

GOVERNMENT OF THE REPUBLIC OF CROATIA Office for Mine Action





## The 15<sup>th</sup> International Symposium "MINE ACTION 2018"

9<sup>th</sup> to 12<sup>th</sup> April 2018 SLANO, CROATIA

**Book of Papers** 













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## **The Ottawa Treaty -**A world without mines by 2025



#### Maputo Action Plan and Maputo +15 Declaration: Fulfilling the Mine Ban Treaty's Promise of a World Free from Landmines

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#### Introduction to the Mine Ban Treaty

The Treaty<sup>1</sup> was adopted in Oslo on 18 September 1997 by more than 90 states and opened for signing in Ottawa on 3 and 4 December 1997. As such, it was the result of joint action and cooperation between the non-governmental organizations (NGOs), at the international level led by the International Committee of the Red Cross (ICRC) and most notably the International Campaign to Ban Landmines (ICBL; for their persistence and determination in calling for the Treaty, the ICBL and its coordinator Jody Williams were awarded the Nobel Peace Prize in 1997), and the core group of states that included Austria, Belgium, Canada, Germany, Norway, South Africa and Switzerland. The unprecedented level of synergies that were forged between like-minded governments and non-governmental sector and civil society in the course of the Treaty's creation were instrumental in fostering negotiations and hosting diplomatic conferences (the so-called Ottawa Process<sup>2</sup>) that would ultimately lead to the adoption of one of the most successful humanitarian disarmament instruments in the history of multilateral diplomacy. The Treaty consequently entered into force on 1 March 1999 and currently has 164 States Parties representing more than 80% of the world's countries. The Treaty is rightfully considered one of the most widely accepted international treaties and one widely implemented. Overwhelming compliance by States Parties and others has meant almost universal acceptance of the mine ban. The annual United Nations General Assembly resolution on the anti-personnel mines has also been systematically gathering support among non-signatories. Furthermore, the Mine Ban Treaty is considered the first disarmament treaty with explicit humanitarian goals, imposing obligations for assisting victims, including social and economic reintegration of mine victims.

#### Key provisions of the Mine Ban Treaty

According to the Treaty, an "anti-personnel mine" means a mine designed to be exploded by the presence, proximity or contact of a person and that will incapacitate, injure or kill one or more persons (...).<sup>3</sup> States Parties commit "never under any circumstances" a) to use anti-personnel mines; b) to develop, produce, acquire, stockpile, retain or transfer them; and c) to assist, encourage or induce in any way anyone to engage in any activity prohibited by the Treaty. States Parties are obliged to destroy all stockpiles of anti-personnel mines within four years, and to clear mined areas under their jurisdiction or control within ten years. Nevertheless, States Parties are allowed to maintain a "minimum number absolutely necessary" of anti-personnel mines for permitted purposes, such as training in mine detection, clearance and

<sup>&</sup>lt;sup>1</sup> A shorter reference (used here for the sake of brevity) to the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction, also known as the Anti-Personnel Mine Ban Convention or even more popularly known as the Ottawa Convention.

<sup>&</sup>lt;sup>2</sup> For a detailed timeline of the most important events in this process see: https://www.apminebanconvention.org/ottawa-process/ overview/.

<sup>&</sup>lt;sup>3</sup> Article 2.1 of the Mine Ban Treaty

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destruction techniques. They also undertake to provide international assistance to other States Parties for implementing their obligations (e.g. mine clearance, victim assistance programs etc.). Other articles cover transparency measures and reporting by states, and ensuring compliance.

#### Organization of work of the Mine Ban Treaty

As stipulated by the text of the Treaty, its work is organized and guided through the annual Meetings of the States Parties (MSPs), convened by the Secretary-General of the United Nations, and Review Conferences (RCs), convened by the Secretary-General of the United Nations as well, in five-year review cycles<sup>1</sup>. MSPs thus serve to analyze the application or implementation of the Treaty, and in particular: the operation and status of the Treaty; matters arising from the reports submitted under the provisions of the Treaty; international cooperation and assistance; development of technologies for mine clearance; facilitation and clarification of compliance with the Treaty; and submission of requests and related decisions as provided for in Article 5. RCs provide States Parties with an opportunity to: review the operation and status of the Treaty; take decisions on submissions of States Parties as provided for in Article 5; if necessary, to adopt in its final report conclusions related to the implementation of the Treaty. In addition to this, the (Informal) Intersessional Work Program was created by the States Parties recognizing the importance of having a half-year assessment of progress in implementing Treaty's provisions. These Intersessional Meetings, unlike MSPs and RCs, are convened by the current President of the Treaty half-way between two MSPs.

Until now, the UN Secretary-General has

convened seventeen MSPs and three RCs.<sup>2</sup>

Apart from the work conducted by meetings and conferences, the Treaty is guided in its day-to-day functioning by its President (presidency starts at the conclusion of the previous MSP and concludes at the end of the following MSP), which is assisted in its work by the Coordination Committee set up of four thematic committees.<sup>3</sup> Finally, the entire machinery of the Treaty is supported by the Implementation Support Unit (ISU)<sup>4</sup>, the *de facto* secretariat of the Treaty which supports the States Parties and is directly accountable to the States Parties.

#### **Review Conferences in General**

As mentioned before, three review conferences had been organized so far; the first was held in Nairobi, Kenya in 2004; the second in Cartagena, Colombia in 2009; and the third in Maputo, Mozambique in 2014.5 The importance of review conferences lies in the fact that each one serves as the all-inclusive platform enabling meticulous assessment of the progress made in the previous review cycle. In practice, this means that every aspect of the Treaty and mine action in general, will be thoroughly discussed, analyzed and assessed in order to ensure sound foundation upon which the recommendations for the new review cycle will be modeled. All these recommendations are then channeled and shaped in the form of a relevant action plan which is the ultimate outcome of every review conference. This action plan is the roadmap for the future work, containing a set of concrete measures that provide States Parties with ad-

<sup>&</sup>lt;sup>1</sup> Articles 11 and 12: http://icbl.org/media/604037/treatyenglish. pdf.

<sup>&</sup>lt;sup>2</sup> More on this: https://www.unog.ch/80256EE600585943/(http Pages)/7177FF06087BE4F3C12582180064B82C?OpenDocument.

<sup>&</sup>lt;sup>3</sup> For more on the work of committees see: https://www.apminebanconvention.org/committees/committees-overview/.

<sup>&</sup>lt;sup>4</sup> For more on the ISU see: https://www.apminebanconvention. org/implementation-support-unit/activities/overview/.

<sup>&</sup>lt;sup>5</sup> https://www.apminebanconvention.org/review-conferences/.

equate tools to implement provisions and obligations of the Treaty.

#### The Third Review Conference - "The Maputo Review Conference on a Mine-Free World"

At the critical moment in the Treaty's history - fifteen years after its entry into force and fifteen years after the First MSP in 1999 in Maputo, Mozambique - the States Parties met again in Maputo to review the Treaty's implementation and assess the remaining challenges in eradicating mines from the world. From June 23rd to 27th 2014 nearly one thousand delegates participated in formal sessions and dozens of side events acknowledging the Treaty's accomplishments and preparing for the next phase of work. In total, 79 States Parties participated in the conference, with twelve States not parties attending as observers, including the United States of America, China and India. Libya and Lebanon also attended the meeting. "The Maputo Review Conference on a Mine-Free World" was organized in a country bearing a significant symbolic meaning, which in turn marked that particular time in the life of the Treaty for a number of reasons. Here, we will cite some of them: a) in the early 1990s, Mozambique was one of the countries with the highest level of negative humanitarian effects of anti-personnel mines use. Along with some other heavily mine-affected countries, Mozambique was one of the birth-places of the anti-landmines movement whose positive effects could be best witnessed first-hand in Mozambique; b) when the Treaty was adopted, the clearance of all mined areas was a distant goal, and to many for a number of reasons, a rather abstract one. By the time of the Third Review Conference, however, Mozambique has cleared almost all of its suspected hazardous areas except some remote ones which were cleared later in the year thus allowing

Mozambique to declare a mine-free status in 2015; c) soon after the Treaty entered into force, Mozambique hosted and presided over the Treaty's First Meeting of the States Parties (1MSP) in May 1999, which established the Treaty as the international community's framework for mine action. The Maputo Review Conference marked the return to where international efforts to implement the mine ban actually began, only this time building on fifteen years of lessons learned and experiences gained; d) in May of 1999, there were only 55 States Parties to the Treaty, and Mozambique was only one of 18 States in Africa that had committed to mine ban. Moreover, at the same time the 1MSP was taking place, new use of anti-personnel mines was taking place. In 2014 however, there were 161 States bound by the Mine Ban Treaty making it virtually universalized in Africa. Since the strong international stigma against landmines had developed in the meantime, the new use of mines became a rare practice.World leaders and ordinary citizens considered it unacceptable in the modern world, meaning the norms embodied by the Treaty have taken a firm hold; e) the international community made a solemn promise to mine victims obliging States Parties to continue providing assistance to victims long after mines are cleared and stockpiles are destroyed. As an added value, the "Maputo Review Conference on a Mine-Free World" was an opportunity to re-energize a high level international interest to continue momentum in the fight against landmines and revive the Treaty in a changing and new environment.

#### The Maputo Action Plan (2014-2019)

Despite significant progress that was made and numerous lives that were saved, the States Parties were quite aware that challenges remain and therefore the Maputo Review Conference was used as a venue for the in-

ternational community to regroup in order to deal better with the realities of what remains to be done in the anti-landmines movement. Building on the Nairobi (2005-2009) and Cartagena (2010-2014) Action Plans, in the Maputo Action Plan for 2014 to 2019 (MAP)<sup>1</sup> States Parties agreed to promote universalization of the Treaty and to implement remaining obligations on mine clearance, stockpile destruction, victim assistance, international cooperation, transparency and information exchange, compliance and implementation support. In fulfilling the promise of a mine-free world, at the high political level States Parties adopted the Maputo Action Plan with 31 specific commitments to enhance implementation and promotion of the Mine Ban Treaty during the period leading to the Treaty's fourth fiveyear review in 2019. The value of the MAP lies in the fact that it aims for significant and sustainable progress towards the achievement of time-bound obligations while acknowledging local, national and regional circumstances in its practical implementation. By agreeing to the MAP, the States Parties also undertook to implement the measures in a cooperative, inclusive, age-appropriate and gender-sensitive manner.

#### "Maputo +15 Declaration"

In addition to the MAP, the States Parties adopted the "Maputo +15 Declaration"<sup>2</sup> committing themselves to intensify efforts to advance the goals of the Treaty. But most importantly, by subscribing to the Declaration, the States Parties expressed their aspiration to meet these goals to the fullest possible extent by 2025.

#### Conclusion

The innovative mechanisms, that were established in 1999 to support the implementation of the Treaty, have proved useful for States Parties, international organizations and civil society for coordinating efforts to ensure that the Treaty's obligations are met. At the Third Review Conference States Parties have reassessed those structures and adapted them to meet the challenges of the future. However, their success will be measured in terms of concrete results: cleared minefields, destroyed stockpiles, improved assistance for victims, success in ensuring respect for the Treaty's prohibitions and norms and effective international cooperation and assistance. In this sense, it seems only logical, as provided in the Maputo Action Plan, to maximize opportunities for creating synergies with other relevant instruments of international humanitarian law and human rights law, to ensure the best use of resources, thus reflecting the realities of mine action in the field. As it was emphasized many times before, cases of Mozambique or Algeria and other States Parties that finished clearing their minefields or are very close to doing so, are living proof that the challenge of eradicating anti-personnel mines can be met through high-level political will, good planning and the necessary human, technical and financial resources, supported by the solid partnerships which have underpinned the success of the Mine Ban Treaty.

<sup>&</sup>lt;sup>1</sup> https://www.maputoreviewconference.org/fileadmin/APM-BC-RC3/3RC-Maputo-action-plan-adopted-27Jun2014.pdf.

<sup>&</sup>lt;sup>2</sup> https://www.maputoreviewconference.org/fileadmin/APM-BC-RC3/3RC-Maputo-declaration.pdf.

## **Global mine action experiences** (Mine and ERW contamination)



# Experiences from the Federation of Bosnia and Herzegovina in Residual Unexploded Aircraft Bombs Management

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#### Introduction

From 2007 to 2017 Federal Administration of Civil Protection has disposed of 50 heavy weight unexploded aircraft bombs (UXB). It is five times increasing as compared to the 1997-2007 period. That urged evaluation and identification<sup>1</sup> of the risks related to this kind of the explosive remnants of war. In addition to that disposal procedures needed to be analyzed too and necessary improvements suggested.



Image 1: Areas where UXBs have been found from 2007 to 2017

#### Location-contamination-activity

Excavations in construction engineering caused uncovering of the most unexploded aircraft bombs, thirty-three or 66%. All bombs in urban and suburban environment

are found 0.4 to 6 meters deep. Five are found under the buildings or roads during demolition or reconstruction, and only two are excavated with manual tools. Agriculture led to four findings of which two on surfaces that have been previously processed. During mass tombs exhumations four bombs are found, during mine clearance one, outdoor activities two and during diving six bombs are found underwater. Only three bombs, two in uninhabited and one in rural environment are found on the ground. Upon field results excavations have been identified as the activities with the highest and demining with the lowest risk of finding an unexploded aircraft bombs.

Forty-four or 88% of found bombs are World War Two leftovers and 6 from War in Bosnia and Herzegovina 1992-1995. Most of the bombs from WW2 have been found in suburban (47%) and urban (30%) environment, while only one bomb from The War in Bosnia and Herzegovina 1992-1995 has been found in the suburb. As the criteria for the characterization of the environment population density and the development of the infrastructure within the bomb danger radius is taken. Out of thirty-three bombs found in urban and suburban environment ten were 500kg/1000lbs and fifteen 250kg/500lbs (78%). Thirty-two of those bombs were remnants of the WW2. One, which was brought and placed as a demo charge under the local road, remained after the War in Bosnia and Herzegovina. Two German bombs have been placed as the demo charges at the location where German airport use to be and one American was in

<sup>&</sup>lt;sup>1</sup> GICHD Management of Residual Explosive Remnants of War (MORE) issue June 2015.

the same manner by German forces placed on the bridge and found in the river under the bridge. Underwater findings are specific as bombs under the water are out of reach to the general population but it is necessary to mention that all of those are found in the parts of the watercourses through urban (3) and suburban (3) surrounding and all are WW2 remnants. This data place 78%, three quarters, of all unexploded aircraft bombs found from 2007 to 2017 in densely inhabited areas where possible consequences are very heavy and extensive safety procedures for the disposal must be applied. According to that absolutely highest risk from the unexploded aircraft bombs are in urban and suburban areas.



*Image 2: Locations where UXBs have been found in Sarajevo from 2007 to 2017.* 

#### **Historical analysis**

Through analysis of the available sources of the aircraft bombs use in the Bosnia and Herzegovina it is determined that Axis bombs in the urban and suburban areas are left after so called April War- German and Italian attack on the Kingdom of Yugoslavia from 06 to 17 of April 1941. Inthose circumstances military installations were attacked and also cities Banja Luka, Bihać, Bijeljina, Jajce, Mostar, Prijedor, Sarajevo, Tuzla and Zenica<sup>2</sup> were unselectively bombed. In rural and uninhabited areas Axis bombs are in highest number of cases anti-guerilla warfare leftovers.

Remaining Allied forces bombs have been found close to the locations which were targeted by the strategic and sometimes tactical aviation. All strategic targets were located in the areas which are today considered urban and suburban. Analyzing operational chronology<sup>3</sup> and available historical sources<sup>4</sup> related to the Allied bomber air force units' engagements during World War Two, 98 attacks on 30 targets in 20 cities and settlements in Bosnia and Herzegovina are identified. Bosanski Brod had 13 strategic attacks (5 on marshalling yards, 2 on road bridge, 2 railroad bridge, 3 on oil refinery, 1 on city area), Sarajevo had 11 strategic and 4 tactical attacks (11 on marshalling yards and railroad facilities, 4 on airport), Banja Luka had 8 strategic (5 on airport, 3 on German barracks), Višegrad had 8 strategic (4 on bridges i 4 on troops), Mostar 7 strategic (6 on airport and 1 on German military installations), Bihać had 6 strategic and 3 tactical (3 on railroad station, 6 on barracks and troops), Zenica had 4 strategic and 6 tactical (8 on railroad bridge and 1 road bridge), Doboj had 4 strategic (railroad bridge), Prijedor had 2 strategic and 1 tactical (troops), Livno had 2 strategic (troops), Drvar, Bosanska Krupa, Bosanska Gradiška and Bosanski Novi respectively had 1 strategic (troops), Fojnica had 1 strategic (bridge), Prijedor had 1 strategic and 1 tactical (troops), Rogatica had 1 strategic (railroad), Travnik had 2 tactical (railroad), Konjic had 2 tactical (railroad station), Bosanska Otoka had 1 tactical (road bridge), Bijeljina and Busovača had 1 tactical (troops). In relation to the other

<sup>&</sup>lt;sup>2</sup> Vojislav Mikić "Neprijateljeva avijacija u Jugoslaviji 1941-1945", Vazduhoplovstvo u strategiji NOR-a, Vojno-izdavački novinski centar, Beograd, 1986.

<sup>&</sup>lt;sup>3</sup> Richard G Davis, Bombing the European Axis Powers A Historical Digest of the Combined Bomber Offensive 1939–1945, Air University Press, Maxwell Air Force Base, Alabama 2006.

<sup>&</sup>lt;sup>4</sup> Operational and intelligence reports from 2nd, 98th, 301st,376th, 449th, 450th, 454th, 484th Bomber Group (BG), 15th Air Force (AF) USAAF, and No. 25 and No.39 Bomber Squadron SAAF, No.254 Wing, Balkans Air Force.

available historical sources it is determined that all tactical aviation engagements reports have not been revealed<sup>1</sup>. Total amount of bombs dropped in tactical and strategic attacks have been estimated to 8-10 thousand short tons. Aside from bomber aviation also fighter-bomber aviation has been engaged mostly on road and railroad transports, airports and enemy troops in ground support roles. Those attacks were significantly smaller by amount of the bombs dropped and in reports are most often given wider areas of the engagements instead of the specific targets<sup>2</sup>.

#### **Ordnance** analysis

Only two uncovered UXB's needed to be blow in situ as danger from the uncontrolled explosion was unacceptably high due to their fuzes construction. Both were found in suburban area during excavations. Remainder of the bombs, except German, were fitted with impact/inertia action fuzes so removing the fuze and destruction on the demolition range were procedures applied in those situations. German bombs were fitted with lateral electrical impact fuzes and all were extracted from situ without removing the fuzes. On three found bombs fuze were already removed and on one fuze was broken off. Forty-nine bombs were high explosive demolition with contents weight ratio (CWR) from 30% to 50%. Incendiaries were not found even those were used by German Luftwaffe<sup>3</sup>. One was target practice bomb. Nine of ten 500 kg/1000 lbs bombs were British and one was German. Twelve of twenty-one 250kg/500 lbs bombs were American, six German and three were

British. Bombs under 125 kg/250 lbs, in total nineteen, were German (6), Italian (5), Soviet (3), American (2), British (1), French (1), Yugoslav (1). Through analysis of the historical sources it is revealed that German Luftwaffe was using bombs up to 500 kg<sup>4</sup>, American up to 1000 kg<sup>5</sup> (only in attacks on bridges in Zenica, Doboj and Brod) and British up to 2000 kg6 (in attacks on oil refinery in Brod and marshalling yards in Sarajevo). In available historic sources use of the chemical long delay fuzes is recorded in attacks on marshalling yards in Sarajevo, railroad bridge in Zenica, refinery in Brod and targets in Višegrad<sup>7</sup>. Data on bombs removed from 1945. to 1992. is missing thus preventing full analysis but with available pieces of information plausible risk and worst case scenario are identified. Plausible risk on identified targeted locations is finding of the 250-500 kg bomb, most probably American or British during excavations up to 5 meters deep. Worst case scenario means discovery of the 1000 - 2000 kg bomb in the urban area or bomb fitted with a chemical long delay fuze which requires demolition in situ and in the most extreme case it's uncontrolled detonation on discovery or during disposal. Reason for this is exceptional sensitivity and unpredictability of the fuzes of this kind and possibility of the unpredicted detonation even without any manipulation. However, the worst case scenario is much less probable as so far this type of fuze is found on only one bomb.

<sup>&</sup>lt;sup>1</sup> Zbornik dokumenta i podataka, Borbe u Bosni i Hercegovini 1944. god, tom IV, books from 21 to 39, Vojnoistoriski institut Jugoslovenske narodne armije, Beograd, 1960.

<sup>&</sup>lt;sup>2</sup> Zbornik dokumenta i podataka, Jugoslovensko ratno vazduhoplovstvo, tom X, books 1 and 2, Vojnoistoriski institut Jugoslovenske narodne armije, Beograd, 1967.

<sup>&</sup>lt;sup>3</sup> Daily report Fluggruppe Kroatien to XV Gebrigs Korps Wehrmacht dated 20.04.1944.

<sup>&</sup>lt;sup>4</sup> Report of the commander of Zalužani airport to the Headquarters of the 5th Corps of the Yugoslav Peoples Liberation Army on captured air force material dated 26.09.1944.

<sup>&</sup>lt;sup>5</sup> Operational reports: 455th BG, 15. AF dated 9.8.1944, 449. *i* 450. BG, 15th AF dated 23.11.1944.

<sup>&</sup>lt;sup>6</sup> Operational report: Bomber Squadron No.37, 231st Bomber Wing, 205th Bomber Group of Royal Air Force (RAF) dated 07.11.1944.

<sup>&</sup>lt;sup>7</sup> Operational report: 98th BG, 15. AF dated 23.11.1944, 449th BG, 15th AF dated 20.11.1944, Daily report 205. Bomber Group RAF dated 08.07.1944 and 20.11.1944.



Image 3: Aerial photo of the marshaling yards Alipašin Most in Sarajevo bombing by 301<sup>st</sup> BG, 15<sup>th</sup> AF, USAAF on 09.08.1944.

