROMAC
2006	testing of Japanese robotic buggies and mine detection dual sensors (Mine Hunter Vehicle -MHV1 i MHV-2, Gryphon, ALIS)	Tohoku University
2006	STEMD project – systematic test and evaluation of metal detectors used in the region of Southeast Europe	BAM (German Federal Institute for Material Research and Testing)
2006	testing of a mine detection scanner in collaboration (HUMIN/MD project)	Fraunhofer Institute, Germany
2007	testing of Japanese dual sensor systems ALIS (Advanced Landmine Imaging System) i Gryphon + LAMDAR IV	Tohoku University
2012-2017	TIRAMISU project within the EU FP7	EU TIRAMISU
2014-2018	Various trials	Manchester University
2016-2019	Various trials	St. Andrews University
2018 – 2019	R&D of metal detectors, field trials	Faculty of Electrical Engineering and Computing, University of Zagreb
2018-2021	NATO SPS project biological method (bees) for Explosive Detection	NATO SPS
2019	Testing of a drone survey system	SeaTerra GmbH
2022	field testing and data collection with a UAV 3D GPR system	KONTUR AS
2022	testing of fully integrated detector units	Manchester University
2022	MineKafon airborne demining system	The GICHD with support from the HCR-CTRO

Table 1: Partial list of past tests

Results

All landmines are buried, and they are visibly ageing. False alarms are of different sizes and shapes. The area is flat and without any obstacles.

The test site was designed for the landmine risk dominated in the Republic of Croatia when the test site was built.

This site has several strengths:

- One of the main strengths is that landmines and scrap metal are more than 23 years in the ground.
- This type of test site allows repeating testing and comparing the results.
- Good logistic support
- Vicinity of airport, port and hotel.
- Almost ideal weather conditions

Interestingly, the main strength of the Benkovac test site is, at the same time its main weakness.

- It is not possible do extend the site,
- The site is limited to the already set soil types.

What is possible:

- Equipment for long-term measurements of the Earth's magnetic field,
- Set the geodetic reference point on the site.

Test Site Cerovac

Total area: 55ha

Office size (m^2): 75 x 2

Use of explosives up to 10kg TNTe is allowed The test site tests demining machines, mine detection dogs, metal detectors, PPE and new technologies.

Figure 4:
Test site Cerovac

For performance tests of demining machines, three lanes with different soil types have been set up in accordance with the CWA 15044: topsoil, sand and gravel for controlled testing of demining machines. Survivability tests are performed with live mines.

For testing and certification of mine detection dogs and handlers, 66 testing boxes have been set up according to IMAS 09.42: Operational testing of Mine Detection Dogs and Handlers.

Test lanes/areas

At the part of the test site intended for performance tests, three different test lanes contain topsoil, gravel and sand. The lanes are 50 m long and 4,5 m wide.

Survivability tests are performed on a separate area covering 13,330 m^2.

Targets

Survivability tests are performed with live AP and AT mines. The number and type of mines depend on the machine being tested (light, medium or heavy).

Supporting equipment

- soil compactness measuring device
- temperature and humidity measuring device

Testing of Mine Detection dogs and handlers

Figure 5: Testing according to CWA 15044

66 testing boxes according to IMAS 09.42: Operational testing of Mine Detection Dogs and Handlers

6 kernels for acclimatisation

Other trials in the past

- PPE
- non-linear junction detectors, control wireline detectors
- biological methods

Security

The test site is fenced off.

Results

The Site is well known, especially to the manufacturers of demining machines and MDD owners. Another test could have been more consistent.

Test Site Cerovac has several strengths:

The test site allows the development of different scenarios with a focus on the new global threat and experience.

The proximity of the head office and classrooms in Zagreb allows the site to play an essential role in EOD and IEDD training and specialised workshops.

Possibility to use explosives it’s an advantage.

In recent years, worldwide conflicts have shown the increasing use of improvised landmines/IEDs, especially in urban areas. It’s not rare that at one location, a combination of different risks is not only limited to the explosives but very often chemicals, underground objects, height, falling objects etc.

Using the new technologies supported by artificial intelligence and machine learning is increasingly present in the fields. Due to the complexity of the technology it requires plenty of information from the controlled environment. Gathering data in a realistic but, at the same time, controlled environment is essential for AI/ML applications.

Globally there is no exciting “one-stop place” for testing, training and evaluation of this type of equipment and training of this type of personnel.

Conclusion

In the last few years, we have witnessed the “booming” of new technologies and methodologies in the humanitarian demining and explosive ordnance sector. The lack of adequate test sites in the civilian sector presents a bottleneck to future development, especially in the assessment of application of developed solutions. These situations force most testing to occur in real (uncontrolled) conditions. These facts lead to the impossibility of standardisation of testing and the possibility of repeating the results.

Figure: Example of computer vision technologies in mine action
Credit: https://vframe.io/

Development of mine action ecosystems

Dr. Karoly Nagy[1]

Abstract: Ecosystems are efficient "tools" to support the functioning of highly complex systems, processes that occur in holistically managed branches. One of the main reasons for the proliferation of use ecosystems is the circumstances of the so-called VUCA world, the VUCA environment. The term VUCA has become very popular. VUCA stands for volatility, uncertainty, complexity, and ambiguity. It describes the situation of constant, unpredictable change that has become the norm in certain industries and areas of the business world. VUCA requires you to move away from traditional, outdated approaches to management and leadership, as well as day-to-day operations. The world of humanitarian operations differs from the VUCA world in that there is another factor of difficulty. That is hazard. Borrowing from the humanitarian mission environment, we can use the term VUCAH (volatility, uncertainty, complexity, ambiguity, and hazard). The new definition of ecosystem points to a new way to support humanitarian projects and action programs. According to this definition, an ecosystem is a specific, artificial environment of a system or process that helps to balance the internal diversity of that system or process with the diversity of the wider environment. An ecosystem enables the supported system to more easily and cost-effectively act as a buffer to mitigate the harmful and dangerous effects of the VUCAH environment and to mediate between the different actors of humanitarian missions. This study briefly presents the main benefits of ecosystems, focusing on mine action projects and action programs. It also summarizes the findings of the theoretical and methodological basis for humanitarian ecosystem development.

Keywords: mine action, humanitarian ecosystem, humanitarian open diplomacy, responsible innovation, transformative research, security, resilience, process integration and synthesis, VUCAH.

Introduction

A 2003 report by RAND's Science and Technology Policy Institute for the Office of Science and Technology Policy assesses the potential of innovative mine detection technologies to accelerate the clearance of the 45-50 million landmines in the world. The Office of Science and Technology Policy commissioned the report because it was concerned about the slow pace of humanitarian demining. The RAND assesses the situation as follows, "The United States currently invests about $100 million annually in humanitarian mine clearance-the largest commitment of any country. Despite this investment and funding from many other developed nations and non-governmental organizations, clearing all existing mines could take 450-500 years at the current pace" [1]. Since the RAND report, the situation with mines and explosive remnants of war has not improved. Therefore, the international humanitarian community must pay special attention to the problems created by the war in Ukraine. Based on our research results, the development of demining ecosystems can significantly improve not only the efficiency of detection and clearance of antipersonnel mines, but also all other pillars of demining. As Jean-Baptiste Richardier, co-founder of Handicap International, has said, "mine action is an essential component of humanitarian assistance"[2]. This is why we have developed a demining ecosystem. Moreover, we can say that a mine action ecosystem is in fact a humanitarian ecosystem.

The concept and basic considerations for the design, development and management of an innovation ecosystem are based on the previous research results published in prestigious international conferences and scientific journals with high impact factor [3], [4]. These results have been adapted to support the development of humanitarian ecosystems. What are the main benefits of "ecosystem support" of mine action? As examples, we can first mention the following three.

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First, integrating mine action into unity with other humanitarian, innovative, and development activities opens the way to "integrated mine action" AUSTCARE's excellent initiative is defined as the next: "integration with development, which refers to the potential of mine action to reduce the direct and indirect impacts of landmines while contributing to economic and social development" [5]. Within the ecosystem, we can integrate the mine action with responsible innovation [6]. In this way, mine action directly serves the achievement of the Sustainable Development Goals. Second, the ecosystem provides the opportunity to overcome the barriers to full development of innovative technologies [7]. Third, leveraging the ecosystem provides an answer to the question of how charities can maximize their future fundraising potential [8].