#### **Disposal protocols**

In Federation of Bosnia and Herzegovina Federal Administration of Civil Protection (FACP) has exclusive jurisdiction over unexploded ordnance disposal for which purpose 8 explosive ordnance disposal (EOD) teams have been formed. Order of actions applied for the disposal of the single bomb is isolation, evacuation, neutralization, extraction, destruction, asanation. Isolation is the initial action taken by the first authorized person in situ, usually a police officer, and it means full access ban in the bomb's immediate surrounding. Upon FACP EOD team arrival positive identification of the item and also hazards and risks is undertaken and accordingly operational plan is made. According to the plan external services; local civil protection, paramedics, police, firefighters and Red Cross are being engaged as the logistic and operational support. Also responsible authorities are requested for complete traffic ban on endangered roads, railroads and waterways and for the establishing of the no flight zone over the risk area. According

to the surrounding, planned rendering safe procedure and bomb mass evacuation is being carried out within the radius from 200 to 1000 meters. The biggest evacuation was undertaken in Bosanska Otoka when total displacement of the population within 1000 meters radius is done for the in situ demolition of the 250 kg bomb. Evacuation is the responsibility of the local community services and practically and logistically is the most demanding phase in the single bomb disposal process. For executing full obligatory evacuation it is needed, according to the existing laws, to declare state of the emergency within the bomb's danger radius otherwise it is impossible to force residents to evacuate. Because of that in some local communities for a lower risk tasks residents are being given a choice whether to evacuate with obligatory movement ban within danger radius during the task execution. However in the worst case scenario, when immediate evacuation might be mandatory, current practice would not be sufficient and efficient enough. Neutralization is the rendering safe procedure. This means disassembling the fuzing mechanism from the bomb, usually by one of the dynamic tools (dearmer or rocket wrench) and rarely manually. In situations when fuzes are identified as an unarmed or when bomb is German with the electrical fuzes, bombs are transported with the fuzes. Extraction is the phase which comprehends loading, transporting, eventual temporary storing and unloading of the bomb. All UXB transports on public roads are done under the police escort between 0300 and 0500 hrs in the morning on the roads completely closed for all other traffic. Transport is done by two element convoy; first element transports the bomb and in second element, on the safe distance, medical and firefighting support team is moving along. When demolition in situ is required, extraction is not applied and for the destruction itself one of the low order methods are being used to eliminate shock wave, fragmentation, noise and seismic shock. It is usually done by shape charges and thermite incendiaries. These methods are also applied for the destructions on the demolition ranges in the controlled environment for the training purposes. In two cases when destruction in situ was required extensive protection works have been undertaken. In one of these cases 55000 sand bags containing 2200 cubic meters of sand were used for the protective barrier. Asanation is the process of the returning the location in original state after the destruction and is usually done as the joint effort of the FACP and the local community.



Image 4: British 1000lbs MkIV general purpose bomb destroyed on Lapov Dol range, July 2014.

#### **Needed improvements**

Currently, in Bosnia and Herzegovina practice of obligatory area check for UXBs on identified risk locations does not exist. In addition, program of UXB awareness does not exist for neither endangered populations nor local civil protection professionals. Highly developed mine awareness program is mostly focused on mine risk areas and population threatened by that kind of hazard. For more complete risk management related to the UXBs and also other residual ERW contamination it would be advisable to extend mine risk education program to train at least local civil protection professionals. Trough that activity necessary prevention component in residual UXB management would be established<sup>1</sup>.

<sup>&</sup>lt;sup>1</sup> GICHD, June 2015.

#### Analysis of Demining of Asphalt-Concrete Surfaces of the Airport of Zadar - lessons learned, 25 years later

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#### Abstract

The approach and methodology for demining of the asphalt-concrete surfaces of the Zadar airport twenty-five years later was analyzed in the article. The demining was carried out during the period from February, 04th to May, 04th 1993 during the military operation "Maslenica". The experiences of Pula airport demining were significant for the successful demining of the Zadar airport since the Zadar airport was mined in a similar way. Lessons learned on complex facilities demining like the runways are presented in this article to the expert public as a valuable contribution to humanitarian demining in War conditions.

**Key words**: demining, airport, runway, lessons learned

#### 1. Introduction

The day when the last UNPROFOR member left the airport was considered the day of the liberation of the civil airport from the enemy army, and that was the first time that the Croatian flag was put up on top of the tower. Civilian airport was occupied by enemy army from the 17<sup>th</sup> of September 1991. to 25<sup>th</sup> of January 1993. or a total of 495 days. The Rule of the Conversion of Social Companies was brought out, and the Board decided to change the current name RO "Aerodrom Zadar" into "Zračna luka Zadar" d.d. ("Airport Zadar stock company). Figure 1. shows members of Croatian Army in front of passenger terminal at the Zadar airport.



Figure 1. – Members of the Croatian Army in front of the passenger terminal at the Zadar airport [Source: Chronology of events, 1993]

For better understanding of the then situation at the Zadar airport, specially concerning demining of the civilian and military part of that airport, memories of Ivan Vitanović, Croatian army retired brigadier Ljubomir Cerovac, Croatian army retired brigadier and Antun Jeričević, Croatian army retired brigadier general. Brigadier Vitanović states: "I knew that the runway was mined and I was the first person to find this out in 1992. The area of the civil airport was full of challenges and I was never sure where a trap and surprise were awaiting. I was the commander and the person that was put in direct danger, where I had to always make the first step forward and then command my troops to do the same... According to our discoveries, there were 20 holes with explosive placed under the runway to blow it up, in every hole there was around 160-200 kg of explosive. Below the military runway there were 26 drill holes, and below the aircraft runway there were 18 drill holes (64 drill holes total). The activation of each hole with explosive could be accomplished in many ways. We were mostly concerned with the possibility of activation by remote control. There was a possibility that the enemy could blow up any hole at will or the whole runway by not being close to the civil airport... According to all that we found in

the area of the civil runway, we concluded that the civil and military runway in Zadar was mined in the same way as the one in Pula.. "PU+2xZD" was painted on the civil runway by base paint. The same way in 1992, I also managed to discover and note down all the markers and places of the twenty explosive holes under the civil runway".

What happened at Pula airport, which brigadier Vitanović mentions in his memories? On November 10<sup>th</sup> 1991 about 13:15 hours, during the attempt of puling out the explosive from the pipe at first mined hole under the runway at the Pula airport, for whom they were certain that isn't additionally mined, explosion happened which caused death of Ministry of internal affairs (MUP) pyrotechnicians Stevo Grbić, Vicalj Marjanović, Marijan Vinković and Dušan Bulešić, members of Croatian Army. Figure 2. shows article from Glas Istre from 13<sup>th</sup> November 1991. about the death of four pyrotechnicians at Pula airport.



Figure 2. – Death of pyrotechnicians at the Pula airport [Source: Glas Istre, 13<sup>th</sup> November 1991.]

Difficult task of puling out the death bodies of killed pyrotechnicians from mined area was performed 11<sup>th</sup> and 12<sup>th</sup> November 1991. This task was conducted by lieutenant colonel Ljubomir Cerovac with group of miners. One of the miners was hanging with his hands and head towards ground attached from the crane. From that position he put a steel rope under the bodies, which after that were removed from the spot where they were killed. November 12<sup>th</sup> 1991 Chief of the General Staff of the Croatian Army, general Antun Tus signed an order in which lieutenant colonel Ljubomir Šumanovac was named the commander and lieutenant colonel Ljubomir Cerovac deputy commander of Pula airbase. The next day, 13<sup>th</sup> November 1991 the order for demining Pula airport was signed by the Chief of the General Staff of the Croatian Army. In this order lieutenant colonel Ljubomir Cerovac was named as coordinator for demining, major Jozo Nenadić for demining green area and pyrotechnicians for demining the objects were assigned from Ministry of internal affairs (MUP) Rijeka and rear base of General Staff of the Croatian Army.

Cerovac is remembering:" we didn't know the kind of fuses we were dealing with. My group consisted of Drago Opašić Billy, Danilo and Vlado Dragičević and Slobodan Buršić. We saw that everything is mined and decided to dig meter by meter near the runway until finding the pipe. Problem was that we didn't now which kind of fuses were in them. We concluded that it would be best if we saw the pipe and fix the explosive by wire. On that way we manage to pull from each hole one to two charges, while filing the blanks with sand bags. At Danilos suggestion two connected iron boards were made in Uljanik which were set in part of pipe towards runway. All of that we also covered with sand bags. We didn't touch fuses at the middle of the pipe, we cleaned pipe entries and by using all kinds of tools made in Uljanik, ropes and Tatra truck filed with 8 m<sup>3</sup> of soil and pulled out part of pipe (with charge and fuses inside) on green surface between runways. We left pulled part there for 72 hours in which it had to explode no matter what kind of fuse was inside. 1500 kg of explosive detonated while 8500 kg was saved. Out of 47 holes, 20 detonated while being pulled out, but none of them transferred explosion at runway. Demining lasted until 7th March 1992 when the runway was given for use to Croatian Air force".

Special piety is necessary to be appointed to deceased Croatian Army pyrotechnicians at Pula airport. May they have thanks and glory for all of eternity.

Brigadier general Antun Jeričević remembers: " During the liberation operation "Maslenica" the complex of the Civil and military Airport Zemunik was liberated. Taking into consideration the situation and all the problems that had to be solved in order to quickly put the complex in function again, the Commanding Officer of the Headquarters of the Croatian Army forward a working Organization under his command with the mission of safe and organized enabling of the airport for its function. It is necessary to mention that the runways and the taxi runway were mined and partly destroyed. Certain facilities within the airport and green surfaces were also mined. Besides this, all the objects installations and facilities were destroyed and run down. During the mining of the runway, several members of the enemy army were killed. Unfortunately, during his attempt to clear the mines, a pyrotechnician from Zadar Alen Bruketa was killed. Two French UNPRO-FOR members were killed on the civil runway because of an explosion that was activated by remote control of the enemy army. The runways and taxi runways were mined with deep explosive holes and armed with commando-terrorist fuses type: light, electronically timed, remote controlled and mechanical. There were more than 10 tons of TNT in the holes. More than a thousand different mines and other fatal devices along with several hundred "little bell devices" that were thrown even during the clearing of the mines were removed from green surfaces of the airport. Brigadier Antun Jeričević was the head of this working organization and his deputy was brigadier Josip Bunčuga. The working organization formed four basic subgroups for:

- demining of runways and taxi runways, the head was lieutenant colonel Dario Matika and deputy brigadier Ljubomir Cerovac,
- *demining of green surfaces and facilities, the head was brigadier Fedor Santini,*
- the restoration of the facilitates of the air base Zadar, the head was lieutenant colonel Ivan Pavlinović and deputy major Veljko Bubuć,
- the restoration of the facilitates of the civil airport was done by the mobilized employees of Airport Zadar led by Slobodan Vrdoljak

The majority of work was done by the subgroup for demining the runways and taxi runways that was made up of pyrotechnicians from several commands of the Croatian Army... The mission was completed without any human casualties, except the wounding of the soldiers by a "little bell". The airport was completely cleared of mines and only the military runway was enabled for flights. The civil runway, even though it was cleared from mines, was not ready for flying because of two large construction damages caused by an explosion on the runway induced by the enemy army."

#### 2. Demining and acomplished results

As it was stressed by brigadier general Antun Jeričević in the last chapter, main effort was done by subgroup for demining runways and taxi runways, which constituted pyrotechnicians from many Croatian Army units. Specifically, they were demining asphalt-concrete surface at the aircraft runway of the Zadar airport. Analysis presented in this article will be focused on the runway PSS-2 (civilian runway) which was 2000 m long and 45 m wide. The PSS-2 was placed near the Sukošan-Zemunik road, to be more precise, between villages Babin Dub and Zemunik Donji. Mining of the mentioned runway PSS-2 should have been done according to "Plan for destruction of the Zemunik airport" created in 1981. This Plan for destruction is shown with sketches at Figure 3. and Figure 4., where the holes (mine wells) are shown with numbers from 1 to 20. Each hole contained approximately 250kg of TNT explosive. Figure 4. shows the shape of holes with dimensions.





Figure 3. – Plan for destruction of the runway PSS-2 (civil runway) [Source: Study, 1993]



Figure 4. – Appearance of the hole at taxi runway and runway [Source: Study, 1993]

Holes (mine wells) number 10, 11, 15 and 18 detonated completely and caused a death of two UNPROFOR members and Croatian Army pyrotechnician - Alen Bruketa. Holes number 3 and 9 detonated incompletely and didn't make any damage to the runway PSS-2. The only damage was done to wire lines which were spread along the runway at green surface (night signalization and thunder protection).

By visual examination of the holes (approach to the hole entries was impossible because the green surface wasn't demined) which were marked with stone columns, the following was determined:

 above of all unexploded holes the stone columns were placed (dimensions 100x100x400 mm) in purpose to mark every single hole and to close plastic pipes above the holes which contained explosive charges.

- possible presence of classic commando fuses with explosive charge, electric and remote control fuses. This estimate was made by analyzing the circumstances in which two UN officers and one pyrotechnic from Croatian Army got killed.
- real possibility that wire connections for runway illumination were used to activate selected holes.

Considering that mentioned runway PSS-2 damages were different (dimensions of the damaged runway were from 11x3 m to 15x4m), we started with establishing a possible amount of explosive in each hole. By gathering additional data and further analysis, the amount of explosive was determined in every hole (see Table 1).

OBJECT	Holes from 1-20	HOLE MARK	Length (m)	Amount (kg)	Total amount (kg)
PSS-2	8	1,2,5,7,10,12,15 and 18	27,2	224	1.792
	3	3,8 and 13	26,7	216	648
	1	17	26,2	212	212
	3	14,16 and 19	25,5	208	624
	2	6 and 20	22,5	176	352
	1	4	22	172	172
	1	9	21	160	160
	1	11	17	120	120
Total:	20				4.080

Table 1. – Determined amount of explosive type TNT in every hole under runway PSS-2 [Source: Study, 1993]

All presented data indicated that runway PSS-2 was mined according to Plan for destruction from 1981 but with significant deviations which referred to following:

- a) enemy forces gave up activating explosive charges in holes in a classic way, which is detonating through four formation mine-explosive stations (MES), as it is shown on picture 3.
- b) mine holes were equipped with commando fuses with the purpose of destroying runway PSS-2 and causing as many human casualties as possible.
- c) special electronic and mechanical fuses were used for setting so called "Booby traps" directed against professional pyrotechnicians performing the demining

Towards that, the enemy forces' intention during mining runway PSS-2 wasn't to protect their own forces but to deliberately cause human casualties during the demining of the runway. Their intention succeeded by killing two UN officers and one Croatian Army pyrotechnician, whose assumption was that they are dealing with "classic mining" of runway PSS-2 with force protection purpose, which after the end of fighting activities would be demined the same way. But, the actual conditions were far from international conventions and regulations. Unfortunately, "Criminal mining intention" was confirmed in this case, the same way it happened at Pula airport in 1991, when four members of Croatian army got killed.

#### 3. Lessons learned in demining

Demining of the runway PSS-2 was conducted according to approved Study called -"Conceptual solution of demining asphalt-concrete surfaces of the aircraft runway", which was approved February 19, 1993 by the Chief of the General Staff of the Croatian Army, general Janko Bobetko. The concept of demining was divided in seven phases as following:

- removing vegetation from green surfaces, 7 m from the edge of the runway,
- clearing an approach to the hole entries,
- soil excavation in order to approach the plastic tubes with explosive charges,
- drilling, fixing and sawing the pipes and explosive charges,
- inserting so called "Sandwich" to prevent transfer of detonation,
- destroying front (cut part) part of the pipe,
- pulling out the explosive charge from the rest part of the pipe.

Figure 5. shows an idea how to demine the holes described before trough each phase.



*Figure 5. – Idea of demining the hole [Source: Study 1993.]* 

Commando fuses were placed (electric and mechanical fuses) in the upper part of the hole, which is above so called "Sandwich" for preventing transfer of detonation. In this case the content of the upper part of the plastic pipe wasn't pulled out, it was detonated (counter-mining), taking care of the fact that detonating wave doesn't spread to the lower part of the plastic pipe which contained the rest (substantial higher) of the explosive.

Counter – mining neutralized commando fuses, which were thrown out to the green surface due to blast wave from upper part of the plastic pipe. All the parts of the commando charges that were thrown on the green surface were collected and distributed to MUP. On April 8, 1993 the Center for crime expertise issued an expert report on the explosives, fuses and detonating capsules gathered during demining of runway PSS-2 at Zadar airport. Figure 6. shows parts of commando fuse with plastic explosive and TNT bullet (MT-4) made of 4 kg TNT explosive that was found after counter-mining the hole number 13.



*Figure 6. - Parts of commando fuse, plastic explosive and TNT bullet.* 

[Source: Expertise report]

Based on expertise, it was determined that hole 13 contained lightening fuse witch is in program of the "Institute for security" from Belgrade, created in factory "Rudi Čajavec" in Banja Luka. Mark of named fuse was "USS\_T". By the rest pieces of the electric-conductor, the expertise concluded that the fuse was connected with electric-detonating capsule, witch meant that it was in active state. Electric battery "VARTA" type 6LR 61 -9V was use as source, electric-detonating capsule for military use with azide initial fuse mark EK-40-69 was used as detonating capsule. It is a capsule identical to capsule number 8 with which it is possible to activate compressed explosive TNT type. Near the earlier mentioned capsule, 207, 4 gr plastic penthrite was set, which is military explosive with purpose in commando actions. It was in formation use in ex-JNA as plastic explosive "PEP-500" packed by 500 gr. It was often used to transfer detonation between initial detonating capsule EK-40-69 and TNT bullet, or to activate charge with help from one additional fuse. Main explosive charge was TNT bullet with amplifier for activation with detonating capsule number 8. Figure 7. shows special commando fuse with detonating capsule and TNT bullet from the hole number 19.



*Figure 7. - Commando fuse with detonating capsule and TNT bul-let* 

[Source: Expertise report]

By the Cyrillic marks at cover of the commando fuse "USE-T RČBL 90 00", expertise had concluded that it was special electronic-tempted fuse made in factory "Rudi Čajavec" Banja Luka in 1990. After opening the fuse it was established that time of activation delay was set at 0900 minutes (possible set is 9999 minutes). Electric battery "VARTA" type 6LR 61 -9V was use as source. Battery was in opened original cellophane cover, while electric lines of the fuse were connected with electric conductors of the detonating capsule and were insulated with black insulation tape. Figure 8. shows special mechanical fuse together with TNT bullet.



*Figure 8. – Mechanical special fuse with TNT bullet* [*Source: Expertise report*]

At the special mechanical fuse, with Cyrillic letters was written "UMNOP-1", that mark points that it is fuse: mechanical-step uponrelease-pull model 1. This fuse was in program "Institute for security" from Belgrade (described in catalog from 1988. under number 228, were offered in complete with other mechanical fuses). This fuse has momentarily activation and is used for completing different formation and improvised explosive devices. In this specific case shown at picture 8, the fuse is missing the safety device from strike needle (radial safety device) which meant that the mentioned mechanical fuse was in active state. It is especially important to mention that there was a perforation made at the bottom side of TNT bullet in explosive through which an insulated wire was pulled with the ring at one end of it. Similar wire of the same kind was found in explosive charge in other holes. Wire with ring and mechanical fuse (UMNOP-1) at the bottom of charge should be used for activating the TNT bullet during the operation of puling out the explosive charge in case of the demining the runways. Namely, from upper side there was primary fuse (lightning or tempted), while in shape of trap from below side was mechanical fuse set for pull activation. That kind of mining is contrary to international conventions and regulations, because its goal was to prevent demining and to cause human casualties. That was the reason of the death of Croatian Army pyrotechnicians at the Pula airport, because the trap was set with special commando fuses. Based on total conducted expertise end evaluation results, it was determined that in mining of runway PSS-2 the following was used:

a) lightning fuse mark "USS\_T" manufacture mark "RČBL". It was developed in Institute for security in Belgrade and was in formation usage in ex-JNA. Activation of the fuse would come after lighting the sensor with light 2-7 Lux of strength, which will enable the contact between source of electrical current (battery 9V) and electric –detonating capsule. The other parts of that kind of fuse were in holes number 13, 15, 16 and 17.

- b) tempted fuse mark "USE-T" with manufacture mark "RČBL" 9000 (produced in 1990). It was developed in the Institute for security in Belgrade (described in catalog from the year 1988 under number 219) and was in formation usage in ex-JNA. Activating the fuse was possible to postpone at max. 9999 min in steps by one minute which was set with dial plate in the shell under the battery. In specific case the dial plate was set to activate after 0900 minutes or 15 hours. The fuse was found in hole number 19; it was not activated.
- c) fuse mechanical-step upon-release-pull model 1 mark "UMNOP-1" was also developed in the Institute for security in Belgrade and was in formation usage in ex JNA. The fuse is activated mechanically by stepping, release or by pulling. In this specific case it was visible that the safety device from strike needle was missing (radial safety device), activation by pulling in direction of fuse was predicted (during puling out the explosive charge). The fuse was found in the hole number 19. Axial fuse was attached to the ring of wire from TNT bullet MT-4, end detonating capsule was in next charge.
- d) TNT bullet MT-4 was main charge. In every plastic pipe hole between 30-53 peaces of these bullets were placed and connected by rope which was passing axially trough every bullet and in that way connecting TNT bullets in one whole. But, at the TNT bullet from the hole 13, besides the rope, there was an insulated metal wire (140 cm in length), pulled through conductors. The purpose of this wire could not be established because some parts that would explain its purpose were missing. But it is possible to assume that this wire could be used as antenna for remote activation. Besides that, its function could be self destruction, because cutting

that kind of wire (through which is flowing electric current) could stop the work of electromagnet which would cause the spring from other side to connect batteries with detonating capsule and activate the explosive. In first case signal connector and appropriate fuse with detonating capsule are missing, and in the other case appropriate electric complex and detonating capsule.

By following all presented evidence from Expertise minutes, it can be claimed that special commando fuses were set to activate explosive charge during the operation of demining of the runways and taxi runways of the Zadar airport. Lightning fuses would have been activated after excavation (lightening) and mechanical during pulling out the TNT bullets from plastic tubes each hole. Tempted fuse represented "sham" or "trap". Although it was set at 0900 minutes (15 hours), it wasn't set in active position by liberation of the mechanical safety, and the time was not running. Taking into the consideration that metal wires near rope in conductors existed, the opinion of expertise is that there was a possibility to activate explosive charge using radio signal, but there were no sufficient evidence for this claim.

All of the fuses, detonators and explosives used in mining the runway PSS-2, were in formation usage in ex-JNA and were developed in the Institute for security in Belgrade.

#### Conclusion

This article analyses the approach and methodology of demining the asphalt-concrete surfaces of aircraft runway of the Zadar airport, at PSS-2 runway example (civil runway). Without knowledge, transferred experiences and lessons learned from demining Pula airport, demining of runway PSS-2 wouldn't be so successful and without human casualties. Special piety is necessary to be given to the deceased at Pula and Zadar airport and their sacrifice should never be forgotten. Mentioned airports and their runways were mined in commando way with fuses, detonating capsules and explosives which were in formation usage in ex-JNA and were developed in the Institute for security in Belgrade. That way implied setting the "sham", "trap" and other non standard forms of mining, which ensures that explosion will occur and cause larger number of human casualties. It needs to be stressed again that in this case civil runway was mined. This way of mining was opposite to all international conventions and regulations.

Lessons learned on demining complex objects (as the airports in Pula and Zadar were) are presented to the expert public and for sure are valuable contribution to the humanitarian demining in war conditions.

#### References

- Dejanović R., Vrdoljak a., "Experts report", Ministry of internal affairs (MUP) – Center for crime expertise, Zagreb, April 1993.,
- [2] Dellavia A., 1993. "From the first balloon to the Zadar Airport: the history of flying in the Zadar region ", Zadar: Airport of Zadara,2009
- [3] Matika D., Cerovac Lj., "Study –"Conceptual solution about the way to demine asphalt-concrete surfaces of the aircraft runway", Work group General Staff Headquarters, Zadar, February 1993.