The methodology used is the transformative research approach [9]. In 2007, Dr. Arden L. Bement, Jr. said, Director of the National Science Foundation, "Transformative research: the art and alchemy of the 21st century."[10] The results of the theoretical and methodological foundations of the development of mine action ecosystems as humanitarian ecosystems provide a solid basis for the practical use of this efficient humanitarian tool to help not only the people of Ukraine in the fastest, most concrete and safest way, but all over the world where repatriation areas are still heavily contaminated with millions of mines and other remnants of war.

Humanitarian ecosystem

My definition of an ecosystem is the following, "An ecosystem is a specific, artificial environment of a system or process that helps to balance the internal variety of the given system or process with the variety of the wider environment". This definition is based on Ashby's law of required variety. "His "law" of required variety states that a system can be stable only if the number of states that its control mechanism can achieve (its variety) is greater than or equal to the number of states of the system being controlled" [11].

An ecosystem allows the supported system to be simpler and more cost-effective as a buffer to mitigate the harmful and dangerous effects of the VUCA environment (volatility, uncertainty, complexity, and ambiguity) and to mediate between the different actors interested in the functioning of the system. The world of humanitarian missions differs from the VUCA world in that there is another factor of difficulty. This is the hazard. Following the context of humanitarian missions, we can use the term VUCAH (volatility, uncertainty, complexity, ambiguity, and hazard). Here we use the term hazard following the IFCR definition [12]. We must emphasize that our VUCAH concept is different from, for example, Mercer's or SAY-U Consulting's concept, where VUCAH is an acronym for the English words Volatility, Uncertainty, Complexity, Ambiguity and Hyperconnectivity [13].

The basic principles of the development and management of humanitaria ecosystems

Based on our research findings and experience, the following principles should be considered in the design and development of humanitarian ecosystems:

A. Create real systems and work with them. The most important principle is to ensure that the humanitarian system or process is a real system, or a process that operates within the context of a real system. Not only in everyday life, but also in pseudoscience, there is a very harmful practice of using the term "system" like a buzzword. Here it is simply a matter of the fact that we cannot say that something is a system without this statement being prepared. The system is always man-made [3]. Only real systems can be supported through an ecosystem. We must ensure the existence of the same condition in the development of the ecosystem. The system theory consists of the system criteria [14], [15].

B. From the first moment of development of the humanitarian ecosystem it is necessary to explain what kind of humanitarian mission should be implemented.

C. The development of a humanitarian ecosystem must have a strategic perspective. Real strategies focus on satisfying the virtual (future) needs of the society and not on solving the current problems. Therefore, it is a big mistake to define the satisfaction of effective needs as a strategic goal.

D. The holistic principle should be followed in the development of the innovation ecosystem, as introduced by Russel L. Ackoff [16].

E. A humanitarian ecosystem must have a dynamic character. An ecosystem is an ever-changing structure that adapts to new needs and new circumstances.

F. Decisions about the strategy for designing, developing, and operating humanitarian ecosystems must be made between developers and key stakeholders on a consensus basis [17].

G. Due to the high degree of hazard and danger in the VUCAH environments of humanitarian operations, we need to return from the popular "resilience approach" to the much more complex "security approach." The resilience approach is not sufficient to create a positive synergy that constantly neutralizes negative synergies that lead to system breakdown. This means that the resilience approach is not able to reduce the mismatch between the threats to the assets to be protected and the available countermeasures [18]. From now on, it will be much safer to work in extreme conditions in humanitarian operations.

Initiating, designing, developing, and operating a humanitarian ecosystem is an extremely difficult task. The main characteristic is that there is no place for centralized management, if only because of its complexity. Everything has to be based on networked solutions. The most problematic issue is the financing of the above tasks. It is related to the ongoing research on the relationship between "fictitious capital and fictitious money to finance the humanitarian mission". In medias res, we can say that due to the fundamental nature of fictitious money [19], it is impossible to spend it for good purposes. This is closely related to the hopefully successful post-conflict reconstruction in Ukraine. It seems that the billions now spent on weapons cannot be converted for reconstruction and development. But this is only a research hypothesis now and to prove it, a lot of work needs to be done.