#### Use of mine detection dogs in Croatia

#### Danko Dežđek

Mine detection dogs (MDD) are used continuously in Croatia from the end of 1990. Their capability for finding mines are dependent on their highly sensitive olfactory system. Dogs are most efficient when odors of explosives in landmines and unexploded ordnance (UXO) are exposed by their defragmentation following use of demining machines.

In Croatia suspected worksite is searched by two different MDD-s at the same part of the worksite, to ensure the same UXO is discovered and that none is missed. Regular work capability testing is performed on testing site where MDD search for mines that are grounded for years. From buried landmines the complete "bouquet" of smells from various chemical compounds is vaporized into the air. The work capability test also include dog identification, vaccination check, obedience and socialization skills. The main goal is correct assessment of dog capability to detect landmines and UXO.

Use of MDD in humanitarian demining, today and in future, is faced with new possibilities and challenges. When mines are grounded on difficult terrain in perspective of configuration, soil characteristics and vegetation where use of other demining procedures are limited, use of MDD is needed. To make landmine-detecting dogs more reliable and make better selection of working MDD lines discovering the effect of breed differences, morphometrical, biochemical and cellular characteristics on dog olfactory system is needed.

Key words: humanitarian demining, dog, testing, smell picture, working lines

New technologies in mine action



# Detection of strong mine presence indicators using intelligent algorithms

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Abstract: In Mine Action domain, reduction of Suspected Hazardous Area extent is a very important task. It can be done by using advanced computer vision methods and artificial intelligence algorithms on airborne and space imagery in order to extract new information of SHA and to detect indicators of mine presence. We introduce the concept and describe a procedure of strong mine presence indicators detection by using convolutional neural networks and rule-based inference. Also, we propose a recommender system that improves detection quality with interactive relevance feedback. Such a system may also assist in post-processing procedures and classification of indicators after their detection.

**Keywords:** Strong mine presence indicators, DNN, Rule Based System.

#### Introduction

In the framework of Mine Action, reduction of Suspected Hazardous Area (SHA) extend is an important goal since it is often overestimated. The Non-technical survey (NTS) is procedure aimed at reducing potentially hazardous area and releasing the land where there is no evidence of mine contamination [1]. In this process, the airborne and spaceborne imagery processing and interpretation can provide valuable evidence about the indicators of mine presence and indicators of mine absence [2]. In particular hyperspectral imagery, which can enable detection of small spatial structures in images due to fine spatial resolution of recently operated sensors.

The concept of mine indirect indicators is introduced by [3]. We primarily focus on detection and extraction of strong indicators of mine presence (IMP) - objects related to the military activities and mine laying(trench, battlement, bunker, shelter) process since they are proven to be more significant than other indicators [2]. Example of one strong mine presence indicator type is shown in Figure 1.



*Figure 1. Color image of the scene with several shelters for heavy weapons.* 

Detection of the strong indicators of mine presence is highly demanding due to a large diversity of object manifestations related to the climatological, topographic, warfare and other features of SHA. Experts with in-depth field knowledge and experience conventionally identify such indicators via visual image interpretation [4]. We consider an intelligent algorithms approach for detection of such indicators in order of reducing photo-interpreter time-consuming job.

#### Detection of strong mine presence indicators with deep neural networks

Artificial neural networks (ANNs) are biologically inspired machine learning algorithms [5]. They can be employed in supervised and unsupervised learning mode. In the first approach they are used as classifiers and in the second for clustering. If they are used as classifiers a significant number of samples must be available for training before the network can be used. The training dataset must be diverse enough to avoid overfitting which, along with excess computing time, are the major issues with ANNs. The overfitting can be detected if an ANN demonstrates near perfect performance during training and very poor results when applied to a general dataset.

Recent developments in ANNs have significantly advanced performance of contemporary visual recognition systems [6]. Thus, ANNs have been very successful in content-based image recognition of different objects, people and animals where a very large number of different images in the same class are available for training. Deep learning networks or deep neural networks (DNNs) are one of the most recent types of ANNs [7]. They are typically feedforward networks but the distinguishing feature are multiple hidden layers between the input and output layers (Figure 2). It has been shown that these algorithms can model complex non-linear relationships. Yet again, as with previous types of ANNs, DNNs also include many variants of a few basic approaches. DNN architecturesare not identical and each has found success in specific domains. Similarly to other machine learning applications, it is difficult to compare performance unless architectures they have been evaluated on the same data sets.



*Figure 2. Typical configuration of a deep learning neural network with densely connected multiple hidden layers.* 

Because of their characteristics we believe that DNNs are currently the most promising approach for strong mine presence indicators detection if multiple representatives of indicators are available. Multispectral and hyperspectral imagery of the same mine suspected area can greatly assist DNNs in detection since each view can be treated as an additional learning set.

In this application a human interpreter must setup an initial feature "ground truth" database which will be used for network training. Selection of optimal imagery is very important since ANNs performance (i.e. classification accuracy and precision) are sensitive to changes in resolution [8]. The choice of spectral channels, image size and other visual pertinent parameters must be maintained once they are set. After the minimal "ground truth" database has been constructed by hand a feedback loop using a recommender system may be used to facilitate the database development [9]. In this iterative process (Figure 3) a neural network will examine a scene and for each segment will present possible classifications to the interpreter. He will select a class which best describes the feature or propose and entirely new object class. The network will continue to go through the images and with each iteration the number of class representative images will grow. Subsequently, system performance in detection of hard mine presence indicators will be continually improved. In the first iteration the class set will be empty and the learning process will entirely depend on selection of visually significant features and the skill of the operator. However, for a new type of terrain another feature dataset will have to be constructed. In this case, even by using the described human-in-the-loop training process, a sufficiently rich corpus of indicator examples may not be always available, or could be difficult and time consuming to develop. In such cases a feature databases has to be constructed for each terrain type.



Figure 3. UML activity diagram of strong mine presence indicators image analysis.

In our approach we suggest that DNNs may be used for detection of strong indicators (such as trenches, military emplacements, bunkers, shelters etc.) while a rule-based reasoning engine are to be employed in construction of mine danger maps. An experienced terrain interpreter is crucial for a successful aided detection of strong mine presence indicators with artificial intelligence algorithms which is a prerequisite for mapping of mine suspected areas.

#### Rule based system as possible replacement for expert eye interpretation of the scene

Although some authors state that human expert can hardly be replaced by automatic methods of digital image processing [10],after detection of strong indicators of mine presence with DNNs, Rule Based System is needed to enables the implementation and application of the human expert logic for categorization and classification of indicators. When a problem is to fiddly and beyond any obvious algorithm based solution and logic changes often, we should use Rule Engine [11].Rule engine systems are applicable to all

industries, and the main features are quick adaptation to changes by adding new or changing existing rules which corresponds to the specificity of indicators, time conditions, facilities on the ground, terrain configuration etc., and frequent changes in rules that arise due to changed operating conditions, new regulations or procedures, new priorities, and enables direct change and manage of rules independently of all other parts of computer infrastructure. [12] Application of rules based system in the allocation of strong mine scenario indicators (trench, roads, buried coverings, bunkers, drywall, rock boulder, bridge, gas) [10] enables interactive management of the system depending on the changes in the indicators and mines, separation of data and logic and building knowledge database.

Expert Systems based on Rule engine could generate confidence and danger maps of mine suspected area with several risks and confidence categories. These kinds of maps provide very important information for the end-user and thus can speed up the decision process of reducing, confirming or extending MSA, if necessary.

#### Conclusion and future work

In the process of Non-technical survey up-todate information of the strong mine presence indicators position is of great importance, but usually is not available. For gathering needed information spaceborne and airborne imagery can be very useful. In the paper, we propose an approach for detection categorization of the strong mine presence indicators on such imagery by applying deep neural networks and Rule Based System. The aim of this approach is to help domain experts by speed-up the process of indicators detection and identification with affiliated confidence level. We believe that DNNs are currently the most promising approach for strong mine presence indicators detection due of their characteristics to model complex non-linear relationships. On other hand Rule Based System can assist in the implementation and application of the human expert logic for categorization and classification of indicators after detection. Also, Expert Systems based on Rule engine can be used to provide important information to the end-user - danger and confidence maps of MSA.

Further work will be focused on initial design development of the proposed system which should be tested with the key use cases to prove the technology's design and applicability in realistic scenarios.

#### References

[1] IMAS 04.10 (2003). Second edition, Amendment 7, August 2014, Available from: www.mineactionstandards.org/standards/ (01.03.2018.)

[2] Bajić, M. (2010). The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas. Journal of Conventional Weapons Destruction, 14(3), 28.

[3] Maathuis, B. H. P. (2003). Remote sensing based detection of minefields. Geocarto international, 18(1), 51-60.

[4] Katartzis, A., Vanhamel, I., Chan, J. C. W., & Sahli, H. (2004, September). Remote sensing minefield area reduction: Model-based approaches for the extraction of minefield indicators. In Theory and Applications of Knowledge-Driven Image Information Mining with Focus on Earth Observation (Vol. 553).

[5] Da Silva, I. N., Spatti, D. H., Flauzino, R. A., Liboni, L. H. B., & dos Reis Alves, S. F. (2017). Artificial Neural Networks. Cham: Springer International Publishing.

[6] Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems (pp. 1097-1105).

[7] Schmidhuber, J. (2015). Deep learning in neural networks: An overview. Neural networks, 61, 85-117. [8] Van Etten, A. (2016). The Effect of Resolution on Deep Neural Network Image Classification Accuracy, https://medium.com/the-downlinq/the-effect-of-resolution-on-deep-neural-network-image-classification-accuracy-d1338e2782c5 (01.03.2018.)

[9] Aggarwal, C. C. (2016). Recommender systems (pp. 1-28). Springer International Publishing.

[10] Krtalić, A. (2016). Analysis of the Segmented Features of Indicator of Mine Presence. ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 519-526.

[11] Drools, Part I. Reference Manual http:// www.jbug.jp/trans/jboss-rules3.0.2/ja/html/ (01.03.2018.)

[12] Boyer, J., & Mili, H. (2011). Agile business rule development. In Agile Business Rule Development (pp. 49-71). Springer, Berlin, Heidelberg.

# Operational consequences of a non-linearity of the harmonic radar

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Abstract: The harmonic radar (usually known as the non-linear junction detector - NLJD) is an advanced solution for the detection of the improvised explosive devices (IED), which are the contemporary invading threats. This radar emits the electromagnetic waves at the frequency  $f_0$  (in decimeter wavelengths) and receives waves on harmonic frequencies ( $2f_{0'}$  $3 f_0$  generated by nonlinear electronic components or by oxidized junctions of different metals in IED. The radars known in mine action (the ground penetrating radar – GPR, the synthetic antenna radar - SAR) detect the targets by means of the electromagnetic waves scattered from passive target structure. The detecting range of these radars can be increased by increase of the radiated power, antenna gain, sensitivity of radar's receiver, while they function in the linear mode. Contrary, the harmonic radars have several limitations which have strong impact on operations which will be described. The availability of the theoretical models for harmonic radar is limited to the use in free space, experimentally derived models for limited selection of targets are dominating. The needs and requirements for harmonic radars are well defined for military and security domains, but since 2014 they have been in ever growing demand for the humanitarian countermine action as well.

**Keywords:** *harmonic radar, improvised explosive devices, humanitarian countermine action* 

#### **1. Introduction**

The harmonic radar is a new technology with expected significant impact in countering

IED [1], [2]. It is also an actual operational detecting tool in Syria conflict [3]. Our work is based on the results from [1] and the later steps made in [4], [5]. After short comments of the empirical data from [1], the consequences of interaction with environment are shortly outlined. The relations of IED with the harmonic radar were analyzed by means of propagation model for linear polarization, electrically smooth soil surface, and for decimeter wavelengths.

#### 2. Set of experimental data

The analysis in this work is based on the data collected for several number of objects which appear in IED activating parts, Fig. 1, [1]. This is consequence of a non-linear features of the harmonic radar. The key non-linear feature is the second harmonic's (n=2) pseudo non-linear radar cross section  $\sigma_n = \sigma_2$ , which is not constant but depends on the product of spatial power density S [W/m<sup>2</sup>] of electromagnetic waves on target and the specific targets radar cross section  $\sigma_{_{\rm spec}}$  [m<sup>4</sup>/W], [6]. The geometry of analysis in [1] and [4], [5] is shown on Fig.2, where are defined maximum detection distance D, height H1 of radar, H2 of a target, the soil surface parameters,  $\Delta h$  surface roughness, r coefficient of the reflection. The influence of the heights H1, H2, soil moisture condition (dry/wet) on maximum distance D where the considered targets were detected is shown in Tab.1. The Tab.2 shows influence of target's angular orientation on maximum detection distance D and on the estimated pseudo non-linear radar cross section  $\sigma_2$ .



Figure 1 Targets used in the analysis (Table 1), obstacles used in the analysis: h) set of bricks, i) concrete blocks, j), k) concrete tube, [1].

Targets	Figure	Ground	H2 = 1.2 m	H2 = 0 m
Toy Car	1a	dry	11.5 m - 18.5 m	11 m - 14 m
IR sensor	1b	dry	20 m - 30 m	11 m - 23.5m
NOKIA1616+El.s.	1c	dry	14 m - 22m	12.5 m - 17 m
Meteo station	1d	wet	12 m -13.5 m	9 m
Remote Control	1e	wet	18.3 m - 20 m	16.5 m - 17 m
Nokia5130c	1f	wet	10.5m - 11m	7 m
Mortar shell 120mm	1g	dry	-	2-3 m
$\lambda/2$ dipole & diode		dry	70 m	23,5 m

Table 1 Detection distances D (m) for components of IED. Ground surface: dry, wet, [1].

	Range	Orientation				
Target	D, $\Box_2$	0°	90°	180°	270°	Difference
Tou con H2-1 2 m	D	13	11,5	15,5	13,5	4,0
10y car, 112–1,2 m	$\sigma_2$	-70,34	-73,53	-65,76	-69,36	7,77
Infra Dad songar H2-1.2 m	D	27,2	20	30	22	10,0
Infra-Keu sensor, H2–1,2 In	$\sigma_{2}$	-51,10	-59,11	-48,55	-56,63	10,56
NOKIA1616 & electric switch,	D	14	19,3	17	18,5	5,3
H2=1,2 m	$\sigma_2$	-68,41	-60,04	-63,35	-61,15	8,37
	D	17	18	16,5	20	3,5
10y car, H2=0,5 m	$\sigma_2$	-63,35	-61,86	-64,13	-59,11	5,02
	D	25,5	21	28	23	7,0
IK sensor, H2=0,5 m	$\sigma_2$	-52,78	-57,84	-50,35	-55,47	7,49
NOKIA1616 & electric switch,	D	16	19,3	22	20	6,0
H2=0,5 m	$\sigma_2$	-64,93	-60,04	-56,63	-59,11	8,30
Toy Car, H2=0 m	D	11	14	13	12	3,0
	σ,	-74,69	-68,41	-70,34	-72,43	6,28
Lefue Ded server LD-0 m	D	11	14	13	12	3,0
Infra-ked sensor, H2=0 m	σ,	-72,43	-74,69	-68,41	-70,34	6,28
NOKIA1616 & electric switch,	D	13,5	15	14	12,5	2,5
H2=0 m	$\sigma_2$	-69,36	-66,61	-68,41	-71,36	4,75

Table 2 Influence of target orientation on D (m) and  $\sigma_2$  (dBm), [1].

Detecting distances D are always smaller if the target was at H2=0 (on the soil surface) if compared with data when target was elevated at H2=1,2 m, Tab.1. Similar analysis has been done for other sets of H1, H2 data with similar behavior. The change of the angular orientation of the target caused variations of D from 2 m to 10 m, and changes  $\sigma_2$  from 4,72 dBm to 10,56 dBm Tab.2.

#### 3. Situational model

The mentioned empirical data were collected in the situation shown on Fig.2. The amounts of D, H1, and H2 have been selected in ranges which appeared in [1]. The surface roughness  $\Delta h_n$  satisfies a Rayleigh criterion for wavelength  $\lambda_n / \Delta h_n < \lambda_n D / (8(H1+H2))$  and the surface is electrically smooth. For decimeter wavelengths and the grazing angles  $< 2^{\circ}$  the reflection coefficient can be approximated by r~1 for linear vertical and for horizontal polarizations. It was provided that the antenna pattern diagram in the vertical plane was nearly constant in directions of R and R1. Total amount of the resulting electrical field E is sum of direct and reflected waves.

$$E = (60PG)^{1/2} (e^{-j\beta R} / R) F(R) + r(60PG)^{1/2} ((e^{-j\beta(R1+R2)}) / (R1+R2)) F(R1)$$
(1)

 $\beta = 2\pi/\lambda$ , P is transmitted power (W) at  $\lambda_1$ , G is the gain of radar antenna, R = [D2+(H1-H2)<sup>2</sup>]<sup>1/2</sup> ~ D+(H1-H2)<sup>2</sup>/2D, R1+R2 = [D<sup>2</sup>+(H1-H2)<sup>2</sup>]<sup>1/2</sup> ~ D+(H1+H2)<sup>2</sup>/2D

$$R1+R2-R \sim 2H1H2/D$$
 (3)

Where  $E_D = (60PG)^{1/2} (e^{-j\beta R}/R)F(R)$  and approximated amount of electrical field is  $E = E_D (1 + re^{-j\beta 2H1H2/D})$  (4)





Figure 2 The propagation model of the harmonic radar and IED above the flat ground plane and electrically smooth surface, for linear polarization, [5].

The oscillatory distribution of E1 and E2 has deep minima, where minima of E2 cause loss of the detection (marked on Fig. 3). In the case of the manual detection of IED, this means a risk for the person which can wrongly conclude that there is no IED



Figure 3 Example of the spatial oscillatory non-monotonic distribution of the electrical field strengths, E1 on  $\lambda$ 1 (radiated by radar), E2 on  $\lambda$ 2 (radiated by electrical and electronic nonlinear elements of IED), [5]. Note that extreme values of E1 and E2 do not overlap.

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#### 4. Conclusion

The harmonic radar (NLJD) is novel tool for detection of the IEDs, and its characteristics are non-linear. The characteristics of IED as a target are non-constant, they depend on the spatial power density of electromagnetic waves on target. The radar equation of harmonic radar exist for the free space but is not available for real situation when radar and target (IED) are above the soil surface. Developed propagation model was derived by use of data from [1] and cannot be applied if empirical data on detecting ranges D are not available.

#### 5. References

[1] Oto Jungwirth, Tomislav V.B. Vondraček, Tamara Ivelja, Sanja Vakula, Milan Bajić (2016). Report on testing of detectors NR-900EK3M EA-GLE, NR-2000 and NR-12C, Report HCR Center for testing, development and training, Ltd., Sortina 1d, 10000 Zagreb, Croatia, May 2016.

[2] SCI-256 RTG (2014). SCI-256 Task Group Investigates Nonlinear Junction Detection for Counter-IED Applications, 12-16 May, 2014.

https://www.cso.nato.int/mobile/page.asp?ID=2242

[3] Max Grishin (2017). 1 - "Uran-6" remotely controlled robotic system, 4 - INVU-3M "Korshun" nonlinear junction locator. 09:42 - 15. 03.2017.

https://twitter.com/GrishinMax/status/842053391576649729

[4] Milan Bajić (2017). Testing of the detectors for non-explosive components of the IED, the nonlinear junction and the control line-wire. Presentation at 3rd C-IED Technology Workshop, Synergistic technologies to defeat improvised threat, Counter Improvised Explosive Devices Centre of Exellence, Madrid 24-26 October 2017, 17 slides.

[5] Milan Bajić (2017). Propagation model of harmonic radar for detection the nonlinear contacts of the improvised explosive devices, Polytechnic & Design, Vol. 5, No. 3, 2017. Zagreb University of Applied Sciences, pp.210-218. (In Croatian).

[6] Kyle A. Gallagher (2015). Harmonic radar: theory and applications to nonlinear target detection, tracking, imaging and classification, PhD Dissertation, The Pennsylvania State University the Graduate School College of Engineering, December 2015.

# Robotics and Remote Sensing for Humanitarian Mine Action & ERW Survey (RRS-HMA)

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#### Abstract

A number of initiatives have been undertaken using robotics and remote sensing in the humanitarian mine action (HMA) sector over recent years. A new consortium of specialists from space and robotics sectors in the United Kingdom (UK) has been formed to determine how to build upon previous knowledge, in taking robotics and remote sensing to the next level in HMA. Focussing on de-risking and applying novel technological solutions to surveying activities. This paper provides an overview of the consortium's proposed strategy and objectives for tackling the current challenges in HMA as well as a brief overview of relevant technologies. The paper shall also outline the objectives of an on-going GCRF funded project, whose outcomes shall lay the foundation for future technological developments and field demonstrations.

#### Introduction

The UK consortium led by STFC RAL Space, together with Cranfield University and Fardoulis Robotics is investigating how to gain the most impact in coming years from spinning in current state-of-the-art space and terrestrial robotics, unmanned aerial systems (UAS) and satellite technology.

Currently there are over 100 million active landmines around the world, with contamination from explosive hazards increasing due to new conflicts. Traditional methods of dealing with landmines involve manual techniques using prodders, metal detectors, heavy machinery, dogs and rats. However, these methods are dangerous, time-consuming, potentially error prone and labour intensive. Current state-of-the-art techniques can benefit from the integration of higher technology and automation.

Large projects such as Tiramisu [1], D-BOX [2], SADA [3], SAFEDEM [4] and others prior have investigated how to assist HMA processes using more advanced technology and systems. Our goal is to build upon previous learning, using past research as a starting point to help streamline workflows and allow time to spend on sensors, system integration, software & techniques. This can take place whilst simultaneously deploying equipment with a high technology readiness (TRL) during field trials. The key will be a balanced research and development (R&D) portfolio - ranging from immediate fieldwork using currently available UAS technology, through to more intensive R&D required to instrument ground rovers and make operation autonomous.

#### **Sensing Scales**

A holistic, toolkit approach is important, as contamination and environmental conditions vary significantly across the world. Three scales of sensing will be required, earth observation from satellites, for relatively low-resolution surface data on a wide-area, country scale. UAS sensing for high-resolution surface data on regional scale, which is explained in [3]. Plus, high-resolution surface and ground-penetrating data from rovers on a site-specific scale. The focus of this paper is on the potential from ground rover and UAS platforms, with plans in the use of satellite technology reserved for explanation in more detail at a later stage.

#### **Overview - Ground Rover System**

In this section, we present an overview of the Ground Rover System (GRS) and a review of relevant technologies, building upon the consortium's prior work and reviewing prior HMA activities. The GRS consists of a rover platform with on-board autonomy capabilities, which has a select sensing payload integrated for surveying activities. The GRS is monitored and can be tele operated by an onsite ground segment.

#### A. Rover Platform

Several mechanical demining and landmine surveying systems have been proposed and demonstrated in the past. A recent FP7 project[5] notes that many lessons have already been learned, however there are still outstanding requirements to be satisfied before small robotic platforms can be effective within HMA. [5] concludes that robotic hardware research should focus on advanced mechatronic designs and robot mobility while reiterating that such systems are best adopted in collaboration with other systems, supporting the proposed holistic approach.