Ecosystem management should be networked [17]. The functioning of these fully networked systems is based on a new culture and knowledge of coordination, collaboration and cooperation, and the ability to reach consensus [20]. Education and training of the experts and managers needed to develop and operate humanitarian ecosystems is an ongoing process. Currently, a curriculum for an MSc course in humanitarian assistance is being developed in close collaboration between two universities, a mine action center, and a global association. The course is based on the theoretical and methodological foundations and best practices of open science, science communication, humanitarian diplomacy, and open diplomacy [21]. In addition, the thematic content of the course consists of various elements of engineering and other sciences. As agreed by the parties, the diploma obtained entitles the student to hold the title of Humanitarian Open Diplomacy Ambassador (HOD Ambassadors), awarded by the Global Association in accordance with the provisions of the Accreditation System for HOD Ambassadors (ASHA) operated by the Association and the Association's Code of Ethics. HOD Ambassadors are independent civilian experts in the field of humanitarian assistance. The main task of the HOD Ambassadors is to organize the solution of such humanitarian problems where the official "state" diplomacy does not get anywhere.

Future research

The results obtained will determine the main directions of future research. One of them is the integration of IMAS enforcement and ISO quality management processes into a unified system where quality is constantly measured [20] . Thank you to this system, we can talk about quality cost analysis. By analyzing the cost of quality, mine action organizations and institutions can determine where they can optimize their costs. The other major advantage of process integration comes from the fact that the use of ISO standards is essential in all post-conflict reconstruction processes. For example, through process integration and synthesis of IMAS and ISO, ISO will serve as a "carrier frequency" for IMAS 07.14 or IMAS 12.10 to continuously reduce mine casualties. The other interesting direction is research related to the "fictitious money problem" mentioned above. The third direction relates to the innovation of demining technologies addressed by the RAND report. This is about the development of quantum sensor technologies to support mine detection using high altitudes payloads. The practical deployment of these technologies is truly a task that cannot be accomplished without ecosystem support.

Conclusion

A humanitarian ecosystem allows us to take a truly effective approach to the problems of humanitarian programs and projects, especially in demining operations. Due to the extremely complex nature and wide-ranging interests of stakeholders, the creation of a humanitarian ecosystem could be based primarily on networked initiation. This also applies to the design, development, and operation of the humanitarian ecosystem. We need experts and managers who can efficiently coordinate, cooperate, and collaborate with each other and with humanitarian mission actors under extreme conditions. An important task is the continuous development of the methodology and theoretical basis of this work. The still missing education, training, teaching and organizational conditions must be created and integrated into a unified system with the existing ones. All this work must be based on voluntary efforts and initiatives. It is necessary to gain the support of humanitarian sponsors, national and international institutions for the creation and development of humanitarian ecosystems. The role of the pioneer in this development process must be assumed by the mine action professional community, because thanks to the IMAS standards, the mine action is the best regulated field in the humanitarian sector. Based on broader collaboration and cooperation between the global community of mine action centers and other humanitarian organizations and institutions, the humanitarian community will be able to respond to current and future humanitarian challenges by launching strategic initiatives that will allow us to develop system-specific solutions based on interdisciplinary research.

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GICHD study on "Difficult Terrain in Mine Action"

Alain Nellen[1], Armen Harutyunyan[2]

Abstract: *Many countries have experienced slower progress in meeting land release obligations under treaties and conventions, partly due to difficult terrain, which impedes access to worksites and hinders the use of preferred survey and clearance methods. Physical constraints such as high elevation, water obstacles, sand, dense vegetation, seasonal variation and weather, remoteness as well as human factors related to restrictive legislation, social and cultural considerations, and border areas, make land release procedures (survey and clearance) even more challenging. Therefore, the study on difficult terrain in mine action, conducted by the GICHD, highlights some of the challenges and good practice examples associated with difficult terrain in several affected countries and territories. Some of the solutions described in this study include, better planning, better data for better results, improve use of technology, government and community involvement, multi-stakeholder partnerships and adaptive land release strategies. This paper is a shorter version of the study that can be accessed through the GICHD website.*

Introduction

This is a shorter overview of the Difficult Terrain in Mine Action study[3] conducted by the GICHD in 2021-2022.

The objective of this study was to assist mine action stakeholders in documenting and disseminating knowledge and good practices when it comes to land release operations in difficult terrain.