The rover platform shall be based upon the existing All Terrain Rover designed and built by RALSpace (RAL-ATR) [6]. The RAL-ATR's development has been primarily driven by the requirements of Agricultural Technology research, which calls for a small, rugged yet low-cost instrumentation platform with advanced mobility capabilities. From such a direct crossover and synergy of applications and field deployment heritage. Further, competitive functional and performance characteristics enforce the suitability of the platform for adoption within HMA surveying. A brief overview of the RAL-ATR is provided in Table 1, where a direct comparison to similar platforms can be made in [5].

Туре	Four-wheeled, All Terrain, Independent Wheel Steering
Autonomy	Autonomous (with payload), Semi-Autono- mous, Tele operated
Cost	~£10,000 (without autonomy payload)
Dimensions / Weight	0.5m x 0.5m x 0.25m / 20kg
Speed (m/s)	Max: 0.5
Operation Time	Max: 8hrs, Li-Ion Batteries, 24V, ~20Ah
Payload	Max: 20kg

Table 1, RAL-ATR Platform Overview

#### **B. Landmine Detection Techniques**

Previous work studying landmine detection used different techniques, and a review is provided by [7]. Five techniques have been proposed: Metal Detector Technologies; Electromagnetic Methods; Acoustic/Seismic Methods; Mechanical Methods; and Biological Methods.

Both Ground Penetrating Radar (GPR) and hyperspectral technologies have shown promising results for landmine detection. GPR technology transmits a regular sequence of packets of electromagnetic energy into the material or ground, and detects signals reflected from the buried target. Then, the presence of the landmine can be detected by analysing reflected signals. Some notable existing works have used GPR for landmine detection[8] and shown good performance. However, it has some challenges such as: GPR measurement is sensitive and can be affected by complex interactions among mine metal content and soil moisture profiles[7].
Therefore, in our study we will overcome this limitation by considering different configurations, and fuse GPR data with other sensors to reduce the false alarm rate.

On the other hand, Infrared (IR) and hyperspectral imaging have been used for landmine detection, with methods in [7] [9] showing promise. They have the advantage of performing the detection remotely, and thus more safely than metal detectors. However, some factors (e.g. wind and rain) should be considered which might affect measurements.

## C. Autonomy Capabilities for Landmine Surveying

Autonomous rovers are becoming a more popular and viable method for landmine surveying<sup>[10]</sup>. There are several advantages such as being; safe, fast, and provide a platform for integrating multiple sensors. However, developing a real time autonomous rover navigation system is a challenging task. Recently, the signal and autonomy group at Cranfield University has developed different techniques for real time autonomous navigation systems, including multispectral navigation for self-localisation[11] and trajectory analysis methods[12], with a review provided by [13].

#### **Overview - UAS Platform**

Small unmanned aerial systems (sUASs), are made up of an unmanned aerial vehicle (UAV or 'drone'), a payload, ground control system, live video feed and other peripherals. The level of field-readiness can be split into commercial off-the-shelf (COTS) equipment, or more novel bespoke, scientific systems. Using sensors operating in the visible light and IR spectrum can provide utility for a range of purposes, as outlined in Table 2. Identifying anomalies from buried contamination near vegetation via sUAS hyperspectral imaging is another option, requiring field trials to determine the feasibility of such a technique. Integrating novel sensors will require a longer timeframe and a greater investment in R&D. Hence, the emphasis in this paper is on firstly deploying COTS equipment, with potential for immediate impact.

#### A. Deployment Gap

sUASs can be better leveraged in the HMA sector. Hence, a case-study approach is part of our strategy, to capture and publish real-world data from field trials, using experienced sUAS operators to closely collaborate with national authorities and HMA actors across a range of operating environments. Such an initiative will help build confidence, explain techniques, and outputs can be used by national authority and INGO partners to help secure donor funding for sUAS capacity building programs.

#### **B. sUAS Utility**

The utility available from sUASs spans a range of operations from; Non-Technical Survey (NTS) to mapping, cartography, GIS, as an airborne asset during EOD operations, QA/QC, through to post clearance assessment, and donor reporting. Gathering decision making data is the key, rather than getting too caught up with technology. Hence starting with COTS, to help stimulate the category.



Figure 1- shows how a FLIR sUAS thermal camera can see AV and AP mines in long grass.

	Approach/ Technique	Technology Readiness Level (TRL)	<b>Examples of sUAS Uses – Deployable Today</b>
	Visual (RGB) & V-NIR sensors Thermography	High (COTS) Now	* Rural NTS * Urban NTS * Site progress reporting & QA/QC * Recce * Cartography, GIS & base maps * Pre-deployment planning * TS & clearance
	Visual (RGB) & V-NIR sensors Thermography	High (hardware)	* Evidence gathering * Spotting in long grass (light vegetation) * Near surface anomalies (needs field testing) * Secondary evidence capture (NTS) * ERW characterisation * Infrastructure inspection

Table 2- shows example uses of sUAS in HMA & ERW clearance, using COTS equipment available today.

#### Goals & Future Work

The current phase of the project is focussed on a feasibility study and building collaborations with national authorities, INGOs and major stakeholders operating in contaminated environments. Collaboration will be essential, to build upon previous learning, gain input into system requirements and to develop methodology. Field trials will be required, which need to take place under the auspices of national authorities, in conjunction with operators. The priority is trying to assist contaminated low and middle-income countries (LMICs), initially staging a collaborator workshop in one of the SE Asian countries of Cambodia, Lao PDR or Vietnam. The consortium is also seeking collaborations with representatives from other LMICs requiring assistance.

Subject to the outcome of the feasibility study, the next phase will be to apply for funding to secure a longer-term R&D, and field demonstration program. COTS sUAS systems could be deployed for immediate field trials, taking place in parallel whilst more intensive R&D takes place for novel rover and sUAS system integration, sensor, and software development. The long-term goal of the UK consortium is to develop and deploy novel, flexible tools to gain better situational data, increase productivity, improve safety and reduce costs for the land release process in post-conflict arenas.

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#### References

[1] *"FP7-Tiramisu,"* [Online]. Available: http://www.fp7-tiramisu.eu/.

[2] "Demining tool-BOX for humanitarian clearing of large scale areas from anti-personnel landmines and cluster munitions.," [Online]. Available: https://d-boxproject.eu/.

[3] M. Kruijff, D. Eriksson, T. Bouvet, A. Griffiths, M. Craig, H. Sahli, F. V. Gonzalez-Roson, P. Willekens and A. Ginati, "Space assets for demining assistance," Acta Astronautica, vol. 83, pp. 239-259, 2013.

[4] "SAFEDEM - Space Assets For Enhanced DEMining | ESA Business Applications," [Online]. Available: https://business.esa.int/projects/safedem.

[5] D. Portugal and L. Marques, "Deploying Field Robots for Humanitarian Demining: Challenges, Requirements and Research Tends," in 17th International Conference on Climbing and Walking Robots, 2014. [6] M. Post, B. Alessandro and T. Xiu, "Autonomous navigation with ROS for a mobile robot in agricultural fields," in 14th International Conference on Informatics in Control, Automation and Robotics (IC-INCO), 2017.

[7] I. Makki, C. Younes, C. Francis, T. Bianchi and M. Zucchetti, "A survey of landmine detection using hyperspectral imaging," ISPRS Journal of Photogrammetry and Remote Sensing, vol. 124, pp. 40-53, 2017.

[8] S. Lameri, F. Lombardi, P. Bestagini, M. Lauldi and S. Tubaro, "Landmine detection from GPR data using convolutional neural networks," in 25th IEEE Signal Processing Conference (EUSIP-CO), 2017.

[9] S. Kaya and U. Leloglu, "Buried and Surface Mine Detection from Thermal Image Time Series," IEEE Journal on Selected Topics in Applied Earth Observations and Remote Sensing, vol. 10, pp. 4454-4552, 2017.

[10] P. Dasgupta, J. Baca, K. Guruprasad, A. Munoz-Mel'endez and J. Jumadinova, "Thercomrade system for multirobot autonomous landmine detection in post-conflict regions," Journal of Robotics, vol. 2015, no. 19, 2015.

[11] A. Beauvisage and N. Aouf, "Multimodal visual-inertial odometry for navigation in cold and low contrast environment," in IEEE European Conference on Mobile Robots (ECMR), 2017. [12] A. AlZoubi, B. Al-Diri, T. Pike, T. Kleinhappel and P. Dickerson, "Pair-activity analysis from video using qualitative trajectory calculus," in IEEE Transactions on Circuits and Systems for Video Technology, 2017.

[13] C. Wong, E. Yang, X.-T. Yan and D. Gu, "Adaptive and intelligent navigation of autonomous planetary rovers - a survey," in NASA/ESA Conference on Adaptive Hardware and Systems (AHS), 2017.

# New technologies in mine action

# Design and development of an NQR-based explosive detection system for humanitarian demining

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#### Abstract

Our group is currently developing the world's first low-cost, rugged and portable system for anti-vehicle mines (AVMs) detection in the humanitarian demining setting. Our portable system is developed with a Field Programmable Gate Array (FPGA) based controller, which controls an in-house designed, energy-efficient Class-D power amplifier that can power the in-house developed magnetic loop antenna (MLA) probe sensor transceiver of the system. Finally, we propose a novel method for robust interference cancellation from the outdoor environment, which can further improve the system's detection performance.

Landmines are a major international problem, and it is important to detect suspicious objects with high probability of success. Nuclear Quadrupole Resonance (NQR) is drawing attention as an effective method for remotely detecting bulk explosives. The main methods utilized today for landmine detection such as metal detection and Ground Penetrating Radar (GPR) aim in detecting the casing material of mines. However, metallic debris is often present on the ground leading to false alarms, delaying the landmine clearance process. As NQR exploits signal detection specific to the target explosive material, it can allow deminers to specifically look for explosives used in landmines, making NQR an effective method for landmine explosive detection by reducing the rate of false alarms compared to the more commonly utilized metal detection methods.

#### Introduction

NQR is a radiofrequency spectroscopic technique where explosive materials are detected by applying transmission pulses at a particular resonance frequency specific to the material of the target explosive, and detecting the presence of the signals emitted from the target. In particular, an external alternative-current (AC) magnetic field at a specific resonance frequency is irradiated against a target substance containing nuclei with the nuclear spin of 1 or above. By detecting the magnetic resonance signal from the excited substance during its relaxation, the target substance can be remotely inspected. As many explosives include the nitrogen nucleus 14 with a nuclear spin of 1, it is possible to detect them through the use of NQR [1].

Unlike Nuclear Magnetic Resonance (NMR), NQR does not require a static magnetic field to be additionally applied, which provides the opportunity to reduce the overall NQR system's size. Its main hardware components are an NQR console, a transmitter-receiver circuit and an antenna.

#### NQR spectrometer

The structure of the portable NQR apparatus are shown in Fig. 1. A gradiometer coil was used for the NQR antenna to eliminate the environmental noise [2, 3]. The system was constructed from a low impedance transceiver circuit comprising a class-D amplifier for transmission, a trans-impedance amplifier for reception and a transmit-receive (TR) switching circuit. The system is controlled by an FPGA (De0-nano, Altera Corp.), which is used to generate burst waves to the power amplifier, process acquired signals and control the TR switching circuit.



*Fig. 1: The schematic diagram of the proposed portable NQR spectrometer.* 

The output impedance of the in-house developed class-D amplifier is very low  $(Z\sim 1\Omega)$  [4], and therefore it does not require series and parallel capacitors for tuning and matching as in commonly used 50  $\Omega$  resonance circuits. Consequently, the output current from the power amplifier is shunted to an antenna and a parallel capacitor. This parallel capacitor reduces the current flow into the antenna. In order to achieve stronger magnetic field generation, a series resonance circuit is directly connected to the output of the class-D amplifier, without a parallel capacitor, compensating for the amplifier's low output voltage.

#### **Experiments**

The NQR signal from sodium nitrite  $(NaNO_2)$ , which has an NQR response with similar characteristics as the RDX explosive compound, was successfully obtained by our portable NQR system (Fig. 2). The resonance frequency during the transmission and the reception was set to ~3.605 MHz. The set parameters for the NQR measurement were as follows: detection sequence, Free Induction Decay (FID); time between pulses, 100 msec; number of accumulation, 200; total acquisition time, ~20 sec.



Fig. 2: NaNO<sub>2</sub>NQR spectrometer signals.

#### **Antenna Design**

We selected a single turn magnetic loop antenna (MLA) coil as the system's probe. The MLA functions as a narrowband transceiver surface coil in order to detect <sup>14</sup>N NQR signals in the frequency of 3.41 MHz. As its functional specification is the detection of AVMs, its sizing is designed to be proportional to an AVM size, leading to a coil diameter in the region of 400 mm. The preliminary conceptual electromagnetic design of the engineering parameters of the antenna is performed through the use of Finite Element Analysis (FEA, Comsol Multiphysics, Fig. 3) [9].



Fig. 3: FEA simulation of MLA and magnetic field distribution 400 mm away from its geometrical centre, which is the usual distance of a buried landmine.

Out of the commercial options available, a copper wire of diameter of 8 mm and thickness of 2 mm was chosen as the tube conductor, as it exhibited the lowest simulated return loss during transmission. By conducting a frequency sweep with respect to the calculated port impedance of the MLA, its Q-factor is preliminarily calculated as Q22. Furthermore, as an MLA of this size has its resonant frequency in the region of approximately 108 MHz, its operation at 3.41 MHz can be achieved through the use of a fixed tuning capacitor parallel to its conductor connections. A matching capacitor can be added for adjusting the overall impedance as seen by the NQR spectrometer circuit.



Fig. 4: Q-factor preliminary calculation.

#### **Interference Cancellation**

Interference can be a major hurdle in detecting the NQR from the signal of interest. It can be caused by several factors such as impurities in the NQR sample, detection hardware noise or the background environment. However, the main cause of interference is radio signals present in the outdoor environment and it is difficult to shield against at it [5]. Therefore interference cancellation is needed to aid the detection of NQR signal [6-8].

In order to cancel the interference, the data are firstly divided into small parts, with each part containing a single echo. Interference cancelation is then performed in each part separately, by picking out frequency components with strong interference and removing them from overall signal. This is performed by setting a fixed threshold value equal to twice the value of the average threshold spectrum intensity and cancelling out all the interference frequency components whose spectrum intensities are higher (Fig. 5).



Fig. 5: Interference cancellation with fixed threshold value for simulated data shown in both time and frequency domain.

#### Conclusion

In this paper, a summary of the current design and development status of a portable and low-cost NQR explosive detection sys-

tem was presented. The NQR apparatus can be powered by mobile batteries, due to the low power consumption of the in-house designed class-D amplifier, while by the use of an FPGA its size and cost are further reduced. Additionally, the utilization of an MLA easily constructed from commercially available annealed copper tube ensures the low-weight, low-cost as well as the simplification of the antenna manufacturing sophistication. As the size of the substance inspection system based on commercially available NQR spectrometers is generally too bulky to use on the field, these engineering specifications can lead to the effective reduction of the size, assembly effort, total cost of the NQR detection system, ensuring its portability, ruggedness and low weight, while simultaneously maintaining robust detection of explosive materials.

#### References

[1] T. N. Rudakov, V. T. Mikhaltsevich and O. P. Selchikhin, Appl. Phys., vol.30, pp. 1377-1382, 1997.

[2] B. H. Suits, Appl. Magn. Reson., vol. 25, pp371-382, 2004.

[3] J. Shinohara, H. Sato-Akaba and H. Itozaki, Solid State Nucl. Magn. Reson, 43–44, pp. 22–26, 2012.

[4] H. Sato-Akaba, Solid State Nucl. Magn. Reson., 63-64, pp. 30–36, 2014.

[5] N.R. Butt, E. Gudmundson, A. Jakobsson, An overview of NQR signal detection algorithms, in: Magnetic Resonance Detection of Explosives and Illicit Materi- als, Part I, Springer Netherlands, 2014, p. 19-33.

[6] A. Jakobsson, M.Mossberg , M.D. Rowe , J.A.S.Smith ,Frequency-selective detec- tion of nuclear quadrupole resonance signals, IEEE Trans. Geosc. Remote Sens. 43 (11) (2005) 2659–2665.

[7] G. Liu, Y. Jiang, H. Xiong, J. Li, G. Barrall, Radio frequency interference sup- pression for landmine detection by quadrupole resonance, EURASIP J. Appl. SP 20 06 (20 06) 29890. [8] N.R. Butt , A. Jakobsson , S.D. Somasundaram , J.A.S.
Smith , Robust multichannel detection of mixtures using nuclear quadrupole resonance, IEEE Trans. Signal Process. 56 (10) (2008) 5042–5050.

[9] W. Shao, J. Barras, K. Althoefer, P. Kosmas, Detecting NQR signals severely polluted by interference, Signal Porcessing, 2017

[10] "RF Module User's Guide, version 5.3", COMSOL, Inc, www.comsol.com

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#### **Bees for Explosive Detection**

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#### Abstract

NATO Science for Peace and Security Programme accepted to support Bees for Explosive detection at the end of 2017 year. Conditioning of a colony has been challenge and its use in a test mine field conditions was one of the research goals in TIRAMISU FP7 project. An aim of the programme is to develop innovative methods and technologies for the detection of legacy landmines. This will be achieved by the advancement and integration of current state-of-the-art techniques, namely, bee colonies in conjunction with organic semiconductor-based explosive vapour sensing films, and UAVs with high-definition and thermal imaging cameras and image processing and analysis software. The use of these methods together will allow both the passive sampling of an area to confirm the presence of explosive materials, and the active pinpointing of landmine locations. The major objective of Bees for Explosive is to work with end-users and experts to ensure a high-impact delivery of the project's results.

The problem of legacy landmines in post-conflict areas still carries a huge cost in terms of injury to civilians, unfarmed land, loss of trade and communication, and there is potential security threat of the availability of explosive materials being scavenged by terrorist organisations for homemade explosive devices.

Humanitarian demining is expensive, time consuming and presents high risks and threats. Besides well-developed techniques and procedures such as metal detectors and

prodders, use of biological methods is recommended. Existing bio-systems, including bee colonies, can be trained and used efficiently as standalone detection tools. Bees orientate well in space and in their search for food, depend on a well-developed sense of smell [1]. As ideal pollinators, bees collect a particular food, and remain attracted to its odour as long as the pasture exists, even if a new source of food occurs in the vicinity. Knowing their behaviour and biology, it is possible to manage bees. We can direct bees to search the scent that we associate with the source of food, or to have flights in specific area directed by artificial sources of food. Duration of training is very short, i.e. after two to three days bees can link odour with the food source. Persistency to the trained-on odour is not long lasting - only one to three days - but it is possible to prolong interest using short morning re-conditioning. The experience in the training of bees for plant pollination is the basis for training bees to detect the odour of explosives. Since the odours of DNT and TNT are very discreet, training of bees is complex activity. Likewise, it is possible to train bees to recognise the other scents, but the most complex training is on raw military TNT.

Honeybees are widespread in almost all inhabited areas and they present inexpensive tool available at any location. Procedures and methods for honeybee training had been developed (in TIRAMISU FP7-project), and consequently bees can be used as the tool for control of target area on a target scent.

In this project, we propose two complemen-

tary methods for the detection of explosive devices. Both methods use honeybees trained to smell explosive. The first one (passive method) is based on development of new sensors that should enable detection of explosive particles collected by honeybees, and in that way determine if an area covered by the flight of a bee colony is suspected to contain explosives. The second one (active method) is designated for localisation of explosive devices in a suspected area. For this purpose, new methods for monitoring honeybees over the landmines will be proposed, and automatic (computer) analysis of high definition georeferenced video obtained by UAVs will be employed for honeybees detection and tracking. A space-time density map of trained honeybees should point to the location where an explosive device may be located.

#### Honeybees - passive method

The main task of the passive method is to detect the presence, or lack of explosives in a wide area of interest. Honeybees have been used to monitor heavy metals, volatile chemicals, and radioactive materials [2]. As honeybees collect water and forage for nectar and pollen, the electrostatic charge on their body hair attracts dust, pollen, soil, and other particles, including chemicals from their flight area. Thousands of honeybees from a single colony accumulate these particles in flight and bring back to the closed environment of the hive. Honeybees can be directed to fly in specific areas by placing artificial food sources in different positions. On their return, they bring back to their hives particles of chemicals as well as biological agents and other materials collected during flight. The particles of TNT collected in the beehive can be measured and analysed using equipment for the specific detection of nitro-aromatic vapours.

The high sensitivity of organic semiconductor films to nitro-aromatics has led to these materials being considered in recent years as a useful technology for explosive vapour detection [3,4]. The sensors work by a change in light emission (fluorescence or laser light) when minute quantities of TNT-like molecules come into contact with the polymer film. The sensors are promising for detection of collected particles of explosives in bee hives, but more work is required to integrate sampling and detection. Experience has shown that periodic sampling within the hive could allow a much more reliable method for vapour sensing, since several steps are eliminated from the previous procedure.

By combining the passive method of honeybee explosive vapour collection, and improved discrimination of the vapours, it is anticipated that a practical and reliable methodology for explosives detection can be achieved.

#### Honeybees - active method

The main task of the active method is to directly locate explosives in the field of interest. Honeybee colonies will be trained in a closed mesh tent for 4 – 5 days with sugar syrup in an environment of TNT odour. Flying bees in the tent will associate food with the smell of TNT. The conditioned honeybee colony will then be transferred onto the test minefield. Trained bees should search for the targeted odour and then hover over the area of odour presence, i.e. over the location of a buried landmine in a free-flight over an area. However, the main limiting factor in the use of bees for explosives' detection is the inability to track their movements in a free flight. In general beekeeping, many efforts have been investigated in bee monitoring in a hive and at a hive entrance. But monitoring of bees in nature is still an issue. Tracking systems that use video imaging, lidar, radar taggants and pigments have been extensively studied in order to find and track honeybees in a minefield, but an automatic system which allows the establishment of foraging patterns and bee densities is still missing. All the above mentioned technologies have some advantages and disadvantages regarding automatic bee detection, tracking and behaviour analysis. Video acquisition process,

which is needed to be made in order to track movement of trained honeybees across a potential minefield, consists of many task- and equipment-related steps. In order to cover as much ground as possible in the short time, it is necessary to use more than one video camera and an algorithm for movement of unmanned aerial vehicles which carry cameras. The size of each individual honeybee is very small in comparison with the environment which may contain explosives and it is necessary to assure detection of honeybees so that suspicious areas can be isolated. Video acquisition will be achieved using 3 UAVs which fly in formation and provide slightly overlapping videos. This research has the goal of developing an automatic system to establish foraging patterns and space-time bee density map based on data captured in the minefield. We plan to leverage recent advances in the area of computer vision and machine learning in order to design a system for visual detection of bees which is robust to challenging imaging conditions and other sources of degradations. The approach will be based on modern methods for moving object detection and tracking, which are robust to variations in imaging conditions, such as lighting and camera movements. Although a considerable amount of work on these types of algorithms has been done, the algorithms for moving object detection have been focused mainly on larger objects. Therefore, an important challenge that will be addressed in this project is detection and tracking of small moving objects. In order to reduce the number of false positives in detection of honeybees, besides moving object detection, we also intend to use object classification, as bees or other objects, based on their appearance and features. The main ingredients of this approach are representation of images using visual features and their classification via machine learning approaches. In this project we will analyse the possibilities to apply deep neural networks (DNN) to the task of detection of honeybees. We will evaluate using both pre-trained networks and end-to-end training for the specific problem of this project. Furthermore, since it is of interest to move parts of the detection algorithm to an embedded system near the camera, we will investigate the possibilities of implementation of DNN on small embedded systems such as Raspberry Pi. Besides conventional imaging in the visible spectrum, we plan to investigate how using of thermal imaging can help in segmentation of honeybees, as objects of thermal footprints different from backgrounds.