In order to identify global key challenges and good practices, an open sources desk review was conducted including mine action related information platforms, treaties and conventions reports, as well as extension requests. Additional information was gained through remote consultations with mine action stakeholders, as well as through GICHD internal sources in the form of previous studies, field visits and assessments. More detailed examples linked to several mine action programmes, and a good practice matrix, can be found in the original study[4].

Definition and scope

This study uses the following definition of difficult terrain in the context of mine action:

Difficult terrain is land where inflexible physical constraints or human factors render it challenging to access or release suspected or confirmed hazardous areas.

Several physical constraints are included in the study; **high elevation, steep slopes and cliffs, dense vegetation, water obstacles, sand dunes and sandy beaches, seasonal variation and weather, and remoteness**. Operations facing such constraints are often further complicated by human factors related to **legislation, social and cultural considerations, and border areas.** Such factors can also result in terrain being classified as difficult, as they often influence the everyday planning and implementation of land release operations. It needs to be noted that some constraints have been excluded from the study, such as soil composition, depth of contamination and security concerns.

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3 GICHD Difficult Terrain in Mine Action, March 2023, https://www.gichd.org/en/resources/publications/detail/publication/difficult-terrain-in-mine-action/

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Analysis – challenges and good practices

The removal of **vegetation** during mine clearance operations takes up a significant amount of time and effort, as seen in Cambodia, vegetation removal sometimes takes up to 70% of the total time spent on mine clearance. Land release operators use mechanical and manual vegetation-cutting assets to increase productivity and minimise costs in contaminated areas with high and dense vegetation. The use of mechanical assets, such as chainsaws and remote-controlled vegetation-cutting machines, has resulted in a significant increase in clearance rates per deminer per day. The presence of vegetation poses safety and efficiency concerns for land release operations, particularly in areas with tripwire threats. For example, in Croatia, the deployment of mechanical assets and mine detection dogs has contributed to high productivity, while in Kosovo, land release operators have improved the standard operating procedure for battle area clearance by allowing land release operators to walk on uncleared areas to cut vegetation in the areas affected by cluster munition strikes. In some circumstances, cutting vegetation has an environmental impact, where legal and ecological implications must be considered.

Land release operations in **high elevation** areas face numerous challenges due to geographical and topographical factors. The terrain in such areas is more energy and resource-intensive. For example, in Lebanon and Tajikistan, land release tasks in high altitude are difficult to access, requiring specialist training and equipment. Bosnia and Herzegovina and Croatia also have predominantly mountainous terrain, making demining complex and challenging. National authorities in these countries use topographical maps and digital orthophotos to model the operational difficulty of demining and determine the size of the task and optimal assets for each hazardous area. However, conducting surveys and manual mine clearance in high mountains is physically taxing and requires workers to obtain a doctor's attestation of fitness for work at high altitudes. The sparsely populated areas also pose a challenge for non-technical surveys, leading to lower confidence in survey findings. To overcome this, multidisciplinary teams in Tajikistan conduct non-technical and technical surveys simultaneously rather than sequentially. National authorities also permit deviation from the criteria established for use in open areas in hazardous areas where a sheer cliff is within the 'fade-out' area.

Mines are sometimes placed in **water** in areas like tidal zones and shallows of lakes or rivers, creating challenges for clearance efforts when heavy rainfall causes flooding. Floods can displace mines and make it difficult for people to access the area safely. Water obstacles also hinder or prevent traditional mechanical clearance methods and require specialised equipment and skills such as boats and diving capabilities. The issue received renewed attention during flooding in the Balkans in 2014, and wetlands and marshes in areas like north-eastern Croatia are subject to seasonal flooding and pose challenges to clearance efforts. Land release operators must take into consideration the additional time and resources required during wet conditions, and an operational pause is considered if the amount of water on the ground prevents them from performing work of good quality. Boat access is sometimes necessary in hazardous areas, and this is indicated in the tasking documentation.

Several countries have encountered hazardous areas in **sandy terrain**, including the Falkland Islands/Malvinas, where land release was conducted on sandy beaches that contained extensive dunes and rocky outcrops. The sand in the hazardous areas was very fine and easily shifted by winds. To mitigate the challenges of working in sand, measures were identified in an environmental impact assessment, including stabilising sand dunes and replacing excavated sand in a way that allowed natural reformation of sand dunes. The land release operator used a three-dimensional approach to locate the mines, but the machinery used disrupted the original layout of the minefields. To address the risk of missing mines, wider and deeper sections of land were cleared. The deployment of mechanical assets was deemed superior due to its speed and safety, despite potential disadvantages.

Extreme **weather conditions,** such as heat, cold, wind, rain, and snow, can also significantly impact land release operations, affecting the safety and productivity of deminers and animals, as well as the effectiveness of machines. Seasonal considerations need to be factored into land release operators' work plans and survey and planning processes, including the assessment and prediction of future hazardous areas' accessibility. Local infrastructure availability to mitigate seasonal conditions, such as the availability of the fire service during dry spells or shade in summer, should also be taken into account. Some mine action programmes regulate certain aspects of land release operations in relation to seasonal variations, limiting the number of working days, for example. Refresher training or workforce-wide annual leave may also be taken during periods of inclement weather. Protective gear, such as wide-brimmed hats, sunglasses, and waterproof clothing, is essential to protect deminers from the sun, cold, rain, mud, and snow. It is crucial to consider the vagaries of seasons and problematic or changing terrain from the earliest stages of the planning cycle to ensure the necessary resources and time are allocated to the task. Climate change can cause weather extremes to become more regular, making this even more critical.

Social and cultural considerations in the form of social cohesion, local cultures and norms, areas of national sensitivity as well as the local population's perception of `outsiders` are essential components to be considered during land release planning and implementation processes as seen in the Falkland Islands/Malvinas, Denmark and Tajikistan. Engaging communities is also vital because local knowledge of available resources, topography and weather patterns for example, is crucial and contributes to the data gathering techniques. However, obtaining this knowledge requires careful explanation, and the trust of local communities that particularly land release operators and national authorities must build.

Remoteness of a hazardous area poses additional significant number of challenges for land release operators. Those challenges can be access and the provision of necessary resources, services and support such as transportation, communication, food, water and medical care including accident-related emergency evacuation. Addressing these obstacles should take place during the operational planning process by considering local services, infrastructure and knowledge of the operational site, as well as having a mindset of adaption and problem solving but not undermining the safety and wellbeing of deminers. This is important to sustain the quality of the operation by establishing realistic timeframes and potential set up of a temporary camp site, determining staff hiring procedures and allocating sufficient resources (in terms of both finance and equipment). To overcome the remoteness and other obstacles, land release operators have sometimes built their own access roads, repaired bridges. Tajikistan and Thailand for example, have adopted their land release strategy by using additional assets like boats, motorbikes or helicopters through a multi-stakeholder approach to access the remote operational site and/or for medical evacuation.

Apart from physical constraints, **legislation (**national laws, standards and other legislative and normative frameworks) also can contribute to increased complexities and need for adaptions in planning and implementing land release operations. This might lead to the use of more expensive methods and slower or less efficient process. Often the fastest way to clear a hazardous area might disrupt threatened habitats, flora and fauna. For example, Croatia`s mine action activities are governed by laws, by-laws and regulations that are consistent with those of the European Union (EU) including environmental restrictions. Most remaining hazardous areas in Croatia are located within the EU coordinated network Natura 2000. Land release operators have to mark where eagle nests are detected, and operations within 400 metres of a nest are prohibited during the seven-month nesting period from January to July. Similar environmental related legislation has been witnessed in the Falkland Islands/Malvinas and Denmark.

Another complexity in land release operations is often in **border areas**, especially when frontiers are disputed or are not demarcated. Coordination and cooperation among governments and organisations are vital to address this challenge. For example, Thailand and Cambodia requested an extension in meeting their land release obligations mainly due to disputed border hazardous areas that several times resulted in suspensions of operations. Land release operations in border areas are increasingly linked to reconciliation, regional confidence and security-building measures. Regional and multilateral frameworks can play a vital role in contributing to the reconciliation process and depoliticise mine action.