Both honeybee passive and active methods can be used as standalone methods, however better results are expected if used simultaneously or sequentially. For instance, the passive method can be used to initially survey a particular area, followed by the active method then used to pinpoint landmine locations with accuracy. That way, using the active method, costly human and technical resources can be reduced and safety of deminers that are directly involved in the process can be increased. These methods can also be applied for suspected hazardous area reduction and/ or to confirm the completion of the demining process in internal and external quality control.

- [1] Von Frisch, K., (1993) The Dance Language and Orientation of Bees. Harvard University Press, Chambridge, Massachusetts, London, England, Translated by Leigh E. Chadwick, 557.
- [2] Barisic D., J. J. Bromenshenk, N. Kezic, and A. Vertacnik, (2002) "The Role of Honey Bees in Environmental Monitoring in Croatia," in Honey Bees: Estimating the Environmental Impact of Chemicals, J. Devillers and M. Pham-Delegue, eds.. New York: Taylor and Francis, pp. 160-185.
- [3] Thomas, S.W.; Joly, G.D.; Swager, T.M. (2007) Chemical sensors based on amplifying fluorescent conjugated polymers.Chem Rev 107, pp 1339-1386; www.flir.com
- [4] Yang, Y.; Turnbull, G.A.; Samuel, I.D.W. (2010) Sensitive Explosive Vapor Detection with Polyfluorene Lasers. Adv. Fun. Mater. 20, pp 2093-2097

#### Honeybee video-tracking for explosive detection

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#### Abstract:

The utilization of honeybees for automatic explosive detection has been tested during the last few decades. Many biological and technical aspects have been considered, in order to understand all the possibilities for honeybee utilization for explosive detection. The scope of this research is an overview of the honey bees tracking capabilities during the video surveillance of areas potentially contaminated with land mines. The analysis of tracking results may guide to the conclusion of explosive existence which do not include human survey of the examined area. In this paper we present an approach for detection and tracking of honeybees, which enables obtaining a spatio-temporal histogram of honeybees occurrence, and eventually to conclude if there is explosive or not in the area under surveillance.

#### **1. Introduction**

Worldwide, countries that have been involved in war confrontations usually have major problem with remaining minefields, even several decades after the war. Demining methods involving humans are time consuming and dangerous, with possible fatal outcomes. Also, the methods of this kind are usually very expensive.

In the past few decades, many research and

development projects have been realized in order to determine the possibilities of using honeybees in the detection of explosives, landmines and other unexploded ordnance. Honeybees are known to have excellent sense of smell, which they use to look for food. Training honeybees to smell the explosive, enables us to actively use them to search for landmines. Trained honeybees are expected to hover over landmines and explosives. Therefore, honeybees can be used for inspection of areas potentially contaminated with land mines. Using honeybees for explosive detection is safer and cheaper compared to methods involving humans.

Bee4Exp is project, supported by NATO Science for Peace and Security Programme, which investigates methods for the detection of explosive devices using honeybees trained to smell explosive. One of the goals of Bee-4Exp project is to utilize the novel methods for honeybee tracking over the examined area. In this research we try to determine the exact parameters that should be used for video monitoring in order to reliably and accurately track honeybees during the inspection of areas potentially contaminated with land mines.

#### 2. Related work

Possibilities for usage of honeybees for detection of explosives have been widely investigated lately. In several programs of US Defense and Advance Research Projects Agency (DARPA), honeybees were tested for possibilities of chemical signature transport in order to detect explosives and other agents of harm [1, 2, 3].

Important research on honeybees training for explosive detection was done during several research projects. The overall goal of these projects was to determine the methods for bee training and tracing. The method proposed in Tiramisu project included the application of principal component analysis to a sequence of video frames in order to track honeybees [4, 5]. Also, interesting details on possibilities of usage of honeybees in explosive detection is given in [6, 7, 8]. Despite intensive research in previous years, several important questions are left open. How to efficiently capture high quality video during the honeybees' fly over the observed area and how to accurately detect small objects (honeybees) in high resolution videos?

#### 3. Methods for honeybee video-tracking

In this phase of the Bee4Exp project, we implemented a computer vision algorithm for moving object detection and tracking in several video sequences containing flying honeybees. The algorithm includes: video stabilization, optional frame preprocessing, moving object detection and optional postprocessing. In Fig. 1, block diagram of the proposed method is given.

Video stabilization is done by estimating geometric transformation between different video frames, thus it is a crucial step which enables efficient segmentation of moving objects and background. In essence, video stabilization transforms every video frame into the same coordinate system, so moving objects are more likely to be separated from the background.



*Figure 1. Block diagram of the proposed method for honeybee video-tracking.* 

**Frame preprocessing** may include different processing steps in order to enhance moving objects of interest and/or to remove the effect of non-ideal video stabilization. For example, in this research we experimented with calculating difference between the current and previous frame. This difference should emphasize object with large movements between two frames and reduce the background.

**Moving object detection** includes algorithms for background/foreground separation in the sense that foreground represents moving objects, honeybees in our case. In this research, we used mixture of Gaussians for foreground detection.

**Postprocessing** may be included to additionally filter the detection results, model honeybee traces, visualize multiple bee traces or to make spatio-temporal histogram of honeybee's activity over inspected area.

#### 4. Used Videos and Results

In order to test the proposed approach, we used videos captured on different locations and with different cameras parameters. For initial experiments we used short videos obtained during the initial phase of Bee4Exp project. Those videos mostly show individual honeybees in full HD video with 30 fps, taken from about one-meter distance. Next, we experimented with various videos with lower resolution and framerate, captured with mobile devices and few meter distance.

After visual analysis of videos, we could notice the following: (1) Individual bees are hard to detect in a single frame, multiple frames should be used for motion detection; (2) Good contrast of honeybees and background is important for accurate detection and can be obtained during the sunny day; (3) capturing from large distances makes honeybees appear to small and nearly impossible to detect.

The result of honeybee tracking, using the method described in previous section, is the following. For the illustration, a short video with resolution 1080x1920 pixels and framerate of 30 fps is analyzed. An example of a frame from the video, after stabilization, is given in Fig 2. Since the position of a honeybee is hard to determine in a single frame, it is highlighted. In the Fig. 3, the result of frame preprocessing is given. Concretely, this step includes converting frame in grayscale and subtraction of corresponding pixel values of previous grayscale frame. Although the processed frame from Fig. 3 gives a good estimation of honeybee position, it still may contain a significant amount of noise that could lead to false positive detection. Fig. 4 gives the result of foreground detection using method based on mixture of Gaussians. As we can notice, honeybee in the current frame is successfully detected.



Figure 2. One frame from video, showing the honeybee. Position of the honeybee is highlighted.



Figure 3. The result of frame preprocessing.



Figure 4. Result of honeybee detection on the current frame, after the preprocessing and foreground detection (background is given as gray).



Figure 5. Honeybee trace captured during the whole video. The white trace represents the places where honeybee is detected on each video frame (background is given as gray).

Nevertheless, observation of one single frame usually does not give a sufficient amount of information to make any kind of conclusion on bee activity over investigated area. For the purpose of honeybee tracking for explosive detection, we are interested in estimation of honeybee's trace over the specific spot, in order to make a spatio-temporal histogram of honeybees occurrences and to conclude if the observed area is suspicious to explosive or not. Fig. 5 gives honeybee trace for the example video.

#### Conclusion

In this paper, we investigated possibilities to utilize computer vision algorithms for honeybee tracking during the investigation of areas potentially contaminated with land mines. Experimental results showed that tracking algorithm can be successfully implemented in the case of still background, good foreground/background contrast and sufficient video resolution.

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#### References

[1] L. Delaney, 2011, Military Applications of Apiculture: The (other) Nature of War, MMS Executive Summary, link in Bees and Battles, Loudoun Beekeepers Association Newsletter, Nov 2011, Vol. 2, Issue 6.

[2] J. A. Shaw et al., 2005, Polarization lidar measurements of honey bees in flight for locating land mines, OPTICS EXPRESS, 25 July 2005, Vol. 13, No. 15, pp. 5853-5863.

[3] S. W. Webb, S. A. Finsterle, K. Pruess, J. M.

Phelan, 1998, Prediction of the TNT Signature from Buried UXO/Landmines, Sandia National Laboratories for Strategic Environmental Research and Development Program and DARPA, Contract DE-AC04-94AL85000.

[4] Y. Baudoin, TIRAMISU: Technical survey, close-in-detection and disposal mine actions in Humanitarian Demining: challenges for Robotics Systems.

[5] S. Ćosović Bajić, 2014, Analysis of the Possibility of Utilization of Honeybees in Explosive Detection, Polytechnic & Design, Vol. 2. No. 1.

[6] S. Ćosovic Bajić, M Bajić, N. Kezić, 2003, Thermal infrared signatures of the bees as potential biosensors for explosive detection, Int. Conf. Requirements and Technologies for Detection, Removal and Neutralization of Landmines and UXO, 15-18 September 2003, VUB, Brussels, Belgium, Vol. 2, pp. 430-434.

[7] N. Kezić, S. Kemline, N. Pavković, Nikola; R. Noske, H. Gold, M. Bajić, (2006) Use of bees in explosive devices detection. Book of papers, "Mine and UXO detection". Pavković, Nikola (ed). Zagreb: Center for testing, development and training Ltd., 81-84.

[8] N. Kezić, M. Janeš, J. Filipi, M. Dražić, K. Crailsheim, Y. Le Conte, N. Pavković (2013) Conditioning of honeybee colony on TNT and DNT scent. Association of Institutes for Bee Research. Report of the 60th Seminar in Würzburg. 19 - 21 March 2013. Apidologie, 2013 - Vol. 44, p 7-8.

# The rationale and concept of collecting IED, UXO and landmines signatures

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#### Abstract

The actual post-conflict scene is abundant with a variety of the explosive remnants of war (ERW), among them the most important are the landmines, unexploded ordnance (UXO), and the invading threat, the improvised explosive devices (IED). There exist and are known contemporary techniques for detection of landmines and UXOs. The IEDs appear in abundant versions as "remnant IED" or an "operational IED", but the knowledge about IEDs is based on general descriptive data. In comparison with landmines, for IED is typical lack of relevant technical data, from a very limited number of data sources. Our aim is to consider and to discuss the rationale and consider the approach for collecting signatures of the IEDs, UXO, and landmines. Following spectral and sensor domains were considered: hyperspectral (HS) and decimeter wavelengths of harmonic radar (non-linear junction detecting - NLJD). HS imagery of IED in a real environment is not publically available (if it exists at all). The possible approach is to simulate IED objects on HS imagery of various environment types, which are available from different sources. The lack of harmonic radar data of IED causes larger difficulty due to non-linear electromagnetic processes related to target and the propagation in a real environment. Foreseeable direction for research and development of IED detection methods and solutions should be in joining HS and NLJD approach.

**Key words**: IED, UXO, landmine, hyperspectral, NLJD.

#### **1. Introduction**

The landmines and UXO are the most known explosive remnants of war (ERW) with well-established detection methods whereas IED, due to their nature, are hard to detect and demand new solutions, see in [1]: "IED is defined as an explosive device fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic or incendiary chemicals and designed to kill, injure, damage, harass or distract. IEDs are often made from commercially available products and/or military munitions, are simple in design and are usually cheap in labor and cost to produce. IEDs are highly versatile weapons due to the multiple methods available for their construction, delivery, and initiation. This versatility allows them to be rapidly adapted to achieve different effects against varying targets, defeat the tactics and counter-measures employed by opponents and/or changes in the supply of raw material for their construction". The aim of the paper is to present concept of collecting IED, UXO and landmines signatures, which will support and advance the operational research and development of counter IED / countermine action. The order of consideration is IED, UXO, and landmines with focus on the hyperspectral sensing and the application of decimeter wavelengths harmonic radar. Besides the ERW signatures, it is also very important to consider the environment signatures. The concept of the near real time decision support system based on cognitive situational awareness and aerial hyperspectral and harmonic radar concludes the paper.

#### 2. Status of the need

The counter IED awareness is present more than 20 years but significant comprehending step of advancement necessity is made after NATO initiative illustrated in [2]. In 2015, the Egypt military released the description of IED problem and a need for a solution in ground convoy IED protection in post-conflict situations [3]. Described issue is an ongoing problem with periodical intensifications. Due to our experience and references in R&D and operational deployment in countermine and UXO technology [4], [5], [6], [7], Fig.1, Fig.2, in 2016 we were asked to test and certificate harmonic radar technology (NLJD), [8].

Note that harmonic radar was used in operations during 2017 in Syria. Counter IED operational research trends are indicated in [9], [10].





Figure 1. a) UXO reflectance spectra measurements with hyperspectral line scanner. b) Color photography of UXO. c) Color RGB visualisation of the hyperspectral cube. d) Graph of the corresponding reflectance spectra of UXO, soil and grass.





Figure 2. Aerial hyperspectral cube of the terrain example a) RGB visualisation, b) reflectance spectra of trees (green), grassy soil (turquoise), concrete (gray), dirty road (red).

#### 3. Promising tools for counter IED survey - hyperspectral scanner and harmonic radar

Merging the hyperspectral, [7], and harmonic radar data acquisition from the unmanned aerial vehicle (UAV) seems to be a promising technology for early warning systems in front of ground vehicles convoy, [3]. For this approach three crucial problems exist: a) selection of representative IED types and lack of their signatures, b) inability to define IED's response in the real environment when using harmonic radar above the ground, c) lack of IEDs data measured by harmonic radar. One example of representative IED types is given in [10], while Fig 3 shows spectral signature of our measured IED selection.



Figure 3. Reflectance spectra of four landmines/IEDs and soil.

The IED hyperspectral signatures can be collected by imaging sensors and spectroradiometers. Based on applied technologies final output can vary from a hyperspectral cube with reflectance or the radiance values, [4], [5], [6], Fig.1, Fig.2 to discrete reflectance measurements, Fig. 3. The abundance of IED variations is large and growing, but still with no available IED spectral signatures database, including ones within the relevant environment. One of the approaches to deal with this issue is to simulate objects as presented in [11] for landmines. Since landmines can be simulated on a different scenes of the hyperspectral imagery we propose similar approach with IEDs. A simulation will be done based on the collected IED spectral signatures and simulated on available hyperspectral imagery.

Analysis of the data collected with harmonic radar within real surroundings above ground surface is presented in [9]. It shows an obstacle for research and operational application of IED detection.

For the convoy counter IED support, we developed a concept of the advanced decision support system shown in Fig. 4. The goal of such system is to collect and analyze all relevant data in order to assist convoy decision makers in the real time (situational awareness), starting from approved usefull GIS based multicriteria decision support system for mine action [12].

In our future work we will continue research of the situational awareness system and continue collecting IED, UXO and landmines signatures. Cordially invited to establish cooperation.



*Figure 4.* The concept of the situational awareness decision support system for ground vehicles convoy in counter IED support during postconflict operations.

#### References

[1] UNDSS (2017). Improvised Explosive Devices (IEDs), UNITED NATIONS SECURITY MAN-AGEMENT SYSTEM Security Policy Manual, Chapter IV Security Management, Management of Security-Related Incidents, Y. Improvised Explosive Devices (IEDs), UN Department of safety and security, UNDSS, 18 April 2016, Update 10 October 2017.

[2] SCI-256 RTG (2014). SCI-256 Task Group Investigates Nonlinear Junction Detection for Counter-IED Applications, 12-16 May, 2014. https://www.cso.nato.int/mobile/page.asp?ID=2242

[3] Bajić, Milan; Orehovec, Zvonko; Manda, Mislav (2015). Intelligent Counter IED/CBR System For Convoy Protection, presented at CSCM – World Congress on CBRNe Science & Consequence Management, Robotics and Automation in Defense against CBRNe Threats, Zagreb 14 April 2015.

[4] Bajić, Milan (2012). Airborne Detection of UXO, Reconstruction of Former War Zone, NATO EOD COE Demonstrations & Trials 2012 Conference "Detection", September 18, 2012, Trenčín, Slovakia. A book of papers – The EOD Future in the Light of Demonstrations and Trials 2012, pp. 33-41.

[5] Bajić, Milan; Ivelja, Tamara; Krtalic, Andrija; Tomić, Mile; Vuletić, Dejan (2013). The multisensory and hyperspectral survey of the UXO around the exploded ammunition depot, of the land mines test site vegetation. The 10th International Symposium "Humanitarian demining 2013", Book of Papers. HCR-CTRO, Zagreb, Croatia, 2013. pp. 91-96.

[6] Bajić, Milan; Krajnović, Marko; Brook Anna; Ivelja, Tamara (2014). Ground vehicle based system for hyperspectral measurement of minefields. The 11th International Symposium: "Humanitarian Demining 2014", Book of Papers, HCR-CTRO, Zadar, Croatia, 2014. pp. 11-14.

[7] Bajić, Milan; Ivelja, Tamara; Brook, Anna (2017). Developing a Hyperspectral Non-Technical Survey for Minefields via UAV and Helicopter. Journal of Conventional Weapons Destruction, Volume 21, Issue 1 Journal of Convetional Weapons Destruction, Issue 21.1. http://commons.lib. jmu.edu/cgi/viewcontent.cgi?article=2775&context=cisr-journal

[8] Jungwirth, Oto; Vondraček Blašković, Tomislav; Ivelja, Tamara; Vakula, Sanja; Bajić, Milan (2016). Report on testing of detectors NR-900EK3M EAGLE, NR-2000 and NR-12C, HCR Center for testing, development and training, Ltd., Sortina 1d, 10000 Zagreb, Croatia, May 2016.

[9] Bajić, Milan (2017). Propagation model of harmonic radar for detection the nonlinear contacts of the improvised explosive devices, Polytechnic & Design, Vol. 5, No. 3, 2017, Zagreb University of Applied Sciences, Zagreb, Croatia. pp.210-218. (In Croatian).

[10] Mohammed, Salam; Schoolderman, Arnold (2018). Developments in detection technology for military search. COUNTER-IED REPORT, Winter 2017/18, pp. 33-41.

[11] Makki, Ihab; Younes, Rafic; Francis, Clovis; Bianchi, Tiziano; Zucchetti, Massimo (2017). Classification algorithms for landmine detection using hyperspectral imaging, First International Conference on Landmine: Detection, Clearance and Legislations (LDCL), Faculty of Engineering - Lebanese University, Lebanon, April 26-28, 2017. http://www.icldcl.com/

[12] Bajić, Milan (2010). The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas. The Journal of ERW and Mine Action, Issue 14.3, Fall 2010.

#### **Dual Sensor "ALIS " for Humanitarian Demining**

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#### I. Introduction

In conventional humanitarian demining operation, landmine detection was carried out by EMI (Electromagnetic Induction) sensors (Metal detector). However, problem of detection of mines by EMI Sensor is large amount of metal debris which have to be removed together with land mines. In order to increase the efficiency of land mine detection, GPR (Ground Penetrating Radar) has been employed. A combined sensor of EMI and GPR is called "Dual Sensor" in humanitarian demining. We have developed ALIS (Advanced Landmine Imaging System) dual sensor since 2002 and have deployed it in mine affected countries. In this paper, we introduce the technology used in ALIS and its achievements.

## II. EMI and GPR for humanitarian demining EMI

sensors, which is also called as a metal detector, has widely been employed in detection of buried landmines, UXO and explosive substances. EMI sensors can detect only electrical conducting material included in these explosive objects. In contrast, Ground Penetrating Radar (GPR) can also be used for not only metallic objects, but also non-metallic objects. GPR is sensitive to even very small targets such as gravels and tree roots, and even inhomogeneous soil moisture. Therefore, if we use only GPR for detecting landmines, we will be confused by numerous images of subsurface material. Therefore the idea of Dual sensor is we use EMI sensor as a primary sensor, and then we use GPR as a secondary sensor for classifying the detected objects. Tohoku University has developed a dual sensor ALIS since 2002 [2]-[9].

The ALIS prototype was equipped with a camera which is set on the pole of the sensor head, which looks down on the ground surface, and the movement of the sensor was estimated from the captured images of the ground, then it could track the position of the sensor, while it is moved by a hand of an operator for survey. The GPR system used in ALIS uses cavity back spiral antennas and operates at 1-3 GHz. We found that GPR can image more than 20cm, which is required from UN standards. The GPR data and EMI sensor acquired with the sensor position information are recorded on a PC and are processed simultaneously to visualize the data. One of the unique points of ALIS is that it can use Synthetic Aperture Radar (SAR) processing for GPR image reconstruction [3]. As far as we were concerned, there is no other dual sensors which can use SAR processing for obtaining GPR images for hand held GPR sensor, which can be used for landmine detection. It should be noted that SAR processing is equivalent to migration processing used in GPR signal processing.

#### III. ALIS development

The development of ALIS started in 2002, and the first prototype of ALIS was completed in 2004. We conducted field tests of ALIS operation in an evaluation test site prepared in Afghanistan in 2004, using inert mines [5]. In this test we could confirm that SAR processing is quite useful for GPR under the real mine field condition. If we test GPR performance in sandpit, most GPR systems can image the buried landmine clearly, because sand is homogeneous and there is no clutter. In real mine field conditions, very strong clutter which is caused by the gravel and tree roots in the soil, and inhomogeneity of soil moisture distort the GPR image of buried landmines. However, we found that SAR processing reduce the clutter drastically, and we could recover clear GPR images. The initial test in Afghanistan has to be quitted, because of the unstable political situation, and we continued the test in Cambodia in 2006.



*Fig.1 ALIS (Second generation prototype) operated in a mine field in Cambodia.* 

Based on the field experiment, we developed the second-generation prototype ALIS. The first porotype of ALIS was operated by 2 operators. One of the operator scan the sensor head and the second operator processes the data and analyses the SAR images to detect buried mines. However, after the test evaluation, we found that the system should be operated by one operator in real mine fields, and the second generation prototype of ALIS can be operated by one operator as can be seen in Fig.1. The system is composed from 3 components, which include sensor head, PC for signal processing and display and backpack including electrics board and battery. "This type of ALIS was tested in Croatia in 2006 and 2007 at the Test-site Benkovac of the Croatian Mine Action Centre - Centre for Testing, Development and Training (CRO-MAC-CTDT), as part of the wider joint cooperation project between Japan Science and Technology Agency (JST) and CROMAC-CT-DT. In 2008, in co-operation with CROMAC and CROMAC-CTDT, it was used as a verifying method of conventional QA/QC (quality assurance/quality control) procedures that were carried out by QA/QC officers of CROMAC"[6].