Concluding thoughts

The impact of difficult (inaccessible and inoperable) terrain on land release operations is significant. However, recent years have seen increasing use of integrated information-management and data collection approaches and more complex detection and remote-sensing systems. Planning and implementing land release operations in difficult terrain requires local knowledge, and the trust of local communities. Sensible methods and procedures tailored to the terrain and specific circumstances have often been used to manage risk caused by obstacles. Time and resources must be given to data collection and planning, and stakeholders should ensure that adequate resources are available to enable reasonable mitigation measures to be put in place. National authorities should play a key convening role in identifying and obtaining agreement on measures that enable land release operators to operate safely, effectively and efficiently and ensuring that the sector is regulated in a balanced manner. Land release operators should continue to seek solutions for operating in difficult terrain and ensure candid and transparent feedback about the difficult terrain to the national and local authorities, donors, and communities.

The Integrated Cooperation on Explosive Hazards (ICExH)

Sonja Stanisavljevic[1] and Takhmina Akhmedova[2]

Abstract: Established in mid-2013, the overall goal of the Integrated Cooperation on Explosive Hazards (ICExH) programme is to address the risks related to explosive hazards in Central Asia. In particular the ICExH deals with Disposal and Demilitarization of Explosive Ordnance and Improvised Explosive Devices (IED) Disposal and its proliferation in the interested OSCE participating States in Central Asia with the underlying rationale behind that shared challenges and concerns regarding explosive hazards necessitates finding innovative approaches and synergies.

Key words: OSCE, ICExH, Explosive Hazards, Central Asia

Introduction

The Integrated Cooperation on Explosive Hazards (ICExH) programme is an Organization for Security and Co-operation in Europe (OSCE) initiated effort to improve the explosive hazards situation in Central Asia. The programme is developed by the OSCE Programme Office in Dushanbe (POiD) and is being implemented by its Countering Security Threats and Regional Cooperation Unit (formerly Mine Action Unit) of Politico-Military Department with the aim to:

1. facilitate regional cooperation and coordination, predominantly inter-military, and
2. provide long-standing support in building national and regional capacities on individual, collective or institutional level in the field of humanitarian mine action in Central Asia.

By championing the process of obtaining, strengthening and maintaining such regional networks and capabilities, the ICExH is trusted to enable Tajikistan and its neighbors in the Central Asian region to effectively, efficiently and self-reliantly address issues related to explosive hazards over time.

Longevous partnership nexus between the OSCE POiD and Tajikistan enables a seamless implementation of programme activities at the ground level. The Ministry of Defense of the Republic of Tajikistan provides training facilities, in-country logistics and national instructors, while Tajikistan National Mine Action Center (TNMAC) provides certification and validation of training programme.

This programme received financial support from the governments of Austria and the Netherlands in the past, while the Office of Weapons Removal and Abatement in the U.S. Department of State's Bureau of Political-Military Affairs (PM/WRA) has been funding the programme since 2014. The government of Germany through the OSCE Forum for Security Co-operation Support Unit's extra-budgetary assistance programme "OSCE Comprehensive Small Arms and Light Weapons (SALW) and Stockpiles of Conventional Ammunition (SCA) Repository Programme" has been providing funds since 2017. In addition, the ICExH programme is supported by the U.S. Army Central (USARCENT). USARCENT delivers regional trainings and provides high quality training ordnance, equipment, and aids to the training facilities.

This partnership and regional approach are built on a joint vision:

1. to enhance the capabilities of Tajikistan and Central Asian countries to counter explosive hazards;
2. to share knowledge, experience, and good practices among the experts in the field; and

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3. to identify and encourage horizontal and vertical synergies in support of regional cooperation on explosive hazards.

This goal is aligned with the national and regional targeted capacity development with the potential of well-tailored regional initiatives, such as ICExH, to significantly contribute to stabilization of the region in the context of confidence and security building measures (CSBMs).

Regional Context

The ICExH programme has been developed in response to the national and regional requirements and needs to address the risks of explosive hazards, including relevant international norms and agreements, political consensus to cooperate on regional security issues and support safe conduct of operations, and challenging political-military situation in Afghanistan and elsewhere in Central Asia. Over the time, the ICExH also recognized a general trend among participating States of Central Asia to anticipate regional cooperation that goes beyond humanitarian mine action, such as participation in the OSCE Confidence and Security Building Measures (CSBMs) and (UN) peace-keeping operations.