## IV. ALIS deployment in mine afected countries

We conducted the evaluation test of the second-generation prototype ALIS in Cambodia in 2009 together with CMAC

(Cambodian Mine Action Centre). Then, CMAC gave the certificate to ALIS for operation for humanitarian demining, and decided to use the prototype of ALIS in mine clearance operation in mine fields. Tohoku University and CMAC agreed to organize a team for ALIS and 2 sets of the prototype ALIS systems have been used in mine fields since 2009. Since 2009, more than 254,867m2 mine area has been cleared, and more than 80mines have been detected by ALIS. Totally 15,621 metal fragments were detected, and demines have judged that 12,081 (77%) detected objects out of them are not mine. There was not case that mine was judged as a fragment. This means, if ALIS is used for mine clearance operation, more than 70 % of detected objects by metal detectors does not have to be excavated as possible mines. We believe this will drastically shorten the time for excavation.

#### V. ALIS

Based on our experience of operation of ALIS in mine affected countries including Croatia and Cambodia, we have continued hardware development of ALIS and it was completed in 2017. This "Advanced ALIS" is composed from one unit, which include EMI and GPR sensor head and its electronics and batteries, and an Android tablet which is used for SAR processing and data display. One of the major technical change compared to the conventional ALIS is its senior position tracking function. Conventional ALIS has used web camera and image based sensor position tracking system. In the Advanced ALIS, we are now using accelerometer equipped within the sensor head for the sensor position tracking. For the signal processing, we use a tablet (Panasonic Toughpad), which works on Android. Other technical specifications of the advanced ALIS including EMI and GPR performance have not been charged from prototype ALIS.



Fig.2 Advance ALIS (Size for transportation is shown)

Therefore, we believe that the technical performance of the advanced ALIS has already been validated by ALIS prototype operations in mine fields.

The system is powered by Ni-MH rechargeable battery, and works more than 6 hours. The size of the system is shown in Fig.3, and it is not much different from conventional EMI sensors (metal detectors) used for humanitarian demining. The total weight of the equipment including the battery is 3.1kg. Data acquisition starts by pushing a button on the sensor handle, and after finishing the data acquisition by pushing the button again, Synthetic Aperture signal processing automatically starts and the EMI signal and 3-D GPR reconstructed image will be displayed on the window of the tablet. The operator can change the depth of the 3-D GPR image and can identify the buried mine and its depth. Semi-automatic landmine detection software will also be implemented for assistance of the mine recognition.

We conducted the evaluation test at a test site of CMAC in February 2018. Fig.4 shows on example of the data. Fig.4(a) shows the EMI signal, superimposed with the trajectory of the antenna. The area of survey is 40cm by 40cm in this case. It will be typically around 50cm by 50cm, which a deminer can scan the sensor head without moving. Fig.4(b)-(d) show GPR horizontal images (C-scan) at different depths. The deminer can change the depth of the C-scan image by sliding the display by a figure, then can judge the shape of the buried objects. After the data acquisition, signal processing takes only a few seconds, and the deminer can judge the images immediately after the scanning.



Fig.3 ALIS system

The scanning operation of the ALIS antenna is not much different from the conventional EMI sensors. Therefore we believe the introduction of ALIS is easy for deminers who have experience on EMI sensor operation.



#### (a) EMI sensor signal



(b) GPR (Ground surface 0cm depth)





#### (d) GPR (11.2cm depth)

Fig.4 EMI and GPR signal processed by ALIS. Type-72 mine model is buried at 10cm in sand.

#### **VI. Conclusion**

We described the development of ALIS, which is a dual sensor for humanitarian demining in this paper. ALIS technology has been established based on the evaluation test of operation in real mine fields in Cambodia. ALIS is 3,100g in weight and much smaller than the previous prototype ALIS equipment. Software is implemented on Android tablet and 3-D GPR reconstructed image can be shown on the display by Synthetic Aperture Radar processing.

#### References

[1] http://www.the-monitor.org/en- gb/reports/2017/landmine-monitor- 2017.aspx

[2] M.Sato, "Evaluation test of ALIS in Cambodia for humanitarian demining," Proceedings of SPIE - The International Society for Optical Engineering 7664 - April, 2010.

[3] X. Feng, J.Fujiwara, Z. Zhou, T. Kobayashi and M. Sato, "Imaging algorithm of a Handheld GPR MD sensor (ALIS)," Proc. SPIE 5794, 1192-1199, 2005.

[4] M. Sato, J. Fujiwara, X. Feng, Z. Zhou and T. Kobayashi," Development of a hand-held GPR MD sensor system (ALIS)," Proc. SPIE .5794, 1000-1007, 2005.

[5] M. Sato, "Dual Sensor ALIS Evaluation Test in Afghanistan, "IEEE Geoscience and Remote Sensing Society Newsletter, 22-27, 2005.

[6] M. Sato, "ALIS evaluation tests in Croatia," Proc. SPIE.7303, 73031B-1- 73031B-12, 2009.

[7] M. Sato, J. Fujiwara and K. Takahashi, "The Development of the Hand Held Dual Sensor ALIS," Proc. SPIE, 6553, 65531C-1-65531C-10, 2007.

[8] M. Sato and K. Takahashi, "The Evaluation Test of Hand Held Sensor ALIS in Croatia and Cambodia, "Proc. SPIE, 6553, 65531D-1-65531D-9, 2007.

[9] M. Sato and K.Takahashi, "Development of the hand held dual sensor ALIS and its evaluation," Proc. 4th International Workshop on Advanced Ground Penetrating Radar. Pp.3-7, 2007.

[10] Riafeni Karlina and Motoyuki Sato, "Model-Based Compressive Sensing Applied to Landmine Detection by GPR," IEICE Transactions on Electronics, E99-C(1), pp44-51, 2016.

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# The Indicators of Mine Presence and Absence in Airborne and Satellite Non-technical Survey

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#### Abstract

The key object of interest in airborne and satellite Non-technical Survey are the indicators of mine presence and absence. That is why it is of great importance to establish an adequate list of indicators that will ensure the quality use and implementation of aerial and satellite Non-technical Survey. Close cooperation of all experts in the process of airborne and satellite Non-technical Survey is needed. Experts in the Mine Action Centers conduct an analytical assessment of existing Mine Information System data and establish a list of special and general requests for collecting additional information from the depth of Suspected Hazardous Area. Experts in remote sensing methods help them in forming the list of indicators for a specific geographic area. After multi-sensor airborne data collection and procurement of satellite images of a particular Suspected Hazardous Area, mine scene interpreters are locating and extracting the indicators from these images. The level of confidence is then assigned to the extracted indicators. In locating the indicators in the images, mine scene interpreters use expert and contextual knowledge of conducting war doctrines in particular geographic areas and (optional) simpler image processing methods. Geocoded indicators and their confidences are input for the production of Mine Danger Maps. This paper describes the role of indicators in Non-technical Survey processes in Croatia and Bosnia and Herzegovina within TIRAMISU - Advanced Intelligent Decision Support System.

*Key words:* non-technical survey, indicator of mine presence, indicator of mine absence, mine scene interpretator, georeferencing, confidence

#### **1. Introduction**

The 'Non-Technical Survey refers to the collection and analysis of data related to the presence, type, distribution and surrounding environment of mine/ERW contamination without applying technical interventins, in order to provide better determination of the presence or absence of mine/ERW contamination, and to support land release prioritisation and decision-making processes through the provision of evidence' [1]. Remote sensing used for that purpose in the humanitarian demining in Croatia [2] and Bosnia and Herzegovina [3]. Remote sensing can provide a good insight in the areas that are contaminated by mines [4] without entering these areas. The goal of using remote sensing is to collect image data (aerial and satellite images) about Suspected Hazardous Area (SHA), and find and/or extract the indicators of mine presence [5], [6] or absence [7] on it. The indicators of mine presence depend on the geographical area where the conflict takes place and the doctrine of warfare in that area. This is why close cooperation between demining experts and remote sensing experts is needed to determine an adequate list of indicators. The mine scene interpreters [8] and experts in image processing are needed for finding, locating and extracting the indicators. The first ones are photo-interpreters (mainly), former members of the military and familiar with war doctrine. They include contextual knowledge in interpretation and search the indicators manually. On the other hand, the other experts use image processing methods to enhance indicators in images [9], [10]. Consequently, it results making the fusion with the information from other available sources (mine information system) within TIRAMISU Advanced Intelligent Decision

Support System [11], [12]. The interpretation and use of data fusion results are intended for the estimation of the awareness that the assessment of the contamination of suspicious areas should be updated. [13].

## 2. The indicators in mine action in Non-technical Survey

Indicators of mine presence (Figure 1) are the objects within the SHA that are assumed to be protected by mines, and indicators of mine absence (Figure 2) are objects within the SHA that are assumed not to contain mines [4].



*Figure 1. Indicators of mine presence (in red circle) - military position consisting of various fortifications (trenches, drywalls, shelters for soldiers, shelters for artillery).* 



Figure 2. Indicators of mine absence (green polygons) – areas in use within SHA.

The experts from Croatian and Bosnia and Herzegovina Mine Action Centers conduct an analytical assessment of the existing Mine Information System data and establish a list of special and general requirements for collecting additional information from the depth of specific SHA within TIRAMISU – Advanced Intelligent Decision Support System (T-AIDSS) [12]. The purpose of this action is to collect new information about the existing SHA for its redefinition.

#### 2.1 List of indicators

The experts of war doctrine and humanitarian demining in a particular geographical area (Croatia and Bosnia and Herzegovina) formed the list of natural and man-made objects for a specific geographic area (type of terrain and climate) that can be used for military purposes (indicators of mine presence, Table 1) and can be seen on aerial and satellite imagery according to their familiarity with the manner of conducting of conflict and to the experience from demining projects that were previously carried out.

Nr.	Indicators of mine presence	Importancce
1.	Minefield records	1
2.	Mine accidends	2
3.	Table marking of the minefield	3
4.	Fortifications	4
5.	Trenches	5
6.	Bunkers	6
7.	Natural objects modified to serve for fire action	7
8.	Dry wall (in a battle area)	8
9.	Shelters for artiltery, vehicles, infantry	9
10.	Bridges, passes of water ways	10
11.	Dominant hill	11
12.	Edges of forest	12
13.	Fords	13
14.	Heliodrom	14
15.	Roads not in use (in a battle area)	15
16.	Abandoned overgrown areas	16
17.	Demolished houses (on the first front line)	17
18.	Observation posts (usually for hunting)	18
Nr.	Indicators of mine absence	Importance
1	Houses in use	1
2	Areas in use	1
3	Roads in use	1
4	Step terrain, slope greater than 30 degrees	1
5	Swamp terrain	1

Table 1. List of indicators created for SHAs in Croatia.

Furthermore, the possibility of recognition and extraction of indicators of mine presence on aerial and satellite images greatly depends on the image quality and corresponding ground sampling distance. Because of that, the process of creating a list of indicators is of great importance for the implementation of high-quality Non-technical survey. It is necessary to ascertain whether a particular object (indicator) can be detected and recognized on aerial and satellite images. This taks is to be accomplished by remote sensing experts in the process of forming a list of indicators of mine presence and absence. Furthermore, they need to determine the methods of remote sensing and image processing that will ensure locating or extracting the indicators on digital images.

#### 2.2 Locating and extracting of indicators in mine action

The processing and interpretation of aerial and satellite images starts with the visual, subjective triage of the imagery. The mine scene interpreters conduct the subjective analysis of the images using expert, common and contextual knowledge of war doctrine in a particular geographical area. However, image interpretation could be also computer-assisted by conducting some particular methods of image processing for the purpose of extracting of indicators of mine presence [9], [10], [13]. A human as interpreter can hardly be replaced by automatic methods of digital image processing, but, some methods of digital image processing can help in the identification of certain anomalies in the scene and easier detection of indicators. The basic idea of interactive methods of semi-automatic interpretation of digital images of SHA is to provide assistance to the interpreter in the interpretation of digital images rather than to replace him [14]. Methods of image processing should be simplified and automated so they could be carried out by persons without much knowledge of image processing. The images that contain the indicators of mine presence and absence are selected and georeferenced. Georeferencing of an airborne image is an important step in setting up the indicators in relation to other objects in the environment within a common coordinate system. After that, each indicator is vectorized and stored in GIS.



Figure 3. The result of launching the dark line detector – automatically detected part of the trench (blue line within red elipse) [9] on aerial RGB image.

#### 2.3 The level of confidence of indicators

Humanitarian demining is a very dangerous and risky business and no information from the field should be ignored no matter how insignificant it may seem. The quality of interpreter's work depends on: quality and ground resolved distance of images and its processing; knowledge of war doctrine, and in a particular, the experience of interpreter. For this reason, each interpreter determines also the subjective confidence of his statement for each located indicator. If he is sure that the object to be seen on the image is an indicator, he records the confidence = 100%. If he should notice any anomaly in the shape of indicator on the image that he finds suspicious, he records the confidence = 25%. Between these two extreme cases, the confidence from 50 to 75% is applied depending on the interpreter's assessment.

#### 3. Inputs for Mine Danger Map

Determination of confidence level is very important step within T-AIDSS methodology because georeferenced indicators and their confidences are main inputs for the production of Mine Danger Maps [4], [7], [13]. Mine danger maps are products of multi-criterial data analysis and data fusion within T-AIDSS methodology [12]. The most important parameters related to the performance of multi-criterial data analysis are the importance of indicators, the confidence of data in mine information system and the confidence of the statements made by the interpreter of the mine scene. Mine danger maps show areas and hazard levels of mines in SHAs [4], [13].

#### 4. Conclusion

Airborne and satellite Non-technical Survey can provide useful insight in the depth of SHA. In this way, the surveyors of mine action centers can get an insight into the current state of depth of SHA without entering it physically. For the best performance of Non-technical Survey, it is necessary to analyze the existing data in the mine information system and to define the list of indicators of mine presence that can be detected and located on aerial and satellite images. The indicators of mine presence are the main objects that are used to define the boundaries of SHA. On the basis of new information about the existence or absence of indicators of mine presence (that were not known before), it is possible to reconstruct previously defined SHA. The interpreters of mine scenes locate and mark off indicators of mine presence and absences supported by image processing methods. Georeferencing of aerial images is an essential preprocessing step for the most accurate positioning indicators in the surrounding area (a common coordinate system). Image processing methods are a powerful tool that greatly helps in locating the indicators, but the ultimate decision to detect the indicators and determine the confidence is left to the human, the interpreter of the mine scene. The data prepared in this way are input data for the production of a mine danger maps that is the main result of the Non-technical Survey and a useful source of information to experts from mine action center in the process of reducing and better (re)defining of SHA.

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#### 6. References

[1] IMAS 04.10 (2003). Glossary of mine action terms, definitions and abbreviations. Second Edition, 01 January 2003, Amendment 7, August 2014. Retrieved September 1, 2017, from https://www.mineactionstandards.org/standards/international-mine-action-standards-imas/imas-inenglish/ (7/3/2018)

[2] ITF (2008). Deployment of the Decision Support System for Mine Suspected Area Reduction, Project, International Trust Fund for Demining and Mine Victim Assistance, Ig, Slovenia

[3] ITF (2009). Deployment of the Decision Support System for Mine Suspected Area Reduction in Bosnia and Herzegovina, Project, International Trust Fund for Demining and Mine Victim Assistance, Ig, Slovenia

[4] Acheroy, M.; Yvinec, Y. (2008). Mine-suspecte Area Reduction Using Aerial and Satellite Images, Humanitarian Demining: Innovative Solutions and the Challenges of Technology, Book edited by: Maki K. Habib, ISBN 978-3-902613-11-0, pp. 392, February, I-Tech Education ans Publishing, Vienna, Austria

[5] van Genderen, J.; Maathuis, B. (1999). Pilot Project for Airborne Mine-field Detection in Mozambique, EC-DG8, Angola project

[6] Vanhuysse, S. (2002): Mission Report (fieldwork in Croatia), SMART, EC IST-2000-25044

[7] Yvinec, Y.; Bajić, M.; Dietrich, B.; Bloch, I.; Vanhuysse,

S.; Wollf, E.; Willekens, J.; (2005). Final Report, Space and Airborne Mined Area Reduction Tools, project SMART, European Commision IST-2000-25044, Classification: Public http://www.smart.rma.ac.be/ (7/3/2018)

[8] Krtalic, A.; Vuletic, D. (2005): The role of the mined scene interpreters, presentation, Inventory and analysis of operationally validated results related to mine action space - and airborne surveys, workshop, 30/11/2005., Faculty of Electrical engineering and Computing, Zagreb, Croatia

[9] Lacroix, V.; Vanhuysse, S. (2014). Indicators of Mine Presence: Focus on Trenches, South-Eastern European Journal of Earth Observation and Geomatics, 3, 2, 635-639

[10] Vanhuysse, S; Hölbling, D; Friedl, B.; Hanson, E.; Krtalić, A.; Hagenlocher, M.; Racetin, I.; Wolff, E. (2014). Object-Based image analysis for detecting indicators of mine presence to support suspected hazardous area re-delineation, GEOBIA 2014, Advancements, trends and challenges, 5th Geographic Object-Based Image Analysis Conference (2241-1224), Vo3 (2014), No2S; 525-530

[11] Bajić, M. (2010). The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas, Journal of Conventional Weapons Destruction, Vol. 14, Issue 3, article 28, pp. 69-75

[12] Krtalić, A. (2016). TIRAMISU Advanced Intelligence Decision Support System, The 13th International Symposium MINE ACTION 2016, Book of papers, 26-29 April 2016, Biograd, Croatia

[13] Yvinec, Y.; Milisavljevic, N.; Beumier, C.; Mahamadou, I.; Borghys, D.; Shimoni, M.; Lacroix, V. (2017): Mine Action - The Research Experience of the Royal Military Academy of Belgium, Chapter 5 - Remote Sensing for Non-Technical Survey, INTECH, http://www.intechopen. com/books/mine-action-the-researchexperience-of-the-royal-military-academy-of-belgium (7/3/2018)

[14] Racetin, I.; Krtalić, A.; Candjar, Z. (2014). The concept of method for semi-automatic interpretation within T-AI DSS, The 11th International Symposium MINE ACTION 2014 - 23rd to 25th April, Zadar, Croatia

#### The Influence of Spatial Calibrations of Hyperspectral Line Scanners on the Accuracy of Geocoding of Hyperspectral Cube

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#### Abstract

Although calibration during geocoding process shows drastic improvements in achieved geocoding accuracy, the internal orientation error remains. In order to properly determine these errors, we must first of all know the mathematical model of mapping of the line sensor. The mathematical model of mapping of the line sensor has been expanded to account for the distortion of the lens in order to eliminate all systematic errors induced by displacement of the real sensor mapping plane from the ideal mathematical model of the central projection. After a mathematical model was established, a calibration of the hyperspectral scanner was performed in the laboratory, observing test samples from 5 different recording sites. Calibration elements are determined by airborne beam equation (BBA method).

*Key words:* hyperspectral scanner, spatial calibration, parametric geocoding, accuracy

#### 1. Introduction

The presence of mines, which remain in the field after the military operations, is a major threat, even after military operations are over,. By the November 2015, 61 countries contain areas with left behind mines [1]. Croatia is particularly vulnerable to mine danger due to proximity of the populated areas to the minefields. Therefore, often comes to the triggering of murderous mines and explosives with tragic consequences for unaware civilians. There are basically two approaches to detect dangerous areas polluted by mines: 1. Detection of individual mines - explosive

detection procedures, and 2. Detection of mine presence and mine absence indicators - using contextual knowledge. Although numerous research is being conducted on appropriate explosive detection technologies, the reliability of mine detection is still unsatisfactory, especially in the conditions of the harvested terrain - which is also typical for mine suspected areas [2]. Therefore, a second approach was used within scope of the complex technology-research project TP-06 / 0007-01, where multispectral and hyperspectral imaging technology was successfully used for the purpose of detecting mine presence and absence indicators visible from the scene. For this purpose, a multi-sensor pod has been constructed with a built-in hyperspectral scanner and an inertial measuring unit (IMU) (Fig 1)



Figure 1. Placement of push-broom hyperspectral scanner and the inertial measurement unit (IMU) within the multisensor pod.

#### 2. The module for hyperspectral imaging

This module allows obtaining georeferenced data recorded by the ImSpector V9 hyperspectral line scanner (HSLS) equipped with CCD sensor (PCO PixelFly) when scanning from the aerial platform. To allow recording with relatively unstable platforms such as light airplanes and helicopters, the hyperspectral line scanner is equipped with additional devices that allow continuous measurement of the position and orientation parameters of the scanner during flight. The inertial measurement unit iMAR-iVRU-RSSC is integrated with L1 frequency GPS receiver, an optimum positioning sensor, taking into account spatial resolution of the hyperspectral line scanner at the expected flight profiles and the need of targeted applications such as: staining on the Adriatic, burning of fires, recording mine suspect surfaces, water quality monitoring, disease detection, etc.

The hyperspectral imaging module is deployed at different platforms [3], further justifying the need for calibration of the system with this level of complexity in order to obtain high-quality results. The methodology for creating a geocoded hyperspectral cube based on a line scanner was developed within TP-06 / 0007-1 and detailed in [4]. Examination of the geocoding accuracy of the hyperspectral cube was carried out at the Faculty of Geodesy of the University of Zagreb, Department of Photogrammetry and Remote Sensing [5].

## 3. Calibration of hyperspectral line scanner during geocoding

During parametric geocoding process performed in PARGE software (by ReSe company) it is possible to calibrate the parametric geocoding system in such a way as to observe the point of the calibration field. This calibration eliminates the impact of the most significant errors in parametric geocoding, the errors of the orientation parameters provided by inertial reference system and positional parameters provided by the GNSS unit, and error induced by unaligned axis of the hyperspectral scanner with the parts of the inertial reference system and visual field of view of the hyperspectral scanner. For the purpose of carrying out this calibration, a calibration field was prepared at the airport of Pula (Fig. 2). This calibration field consists of 10 ground control points (GCP) marked as white crosses. The "true" coordinates of GCPs were determined by the static GNSS measurements and precise tachaeometry.



Figure 2. Calibration field at the military airport of Pula. Ground control points are marked as white crosses.

The differences between ground truth (reference), geodetic coordinates of ground control points (GCP), and the coordinates read from the geocoded hyperspectral cubes, with and without calibration performed in PARGE during geocoding process, are shown in Table 2. The significant rise in geocoding accuracy by use of calibration during geocoding process is evident.

## 4. Laboratory calibration before geo-coding

Although calibration during geocoding shows drastic improvements in geocoding accuracy, the internal orientation errors remain. In order to properly determine these errors, we must know the mathematical mapping model of the line sensor. The mathematical mapping model of the line sensor has been expanded to account for the influence of the lens distortion in order to eliminate all systematic errors induced by displacement of the real mapping sensor plane from the ideal mathematical model of the central projecNew technologies in mine action

tion. After the mathematical model was established, a calibration of the hyperspectral scanner was performed in a laboratory, by observing test pattern (Fig. 3) from 5 different recording sites.



*Figure 3. Test pattern for laboratory calibrati-on of the hyperspectral scanner* [6].

Intrinsic parameters of the hyperspectral scanner are determined by bundle block adjustment method (BBA) and are shown in table 1. The diagram of radial distortion is shown in Fig.4 [6]

Using the intrinsic parameters of the hyperspectral line scanner, obtained by laboratory calibration, significantly improves the accuracy of the geocoded hyperspectral cube, compared to the calibration performed during geocoding process, making it twice better than without it, as it is shown in Table 2.

$x_0$ (pix)	c (pix)	K1	K2	K3
497.5	3605	0.69	-0.08	0.003
+-0.1pix	+-14 pix			

 

 Table 1. Intrinsic parameters of the hyperspectral scanner for yellow-green colour [6]



*Figure 4. Diagram of radial distortion for ImSpector V9 and yellow-green colour (in pix.).* [6]

Coordinate differences on GCPs (true - geocoded)							
Without calibra- tion		Calibration during geocod- ing		Laboratory ca-li- bration before geocoding			
Δy	Δx	Δy	Δx	Δy	Δx		
[m]	[m]	[m]	[m]	[m]	[m]		
-23.70	10.20	-1.10	-1.10	-0.31	0.21		
-25.43	1.94	-1.27	0.96	-0.58	0.33		
-23.80	15.81	-0.3	0.49	-0.36	0.45		
-24.96	-2.81	-0.44	0.01	-0.44	0.15		
-22.99	9.45	-0.61	-0.25	-0.26	-0.35		
-23.87	2.67	-1.13	0.93	0.31	0.11		
-24.44	6.38	0.34	0.32	0.22	0.21		
-25.21	8.67	0.61	-0.27	0.28	-0.17		
-24.70	8.20	1.30	-0.32	0.53	-0.28		
-23.75	8.00	0.65	-0.52	0.41	-0.32		
$\sigma_y =$	σ <sub>x</sub> =	$\sigma_y =$	σ <sub>x</sub> =	$\sigma_y =$	σ <sub>x</sub> =		
0.78	5.16	0.88	0.65	0.40	0.29		

Table 2.

#### 5. Conclusion

The spatial calibration of hyperspectral line scanner has shown as a necessary method to reach a useful accuracy of the geocoded hyperspectral cube. It is especially the case when the scanner is bundled with low-cost inertial measuring unit, GNSS-sensor and unstable aerial platform. However, even in such cases it is possible to get reliable results and obtain hyperspectral cubes of reasonable spatial accuracy. First of all, the ground control points are necessary to remove the impact of systematic errors due to the imperfections in system integration of hyperspectral scanner, GNSS and IMU. Although in many applications of the remote sensing achieved spatial accuracy might be satisfactory, the previous laboratory calibration of the hyperspectral scanner has a major impact on the geocoding accuracy.

#### 6. Acknowledgement

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#### 7. References

[1] Landmine Monitor, 2015. International Campaign to Ban Landmines- Cluster Munition Coalition (ICBL-CMC). ISBN: 978-2-8399-1707-0 http://www.themonitor.org/media/2152583/ Landmine-Monitor-2015\_finalpdf.pdf.

[2] Makki, I., Younes, R., Francis, C., Bianchi, T., Zucchetti, M. (2017). A survey of landmine detection using hyperspectral imaging, ISPRS Journal of Photogrammetry and Remote Sensing 124 (2017) 40-53

[3] Bajić, M., Ivelja, T., (2016) New technology for mine action – the hyperspectral Non-Technical Survey from UAV and helicopter, Symposium "Mine action 2016"

[4] Šemanjski, S., Gajski, D., Bajić, M., (2008) Transformation of the Hyper-spectral Line Scanner into a Strip Imaging System. Proceedings of the 1st International Conference on Remote Sensing Techniques in Disaster Management and Emergency Response in the Mediterranean Region / Marinko Oluić (ur.). Zagreb : European Association of Remote Sensing Laboratories (EARSeL), 2008. 369-375

[5] Jakšić, J. (2009) Parametarsko geokodiranje hiperspektralnih snimki, Diplomski rad, Geodetski fakultet Sveučilišta u Zagrebu

[6] Vanja, M., (2017) Prostorna kalibracija multispektralnih i hiperspek-tralnih senzora u blizupredmetnoj foto-grametriji, Doktorska disertacija, Geodet-ski fakultet Sveučilišta u Zagrebu.

# Uncertainty in Mine Risk Visualization within Non-technical Survey

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#### Abstract

Landmines affect the lives of people living in war-affected countries. The real challenge in humanitarian demining nowadays, within Non-technical Survey, is finding new approaches to SHA reduction. The establishment and use of mine information systems in humanitarian demining can improve the land release process by efficient mapping of suspected hazardous areas and visualizing of mine risk on it. Croatian Mine Action Center established such system and uses it for marking all suspected hazardous areas in Croatia. Nevertheless, data in this system comes from different sources and contains some inherent uncertainty. The level of ambiguity is being attempted to diminish by conducting analytical assessments of mine information system data and by collecting additional information about suspected hazardous areas. The landmine risk mapping requires defining the input data (indicators) from mine information systems and additional data that most suitably capture the association between the spatial objects of interest in the surrounding geographic area. The confidence level for each indicator is determined, which is, in fact, an estimate of the level of uncertainty. The fusion of all existing data is used after that for the purposes of creating of mine danger maps. These maps show the overall uncertainty of all input data and need further action for their use in reduction according to the Croatian Mine Action Center Standard **Operational Procedures.** 

*Key words:* uncertainty, confidence, input data, area reduction, danger maps

#### **1. Introduction**

Croatia confirmed its resoluteness in solving the mine problem by bringing the Law on Demining in 1996 and by the establishment of the Croatian Mine Action Center in 1998. The ultimate result of all mine action activities is a defined suspected hazardous area (SHA) in 2008 [1]. Croatian Mine Action Center has developed its own mine information system, adjusted to complex humanitarian demining procedures and the implementation of public procurement and quality control processes for technical surveys and demining in Croatia [2], [3]. All data collected about SHAs are stored in that system. In 2010 Standard operating procedure - Mine Reduction in SHA [4] was adopted and the reduction of SHA has begun. However, experience in working with data and data analysis showed a high level of uncertainty of data [5]. It is possible to reduce or eliminate the level of uncertainty and ambiguity of data by collecting new data on the current state of the SHA. Among other methods, aerial and satellite Non-technical Survey [6] in Croatia and Bosnia and Herzegovina was used for this purpose [7], [8]. An overview of the risk visualization according to the data from mine information system and new collected data on SHA is presented in the article.

## 2. Croatian Mine information system for mine action

The main components of the Croatian Mine information system are: spatial database (Figure 1), applications for system administration, system for collection of field data, and center for data conversion (scan center) [3]. Information and data in this system comes from different sources (field survey,

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interviews with the local population, military maps, publications of war actors) and contains certain level of uncertainty. These information allow estimates of the impact of the mine problem on the affected areas, therefore it is necessary to minimize the uncertainty.



Figure 1. Display of spatial data stored in mine information system (by the courtesy of Croatian Mine Action Center).

#### 2.1 Uncertainty of data

Uncertainty of data is manifested in the impossibility of positioning minefields or any other object used for military purposes (indicator of mine presence) within the SHA based on minefield record or existing (unchecked) information stored in mine information system [5]. Indicators of mine presence are objects on the Earth's surface (residues of war activities) that point to mine risk in their surroundings [9], [10]. For the purpose of characterization of uncertainty, the level of confidence is introduced and associated with every information and data entering in mine information system. Furthermore, the confidence level is also assigned to each new information or data (indicator) which enters in mine information system by Non-technical survey actions. All indicators do not have the same importance, so the level of their confidence is a very important parameter in landmine risk visualization.

#### 2.2 Input data

The input includes data from the mine information system (Figure 1), expert knowledge, airborne and satellite data from Non-technical survey, contextual data. More precisely, it includes indicators of mine presence (detected on visual input data from mine information system and additional collected aerial and satellite images) and their impact on the environment (expert and contextual knowledge). Remote sensing is applied in the field of mine action by multispectral sensors that detect individual indicator through the use of aerial and satellite data (Figure 2), hyperspectral imaging or ground-penetrating radar [5].



Figure 2. Indicators of mine presence (red and blue) and absence (green) detected on aerial and satellite images (new information) and stored in mine information system (known information).

#### 3. The landmine risk visualization

The mine risk visualization is based on the representation of the position of indicators of mine presence in the coordinate system (Figure 1 and 2) and their impact on the environment. This impact is shown by the polygons (buffers) around the indicator. The mine risk is presented with (mostly) color scale, and confidence affects the color level (darker color indicates higher risk) (Figure 3). Uncertainty has been introduced in mine risk visualization in this way. TIRAMISU Advanced Intelligent Decision Support System (T-AIDSS) [11] is an operational Non-Technical Survey system which can collect data about SHA, conduct multi-criteria analysis and data fusion and, produce Mine danger maps [12] of SHA.

#### 3.1 Mine danger Maps

Mine danger maps are the final outcomes of

the methodology implemented within the T-AIDSS (based on multi-criterial analysis and data fusion) and represent the visualization of mine danger based on scientific methods (Figure 3). The results of these methods include overall uncertainties of information and data from mine information system and additional collected data. Two variants of risk visualization are made for each SHA. One for indicators of mine presence – *Mine danger map* (Figure 3), and one for indicators of mine absence - *The proposal to reduce the SHA* (Figure 4).



*Figure 3. Part of Mine danger map with scale of danger (a darker red area means a greater risk of mine).* 

Visualization of the position and zone of influence around the indicator gives a better insight into the state of the SHA than presenting only the position of indicator of mine presence.



Figure 4. The proposal to reduce the SHA (green areas).

Experts from Mine action centers can use these maps for various actions in humanitarian demining. The result from the maps seek to improve the identification of the areas where there is no threat, and thus the parts of SHA can be proposed for mine reduction (Figure 5) or better definition of existing SHA. Based on the visualized IMP zones of influence, potential danger areas and those with no IMP influence can be detected. Surveyors from national MACs can be sent into these areas to confirm or refute information from mine danger maps on the basis of legal procedures.



Figure 5. The evidences derived in a mine danger map enable expert to reduce area declared for demining. Legend: SHA – light blue; Mine danger – different levels of red; Indicators of mine presence – pink, Area at a back of trenches that can be reduced – light green. In the example this reduction covers 0.770 km<sup>2</sup>.

#### 5. Conclusion

A well-organized mine information system and quality spatial data (with low level of uncertainty) about SHA are of great help for quality visualization of mine risk. Gradation of uncertainty is achieved by determining the

level of confidence for any data that exists or enters the mine information system. Existing uncertainty of data about defined SHA stored in mine information system can be diminished by conducting analytical assessments of mine information system data and by collecting additional information about SHA. The aerial and satellite based Non-technical survey for collecting additional data from SHA is used in Croatia by T-AIDSS. The impact of all indicators on the environment are visualized on the mine danger map, as well as the remaining overall uncertainty of data. However, mine hazard maps are a useful source of information to formulate proposals for better definition of SHA or for its reduction.

#### 6. Acknowledgement

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#### 7. References

[1] Republic of Croatia: National Mine Action Strategy of the Republic of Croatia, Retrieved February 11, 2018, from https://www.hcr.hr/pdf/Strategija%20eng.pdf

[2] Jelenić, D.; Šaban, S. (2000). The Role of GIS in the Process of Humanitarian Mine Clerance. In: D. Kereković (editor). GIS Croatia 2000 International Conference & Exhibition Proceedings. Hrvatski Informatički Zbor - GIS Forum, 469-477

[3] Biljecki, Z., Pavičić, S., Tonković, T. (2006). Concept and Establishment of the Mine Information System within the CROMAC GIP Project. Cartography and geoinformation, Vol.5 No.6 December, 76-88

[4] Croatian Mine Action Center (CROMAC) (2010). Standard operation procedure – Area reduction in SHA, Retrieved February 11, 2018, from https://www.hcr.hr/pdf/ SOP%20REDUKCIJA%2012.10.2010.%20KONACAN\_ eng.pdf

[5] Krtalić, A, Čedo, M. (2010). Statistical Processing of Minefield Records, International Symposium Humanitarian Demining 2010, 27 to 30 April, Šibenik, Croatia, 78-81

[6] IMAS 04.10 (2003). Glossary of mine action terms,

definitions and abbreviations. Second Edition, 01 January 2003, Amendment 7, August 2014. Retrieved September 1, 2017, from https://www.mineactionstandards.org/standards/international-mine-action-standards-imas/imas-inenglish/ (7/3/2018)

[7] ITF (2008). Deployment of the Decision Support System for Mine Suspected Area Reduction, Project, International Trust Fund for Demining and Mine Victim Assistance, Ig, Slovenia

[8] ITF (2009). Deployment of the Decision Support System for Mine Suspected Area Reduction in Bosnia and Herzegovina, Project, International Trust Fund for Demining and Mine Victim Assistance, Ig, Slovenia

[9] van Genderen, J.; Maathuis, B. (1999). Pilot Project for Airborne Mine-field Detection in Mozambique, EC-DG8, Angola project

[10] Vanhuysse, S. (2002): Mission Report (fieldwork in Croatia), SMART, EC IST–2000-25044

[11] Krtalić, A. (2016). TIRAMISU Advanced Intelligence Decision Support System, The 13th International Symposium MINE ACTION 2016, Book of papers, 26-29 April 2016, Biograd, Croatia

[12] Yvinec, Y.; Milisavljevic, N.; Beumier, C.; Mahamadou, I.; Borghys, D.; Shimoni, M.; Lacroix, V. (2017): Mine Action - The Research Experience of the Royal Military Academy of Belgium, Chapter 5 - Remote Sensing for Non-Technical Survey, INTECH, http://www.intechopen. com/books/mine-action-the-researchexperience-of-the-royal-military-academy-of-belgium (7/3/2018)

#### Segmentation of the aerial RGB images of Suspected Hazardous Area for the needs of Non-technical Survey

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#### Abstract

In the mine action community, Non-Technical Survey is implemented to provide information for better spatial definition of mine or explosive remnants of war contamination. Airborne and spaceborne surveys of wider Suspected Hazardous Area (SHA) regions are often executed to collect information about physical changes and circumstances that may be employed in the subsequent technical interventions. Simple electro-optical sensors which acquire data from the visible part of electromagnetic spectrum, like DSLR or SLR cameras, can be used for this kind of surveys. These aerial RGB images are then inspected by trained human photo (mine scene) interpreter who is familiar with the military doctrine and specific characteristics of the conflict. Mine scene interpreter seeks for the indicators of mine presence and absence. Novel image processing techniques could provide benefits to the standard photointerpretation workflow by making it more efficient. Geographic object-based image analysis (GEOBIA) is one of them. The idea of GEOBIA is to process georeferenced images at the object level, as the entities found in the environment are usually objects (or grouped pixels) instead of single pixels. This approach enables analysis of spatial relations and geometrical object parameters. The main step influencing the GEOBIA results is the quality of image segmentation. In this paper, results of more image segmentation algorithms are tested on the color aerial images of SHA and images of exploded ammunition depot in the Croatia. Acquired results are discussed, while potential and constraints of image segmentation for application in the Non-technical survey are underlined.

Keywords: humanitarian demining,

non-technical survey, indicators of mine presence, GEOBIA, segmentation

#### Introduction

In the mine action community, Non-Technical Survey (NTS) is implemented to provide information for better spatial definition of mine or explosive remnants of war contamination (ERW) [1]. Airborne and spaceborne surveys of wider Suspected Hazardous Area (SHA), as the integral parts of NTS, are often executed to collect information about physical changes and circumstances that may be employed in the subsequent technical interventions. Simple electro-optical sensors which acquire data from the visible part of electromagnetic spectrum, like Digital single-lens reflex (DSLR) cameras, can be used for this kind of surveys. These color aerial images of mine scene are then usually inspected by the trained human photo-interpreters (mine scene interpreters) who are familiar with the military doctrine and specific characteristics of the conflict. Mine scene interpreter seeks the indicators of mine presence and absence (IMP and IMA). This process is time consuming and relies on the knowledge and experience of the interpreters, while simultaneously the number of trained interpreters is limited.

Novel image processing techniques could provide benefits to the standard photointerpretation workflow by making it more efficient. Geographic object-based image analysis (GEOBIA) is one of them [2]. The idea of GEOBIA is to process georeferenced images at the object level, as the entities found in the environment are usually objects (or grouped pixels) instead of single pixels. This approach enables analysis of spatial relations and geometrical object parameters. The main step influencing the GEOBIA results is the quality
of image segmentation. Segmentation is the underlying concept for creating objects from pixels, and involves dividing the image into regions or objects that have common properties [3]. In this paper, performance of image segmentation algorithms on the color aerial images of SHA and images of exploded ammunition depot in the Croatia for the needs of humanitarian demining is compared.

#### Data and methods

Color aerial image (RGB) of SHA located in the Dinara mountain range (Croatia) acquired in October 2013 by 3K system [4] was used for evaluation of image segmentation algorithms for extraction of the IMP (Figure 1). For the analysis of ERW and unexploded ordnances (UXO), color aerial image of exploded ammunition depot in Padjene, Croatia (Figure 2) acquired by Nikon D90 camera (integral part of AI DSS system) was selected [5], [6]. Both flight campaigns were carried out in the scope of EU FP7 project TIRAMISU.



Figure 1 Color aerial image of SHA on the Dinara mountain, IMP are marked with red boxes



Figure 2 Color aerial image of UXOs and aluminum markes used for analysis in Padjene, Croatia

Image segmentation algorithms implemented in the eCognition (Trimble Geospatial, Sunnyvale, California) and ENVI (Exelis Visual Information Solutions, Boulder, Colorado) were evaluated. Image segmentation process incorporated in the ENVI consists of four steps: computation of gradient map from the input image, computation of cumulative distribution function from the map, map modification by Scale Level value and segmentation of modified map using the watershed transform. Edge and intensity methods are used for transforming the multispectral to single-band images. In this study, edge method was used, while scale parameter was determined heuristically.

Chessboard, quadtree-based, contrast split, multiresolution, multi-threshold and contrast filter segmentation are supported in the eCognition and they execute at the pixel level [3]. From this list of algorithms, multiresolution segmentation is the most general one and it is applied in this study. It is a bottom-up segmentation algorithm which locally minimizes average heterogeneity of image objects for a given scale. Multiresolution segmentation is defined by scale parameter which defines maximum standard deviation the homogeneity criteria and homogeneity criteria which is defined by shape and compactness values. To determine the values of the scale parameter in the eCognition, an Automated Estimation of Scale Parameter (ESP2) tool [7] was used. ESP2 tool results with three different scale parameters at the three different hierarchy levels. Only first two hierarchy levels are presented, as the size of IMP and UXO on the used images is small in relation to the mine scene area.

#### **Results and discussion**

In the ENVI algorithm, value of scale parameter for the Edge method was 65 (Figure 3b) for the mountain Dinara scene, while for the Padjene scene two segmentation with 40 (Figure 4b) and 65 (Figure 4c) scale values. Size of kernel was 3 and no merging was done. In the case of multiresolution segmentation algorithm, scale values of 59 (Figure 3c) and 173 (Figure 3d) were used for Dinara scene, while 84 (Figure 4d) and 144 (Figure 4e) for Padjene scene. Values of shape and compactness parameters where 0.1 and 0.5 respectively.

By visually inspecting the aerial photos (Figure 3a and 4a) we can easily spot man-made object placed in the natural scene (bunker in Figure 3a, aluminum crosses and UXOs in the Figure 4a). Translation of human visual and cognitive system for mine scene interpretation to the computer language proves not to be easy task at all.

IMP, like bunker of shelters, are usually made of material found in their surroundings (stone and wood). Because of that, for segmentation algorithms it is difficult or even impossible to delineate them as separate segments. If the IMP stands out from the terrain, then its shadows increase the contrast from background. In these cases, it is possible to produce segments which will represent the IMPs (Figure 3).

Depending on the amount of detriment, UXO can differ in its shape and color. It may be slightly damaged, so only its shape experienced changes. On the other hand, it could be burned or corroded which affects its color. In the visible part of spectrum, aluminum is quite similar to the white stones, corroded metal to the earth, while there are no significant color tone differences between burned (grimed) objects (e.g. UXO or tree). If the UXO is placed on the objects with similar tones (aluminum UXO on the stones or corroded UXO on the earth), we should not expect great results from segmentation. But in the opposite case (e.g. corroded UXO located over the stones), segmentation will be useful tool.



*Figure 3 a) color aerial image, b) ENVI segmentation, c) and d) multiresolution segmentation with different scale parameter* 



Figure 4 a) color aerial image of UXO, b) and c) ENVI segmentations with modified scale parameter, c and d – multiresolution segmentations with different scale parameter

#### Conclusion

Airborne and spaceborne surveys, as the integral parts of NTS, are executed to collect additional data about SHA. Standard procedures of data processing rely on the mine scene interpreters, which manually examine the aerial images and seek for IMP/IMA or ERW/UXO. Interpreters use not only images, instead they gather all available data (topographic maps, contextual data) before the image inspection, while being the familiar with the military doctrine of local conflicts.

Tested segmentation algorithms showed potential when the high contrast between the target (IMP or UXO) and background is present. But when this condition is not met, segmentation struggles to create adequate segments. GEOBIA can be useful tool to the photo interpreter to reduce its workload but can't be its replacement.

#### Acknowledgment

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#### References

[1] IMAS 08.10 (2009). Non-technical survey. First Edition, 10 June 2009, Amendment 2, March 2013. Retrieved March 1, 2018, from https://www.mineactionstandards. org/fileadmin/MAS/documents/imas-international-standards/english/ (01/03/2018)

[2] Blaschke, T.; Hay, G. J.; Kelly, M.; Lang, S.; Hofmann, P.; Addink, E.; ... & Tiede, D. (2014). Geographic object-based image analysis-towards a new paradigm. ISPRS journal of photogrammetry and remote sensing, 87, 180-191

[3] Navulur, K. (2007). Multispectral Image Analysis Using the Object-Oriented Paradigm, Taylor & Francis Group, Boca Raton, USA

[4] Kurz F.; Türmer S.; Meynberg O.; Rosenbaum D.; Runge H.; Reinartz P.; Leitloff J. (2012). Low-cost optical Camera Systems for real-time Mapping Applications. Photogrammetrie - Fernerkundung - Geoinformation, 2012, 159–176

[5] Bajić, M. (2010). The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas, Journal of Conventional Weapons Destruction, Vol. 14, Issue 3, article 28, pp. 69-75 [6] Krtalić, A. (2016). TIRAMISU Advanced Intelligence Decision Support System, The 13th International Symposium INE ACTION 2016, Book of papers, 26-29 April 2016, Biograd, Croatia

[7] Drăguț, L.; Csillik, O.; Eisank, C.; Tiede, D. (2014). Automated parameterisation for multi-scale image segmentation on multiple layers. ISPRS Journal of Photogrammetry and Remote Sensing, 88, 119-127

## Improved organic semiconductor explosive sensors for application on minefields

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#### Abstract

Here we present progress made in the development of an organic semiconductor based sensor system for explosive vapours. The sensors, originally developed in the TIRA-MISU project<sup>1</sup>, monitor a change in fluorescence from a polymer film when it is exposed to trace vapours of TNT and similar explosives. The approach could be promising for applications in remote explosive scent trace (REST detection) for the technical survey of mine fields. Successful deployment of the detection system in the field, however, requires an improved method for sample collection and delivery to the sensor, and an approach to address the potential problem of false detection of distractants. We report here recent progress addressing these challenges.