Although the scale and threat of explosive hazards vary in the region, the participating States of Central Asia and Afghanistan face similar challenges:

1. the illicit use and/or mistreatment, abandonment, and neglect of explosives;
2. unsafe storage and transportation of munitions; and
3. criminal and terrorist actions, among many other, mostly originating from the past or ongoing conflicts.

Such complex regional context calls for new innovative approaches with horizontal and vertical synergies. The ICExH identified the gaps in the regional coordination of mine action and offered new bottom-up approach based on training cycles of Explosive Ordnance Disposal (EOD), Explosive Ordnance Risk Education (EORE) and Training of Trainers (ToT), Physical Security Stockpile Management (PSSM) and conventional ammunition destruction, International Training Board (ITB) meetings and management trainings, Casualty Evacuations (CasEvac) and Medical Evacuations (MedEvac) trainings, and regional operational and technical, as well as experts and practitioners type of platforms for dialogues during study and exchange visits.

ICExH

The ICExH programme provides a system of mechanisms to support the participating States in the region of Central Asia in dealing with issues of explosive hazard. It offers an all-encompassing package to address challenges stemming from explosive hazards, which includes issues related to unexploded and abandoned explosive ordnance as well as landmines, other excess, unsecured and unserviceable engineering munitions and ordnance; and presence of booby traps, explosive and IED.

The key objective of the ICExH programme is to improve the overall hazardous situation in the region, including issues related to Explosive Ordnance Disposal (EOD), Demilitarization of Explosive Ordnance, and Improvised Explosive Devices Disposal (IED-D) in the OSCE participating States in Central Asia by:

1. providing targeted capacity development and technical assistance in responding to explosive hazards, and

2. fostering dialogue through regional cooperation in Central Asia.

Since 2013, the ICExH programme has conducted more than 43 training cycles on subjects related to explosive hazards with almost 630 participants from Central Asian region, Caucasus region, Eastern Europe and South-Eastern Europe. All training cycles have been prepared and delivered in close cooperation with USARCENT and in compliance with the International Mine Action Standards (IMAS).

In 2019, the ICExH constructed the Regional Explosive Hazards Training Centre (REHTC) under the Ministry of Defense of the Republic of Tajikistan with the aim to transfer ownership to national authorities and gradually handover its operations, which requires sustainable capacity building, risk management and response, and continuous efforts to ensure regionally (and foreseeably internationally) recognized and certified training cycles.

Over time the project has evolved from a narrow capacity building programme to a more complex programme with a concrete national ownership transition matrix:

(1) Training ▶ Mentoring ▶ Monitoring approach;

(2) Constructing, refurbishing and equipping the REHTC of the Ministry of Defense of the Republic of Tajikistan; and

(3) Providing a comprehensive set of indispensable measures to support process of becoming self-sustained institution with its distinct and organic organizational structure, functional roles and responsibilities, operational capacity, training programme and accreditation.

In this regard, in November 2022, the OSCE POiD developed the training institution development roadmap with the transition timeline. It was conceptualized through international and national experts' recommendations, which was endorsed by the Ministry of Defense of the Republic of Tajikistan in March 2023.

As the programme matures, the ICExH is to gradually transfer day to day operations to training center, while national authorities are to consolidate provided information, knowledge, experiences, and good practices into sustainable goal – for example, institutionalized cooperation on military education among participating States in Central Asia and Afghanistan in the field of explosive hazards.

Wider Impact

Although the ICExH programme originates in regional necessity to address challenges of hazardousness in a cross-border context, the prospect and impact of the confidence and security building aspects of the programme are widely being perceived as a "success story" by Central Asian participating States, other OSCE participating States, donors, expert community, and host nation.

The ICExH enhances and supports consistent technical explosive hazard coordination, multilateral capacity building and technical level dialogue, which simultaneously encourage and validate confidence and security building in Central Asia. Accordingly, it helps reducing threats to national and regional security posed by explosive hazards in the region, by providing technical and managerial expertise through its training cycles.

It offers assistance to participating States in Central Asia in aligning national regulations with the international standards. In addition, it supports aspirations of the region to participate in peacekeeping operations with their explosive hazard reduction and response capacities.

Finally, the ICExH project supports the wider role of the OSCE in mobilizing national and international actors, offering forum for political dialogue on an extensive range of security issues, and developing a platform for joint action among its participating States in Central Asia aiming to make a lasting difference.


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