#### Introduction

Organic semiconductors are commonly used in OLED television and smartphone displays. Due to their chemical and physical properties they can also be used as a sensor to "sniff" for nitroaromatic explosive vapours<sup>2-4</sup>, such as trinitrotoluene (TNT) with sensitivities comparable to canine methods. This is done by monitoring the light emission from thin films of the organic semiconductor when excited by an external light source such as a laser or LED. The presence of nitroaromatic molecules in the film causes a drop in the light emission, which is taken as an indication as the presence of explosives. In this paper we will discuss the work done to improve vapour delivery to these sensors, and to reduce the possibility of false positives.

## Application to remote explosive scent tracing (REST)

REST detection uses air sampling through a filter which is then tested for the presence of explosives. This technique has been developed by Mechem in their MEDDS system, using trained dogs as the detection mechanism for both explosives and drugs<sup>5</sup>. The REST collection approach could also be combined with the organic semiconductor explosives sensor, to allow on-field testing of samples for minefield area reduction. After initial field trials with the organic semiconductor based system developed in the TIRAMISU project, it was found that adaptations to the sampling filters were needed to enhance the delivery of collected explosives residues to the sensor.

In order to maximize the amount of explosive vapour and particles collected in the filter, materials to which explosives, such as TNT, selectively bind have been investigated.<sup>6</sup> In our studies the fluorinated polymer Aflas® (AGC Chemical Europe Ltd) was chosen as a suitable coating. This polymer acts as a preconcentrator which specifically accumulates explosives molecules, maximising the amount of explosive vapours collected. After sampling, the exposed filter is then placed in a sealed chamber with the sensor film, as shown in Figure 1 to test for the presence of explosives. An apparatus for performing these measurements in the field has also been developed. When heated above a certain temperature, the explosive molecules bound to the preconcentrator gain enough energy to desorb from the film. This generates a cloud of explosive vapour which can then be interrogated by an organic semiconductor explosive sensor, as shown in Figure 2.

These materials are also being used in the Bee4exp project to collect explosive residues picked up by bees while foraging, to develop a passive method of area reduction and quality assurance when clearing landmines. Entry and exit of honeybees from the hive are segregated using tubes which contain paper "doormats" coated with the Aflas® preconcentrator polymer. As the bees forage around a mine suspected area, tiny amounts of explosives residues are picked up on their bodies, which are then deposited and concentrated on the "doormats" in the hive entrance. A preliminary field trial conducted in September 2017 on the Benkovac test site has shown promising results, with work continuing to improve the sampling and collection methods.

## Introducing selectivity using molecular imprinted sol gels (MISG)

We also report an approach to improve the selectivity of the sensor against possible distractants. Much in the same way that not every metal object detected by a metal detector is a landmine, not every nitroaromatic vapour indicates the presence of explosives. Common non-explosive nitroaromatics include pesticides, such as dinoseb and perfume ingredients such as musk ketone. We are addressing this problem through the use of a molecular imprinted sol gel (MISG) to discriminate between similar analytes.



Figure 1: Lab based setup for measuring REST samples. The sensor and filter are placed together in a sealed chamber and the sensor response is monitored as the filter is heated up to release the collected explosive vapours.



Figure 2: Response of a super yellow thin film sensors exposed to silicon wafers that have previously been exposed to DNT contaminated nitrogen. The wafers are heated to 100oC in a sealed chamber with the sensor, and the light emission of the sensor is monitored. The red trace is the response from a bare silicon wafer and the black trace the response from a Aflas<sup>®</sup> coated wafer.

Sol gels are a solution processed glass-like material whose properties can be controlled and adapted by the choice and ratio of precursors used. It has been shown that particular sol gels can selectively bind to nitroaromatic templating molecules<sup>7-8</sup>. The addition of a small amount of nitroaromatic molecules, such as TNT, can imprint the shape of the target molecule into the film when the film is formed. After washing out the template, the film can subsequently selectively sorb the target molecule. We have integrated the recognition sites with our sensor films to increase selectivity against some possible distractants such as agricultural pesticides.

#### Conclusion

The REST sampling method has been combined with organic semiconductor explosive vapour sensors to improve vapour delivery to our sensors with the use of the preconcentrator polymer Aflas®. This preconcentrator material has been used in the Bee4exp project to test for trace amounts of explosive picked up by bees foraging in mine contaminated areas. Further field trials are ongoing to develop the method for area reduction in mine suspected areas.

Molecular imprinted sol gels have been demonstrated as a simple solution to the problem posed to organic semiconductor sensors by nitroaromatic distractants such as pesticides without the need of complex chemistry or the development of new sensor materials.

#### References

1. Gillanders, R. N.; Samuel, I. D.; Turnbull, G. A., A low-cost, portable optical explosive-vapour sensor. Sensors and Actuators B: Chemical 2017, 245, 334-340.

2. Toal, S. J.; Trogler, W. C., Polymer sensors for nitroaromatic explosives detection. Journal of Materials Chemistry 2006, 16 (28), 2871-2883.

3. Wang, Y.; Turnbull, G. A.; Samuel, I. D. In Conjugated polymer sensors for explosive vapor detection, SPIE Photonic Devices+ Applications, International Society for Optics and Photonics: 2011; pp 81180E-81180E-9.

4. Cumming, C. J.; Aker, C.; Fisher, M.; Fok, M.; Grone, M. J. l.; Reust, D.; Rockley, M. G.; Swager, T. M.; Towers, E.; Williams, V., Using novel fluorescent polymers as sensory materials for above-ground sensing of chemical signature compounds emanating from buried landmines. IEEE Transactions on Geoscience and Remote Sensing 2001, 39 (6), 1119-1128.

5. Alan Poling, M. J., Rune Fjellanger et al., Remote Explosive Scent Tracing 2011. 6. McGill, R. A.; Abraham, M. H.; Grate, J. W., CHOOSING POLYMER-COATINGS FOR CHEMICAL SENSORS. Chemtech 1994, 24 (9), 27-37.

7. Della Giustina, G.; Sonato, A.; Gazzola, E.; Ruffato, G.; Brusa, S.; Romanato, F., SPR Enhanced molecular imprinted sol-gel film: A promising tool for gas-phase TNT detection. Materials Letters 2016, 162 (Supplement C), 44-47.

8. Morais, E. C.; Brambilla, R.; Correa, G. G.; Dalmoro, V.; Dos Santos, J. H. Z., Imprinted silicas for paracetamol preconcentration prepared by the sol-gel process. Journal of Sol-Gel Science and Technology 2017, 83 (1), 90-99.

# Benefits of using modern mobile technologies for field data collection and information management in mine action "It all starts in the field"

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#### Abstract

Mines and unexploded ordnance all over the world are still taking its toll as lifelong suffering or death. It strikes blindly and effects innocent civilians. 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. One cost effective and safe solution is the SITE Information Management System, T-IMS.

T-IMS is a GIS centric stand-alone software application built for mobile use to support all field data collection within the scope of Mine Action/Humanitarian Demining, following the steps of Non-Technical Survey (NTS), Technical Survey (TS) and Clearance operations to Quality Assurance/Quality Control (QA/QC) and the final Reporting and Analysis.

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 NG and the new IMSMA Core.

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

#### 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 such as information technology 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.

Mine action would benefit immensely allow-

ing 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 IMS-MA.

#### **Mobile Technologies in Mine Action**





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 Field Data Collection tool primary for the deminer's use in the field. 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 GIS 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 is optionally equipped with off-line CORD (Collaborative ORDnance data repository) which is a result of the cooperation with the James Madison University – JMU). This database consists of approx. 5 000 ordnance objects. 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, meaning that data capture with T-IMS is extremely intuitive and easy. T-IMS is fully usable without a touchpad or a mouse.

#### The TIRAMISU project

The European Union has, by the Project TI-RAMISU, 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 TI-RAMISU 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 TIRA-

MISU project started up in 2012 and was ended by December 2015.

The SITE Information Management System (T-IMS) – described in this document – is an outcome of the TIRAMISU project.

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

T-IMS has been evaluated in Cambodia together with GICHD and CMAA, on three minefields in the Battambang province where CMAC was conducting clearance operations. Article in The Journal of CWD, 20.2.

#### References

- 1.HCR-CTRO (CROMAC/CTDT) https://www.ctro.hr/en/
- 2. Geneva International Center for Humanitarian Demining https://www.gichd.org
- 3. James Madison University JMU https://www.jmu.edu
- **4**. From the Field: Mobile Technologies for Mine Action [Article for The Journal of CWD, Issue 20.2]

https://issuu.com/cisr-journal/docs/issue20-2

- 5. International Mine Action Standards IMAS https://www.mineactionstandards.org
- 6. TIRAMISU http://www.fp7-tiramisu.eu
- 7. Cambodian Mine Action and Victims Assistance Authority – CMAA http://www.cmaa.gov.kh/en/
- 8. Cambodia Mine Action Center CMAC http://www.cmac.gov.kh/en/
- **9**. Information Management and Technology Development in Mine Action By Mikael Bold [article for counteriedreport. com July 2015]

## Mine victims assistance



#### Inclusion model for the first category of the 100% disability Homeland War veterans in the MRE in the Republic of Croatia

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#### Abstract

This paper presents the educational model which involves the members of the special police who participated in training of the Homeland War veterans of the first category with the 100% disability. The idea of this specific approach is to ensure that the MRE of the population is provided throughout involving the Homeland War participants, who could, with their experience and authority, convincingly influence the educational effectiveness of the target groups. The presented model is a result of a project prepared by the Association for the Support and Encouragement of community "Croatia Helps", as approved and funded by the Ministry of War Veterans on a public tender entitled "Psychological and social empowerment and raising the quality of life for Croatian veterans of War, veterans of War with disabilities and family members of a deceased, detained or missing War veterans from the Homeland War". The participants of the education were educated during the course of three modules, which involved the improvement of communication skills and teaching methods, the necessary preparatory information for the MRE of the population and information on the possibilities of starting a job and supporting entrepreneurship in future demined areas.

*Key words:* Education, Mine Suspected Area, 100% disability Homeland War veterans, Communication skills, Entrepreneurship support

#### Introduction

According to the available reports presented by Landmine Monitor, 8.4 million of people, throughout 61 countries, have participated in Mine Risk Educations from 2007 to 2008, indicating an increase in comparison to 2006 and reported 7.3 million of people, which is also the largest number of participants ever evidenced by a Landmine Monitor. [1]

There are different approaches and methods of MRE, and one of the more innovative ones is elaborated in the article entitled "The Child to Adult Method in Mine Risk Education" [2], which outlines six steps of educating the children which afterwards educate adults about the mine risk. This Child-to-Adult approach includes: Understanding of activities, Finding out more, Discussing and planning, Taking action - Educating the adults, Evaluating what was done and Doing it better based on the observations. Although innovative, during the application, results revealed weaknesses of this approach, such as using children as an educator of adults requires confidence in the abilities of children who have no experience and formal educational background, and therefore require parent support and engagement. Due to the lack of experience, the child's self-esteem and communication skills require a lot of encouragement and careful leadership at the beginning of the project. At the same time, the lack of experience and skills children compensate with the openness and creative approach to the problem which also requires adult openness toward accepting children as educators, indicating this as a more significant challenge than training the children for educating the adults.

The paper describes educational model upon which members of the special police units provided training of the trainers, the first category of the 100% disability Homeland War veterans. The idea of this approach is to ensure that the education of the population is performed by the Homeland War participants, who could, based on their experience and authority, through educational activities, more convincingly influence the target groups. The model presented is a result of a project that was submitted by the Association for the Support and Encouragement of community "Croatia Helps", which has been accepted and funded by the Ministry of War Veterans on a public tender entitled "Psychological and social empowerment and raising the quality of life for Croatian veterans of War, veterans of War with disabilities and family members of a deceased, detained or missing War veterans from the Homeland War."

The general objective of the project is the psycho-social reintegration of the Croatian veterans of War, Croatian veterans of War with disabilities, victims and their family members.

The specific objectives of the project are the psychological empowerment of Croatian veterans of War, former members of the special police and the first category of the 100% disability War veterans with the reduction of their social exclusion through their active involvement in the community, increasing their competences for educating the population on the dangers of Mine Suspected Areas.

The education program is in line with the activities of the Croatian Mine Action Center [3] and the CROMAC - Center for Testing, Development and Training d.o.o. (HCR-CTRO d.o.o.). [4]

#### The purpose

The objective of the paper is to illustrate the model where members of the special police from the Homeland War are educating the Homeland War veterans of the first category with the 100% disability, so they could conduct further population education on Mines and Explosive remnants of war in the Republic of Croatia. This model includes training of the trainers (former special police officers), their education of the Homeland War veterans of the first category with the 100% disability, for the implementation of further population education in Mine Suspected Areas and the psychological empowerment of their wives who are actively supporting this demanding process during main education, but also during the field education of the population.

#### The methods

Although around 20 of the War veterans, former members of the special police, passed several education cycles for mine risk educators, the first activity included the selection of four former special police officers who had the best predispositions and affinities to work with Homeland War veterans of the first category with the 100% disability. The mentioned education was held in two cycles: the first in the period from 27 to 29 November 2017, and the second from 7 to 8 March 2018. After the selection, in the first module, four former members of the special police were educated for the education and mentoring tasks of the Homeland War veterans of the first category with the 100% disability. At the same time, as this training of four Homeland War veterans of the first category with the 100% disability led by former members of the special police was performed, their wives / caregivers have participated in a psychosocial empowerment program aimed at supporting their husbands during their education, and during the implementation of population education on mine threats.

The first module included three workshops:

## 1st Workshop: "Specifics of the Individual teaching"

Although previously involved in the training of MRE educators, former special police officers did not have adequate competences for training of the trainers approach, and in particular for the sensitive target group of Homeland War veterans of the first category with the 100% disability. Therefore, it was necessary to acquaint them with the specifics of the education for this population that, apart from basic teaching methods, included the consideration of the special organizational forms to the psychological barriers that may or could appear. Additional topics were verbal, nonverbal and written communication and preparatory and presentation skills performance.

#### 2nd Workshop: "Preparation, implementation and evaluation of education on Mine Suspected Areas"

The aim of this workshop was to enable the special police officers to tailor Mine Risk Trainings to the specificity of the target group, the Homeland War veterans of the first category with the 100% disability. During individual exercises, the participants performed the presentations, received feedback and thus upgraded their communication skills.

#### 3rd Workshop: "Demined Areas - What after?"

The aim was to acquaint the former members of the special police and Homeland War veterans of the first category with the 100% disability on the possibilities of entrepreneurship activities and funding sources for the population after the demining activities have ended. Special attention has been dedicated to the possibilities of applying for national and EU funds and other entrepreneurial support, with a focus on setting up agricultural production on demined areas, especially for the young farmers.

The second module intention was to get Homeland War veterans of the first category with the 100% disability acquainted with the content of MRE in Mine Suspected Areas, in addition to the Mine awareness training and preparation training for the field exercise.

The third module was devoted to the psychological empowerment of wives / caretakers of the Homeland War veterans of the first category with the 100% disability, while the fourth module, which is not elaborated in this paper, involved the practical performance of Mine risk educations, conducted by the Homeland War veterans of the first category with the 100% disability, in the two most Mine-contaminated Croatian Counties (Sisak-Moslavina and Karlovac County). All training sessions were held at the Special Hospital for Medical Rehabilitation "Varaždinske Toplice", an area which was specifically tailored to the needs of Homeland War veterans of the first category with the 100% disability.

#### The results

After each workshop, evaluation of the success was carried out through the evaluation questionnaire. An overview of the evaluation results made by the workshop participants are shown below:

#### Workshop Name:

R1: Specifics of the Individual Teaching R2: Preparation, implementation and evaluation of education

R3: Introduction to the Mine dangers

R4: Demined Areas - What after?

Elements of assessment	R1	R2	R3	R4
Clarity and understanding of the content	4,88	5,00	4,80	5,00
Engagement of the topic	4,88	5,00	5,00	5,00
Quality and clarity of the presentations	5,00	5,00	4,80	4,86
Lecturer presentational skills	5,00	4,83	5,00	5,00
The quality of practical training / exercises	4,88	4,83	5,00	4,86
The usefulness of replies to participants' questions	4,88	5,00	5,00	5,00
Suitability of area and equipment	4,75	5,00	5,00	5,00

Table 1: Overview of the average grades expressed by the educationparticipants according to evaluation elements

Aside from the evaluation of the defined assessment variables, the education participants have also, in the open Q/A session, expressed their opinions on the most useful parts of the course as well as their interest in participating in future educations.

- The most useful parts of the educations, according to the participants, were:
- the practical ability to apply the learned
- preparation to become a lecturer
- communication in the process of teaching others
- new information on investment opportunities in the demined areas (especially for young farmers aged 18 to 40)

Mine victims assistance

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- networking and specific involvement of the wives of the Homeland War veterans of the first category with the 100% disability, in the project activities
- The participants have also expressed their interest for further education in the following topics:
- written business correspondence; e-mail and social networks
- communication skills continuation
- support for the programs intended toward the associations of persons with physical disabilities

#### Discussion

The illness of one member of the family causes the suffering of other members, disrupts effective communication and family dynamics. All those who care about the most vulnerable, especially those with a high degree of disability, share a range of common problems that include disrupted physical and psychological functioning. Given the long-term exposure to multiple stressful situations, the aforementioned problems can lead to more serious health and psychological consequences. There are only a few individuals who can regress their disrupted psycho-physical stability by their own strengths and without sustained support provided from their environment.

It is therefore important to encourage activities focusing on the inclusion of the Homeland War veterans of the first category with the 100% disability into socially beneficial activities, where they will again feel useful, beneficial and socially engaged, in addition to working on useful activities such as MRE. Mentioned educational activities, complete support, mentoring and assistance can be provided by former special police officers, nowadays retired veterans, who are confronted with a very similar challenge in reintegrating into society. Both target groups have a very similar experience from the battlefield, so there is a reasonable expectation that the Homeland War veterans of the first category with the 100% disability will be more open to working with former members of the special police with whom they share experiences from the Homeland War.

#### Conclusion

The synergy of experiences and authorities that in the joint learning and work of former members of the special police force and the Homeland War veterans of the first category with the 100% disability, can effectively influence the educational outcomes of the population during the MRE activities. Lectures provided by the experienced War veterans, and ones with a disability, have additional impact, because they are supported by the authority and experience of their lecturers participation in the Homeland War, and as such, more effectively influence the perception and attention span of listeners, to whom information on risks, dangers and (non) acceptable behaviour and actions, could eventually save life.

Re-socialisation of former members of the special police and the Homeland War veterans of the first category with the 100% disability, through providing education of the population in Mine Suspected Areas, displays one of the possible models of inclusion of these groups into socially useful activities. Their interest in active learning and teaching is inspirational, and shows that there are possible models that can have a positive impact on the individual level, but also on current and useful topics in the wider social context.

#### References

1. Landmine Monitor 2008, http://www.the-monitor.org/en-gb/reports/2008/landmine-monitor-2008/mineerw-risk-education.aspx#footnote-7612-1

2. Hamad, Mudhafar Aziz (2007) "The Child to Adult Method in Mine Risk Education," Journal of Mine Action: Vol. 11 : Iss. 1, Article 24.

3. Hrvatski centar za razminiranje. https://www. hcr.hr/hr/index.asp

4. Hrvatski Centar za razminiranje-Centar za testiranje, razvoj i obuku d.o.o. http://www.ctro.hr/ hr/

## IEDs

Experiences and methods of approach



#### Explosive Hazards Community of Experts Promising C-IED Tools

#### Yvan Baudoin, Yves Dubucq, Torsten Vikström

International CBRNE Institute



#### International CBRNE Institute

#### Introduction

Forming an integral part of the International CBRNE Institute (ICI - www.ici-belgium.be/ news), the EXPLOSIVES KNOWLEDGE **CENTER / COUNTER EXPLOSIVE HAZ-**ARDS Community of Experts (EKC/C-EH CE) intends to ensure sustained impact on the demining community and value to the general public, support the European Union (EU) Security facing explosive hazards threats (and possibly CBRNE threats) and welcome Experts in Explosive Hazards-related issues. The proposed Community of Experts shall, inter alia, focus on the exploitation of the toolboxes and initiatives developed in EC projects so far and on expanding their application to other explosive hazards threatening civil society.

To avoid duplication and ensure the ongoing exchange with practitioners and experts, cooperation with existing Centres will be established, e.g. with the NATO Explosive Ordnance Disposal Centre of Excellence, the Counter Improvised Explosive Devices Centre of Excellence (C-IED COE), the International Centre of Demining (CID), located in Madrid, the United Nations Mine Action Service<sup>1</sup>, the Geneva International Centre for Humanitarian Demining (GICHD<sup>2</sup>), the European Corporate of Security Associations (ECSA<sup>3</sup>).



The Community, administratively managed by his Explosive Knowledge Centre (**EKC**) will be coordinated by a Decentralised Steering Committee, responsible for external relations and visibility, while the members of the community are acting in five Technical Task Forces, or TTF, and will pursue the objectives described below.

#### Objectives of TTF 1 - TTF 5: Technology Watch and Shared R&D

- Continuously improve technologies<sup>4</sup> through an exchange of R&D results among the scientific community and through adequate interdisciplinary technology transfer
- Share expertise and particularly research through dedicated workshops in close cooperation with the above mentioned Cen-

<sup>&</sup>lt;sup>1</sup> www.mineaction.org/unmas

<sup>&</sup>lt;sup>2</sup> www.gichd.org

<sup>&</sup>lt;sup>3</sup> www.ecsa-eu.org

<sup>&</sup>lt;sup>4</sup> In particular: Detection Tools, Robotics (UGV, RPAS), Protection tools, Neutralisatio/Disposal/Forensic

tres and other stakeholders

- Monitor the developed tools and prepare their validation and their wider implementation.
- Prepare the validation and wider implementation of tools, in particular in the current context of terrorist threats in Europe<sup>5</sup>
- Improve technologies countering Improvised Explosive Devices

### Objectives of TTF 2: Validation and European Standards

- Promote EU-wide standards of relevant counter explosive hazards (C-EH) technologies, tests and evaluations of C-EH equipment
- Maintain a dedicated area of permanent lab-space for baseline testing of performance and suggest appropriate test areas for field testing, e.g. the CID or/and the C-IED COE in Spain, the HCR-CTRO Test Facilities in Croatia, the ICI facilities in Belgium, the Joint Research Centre in ISPRA, Italy, among others

#### Objectives of TTF 3: Training and Risk Education (Centrum

- Develop Survey (prediction, prevention, detection) e-Tutor
- Offer advanced multinational e-C-EH courses and C-EH training
- Risk Education tools for C-EH Practitioners
- Develop EOD/IED e-Tutor and have them validated
- Support the training of practitioners in the domain of Improvised Explosive Devices (with possible CBR(N) payload)

#### Objectives of TTF 4: Meeting the C-EH Practitioners Requirements

• Support comprehensive and integrated use of Information Management Systems

(IMS) as requested by end users

 Close cooperation with practitioners in the field of Counter Terrorist activities and the European Corporate Security Associations (ECSA)

The ICI-EKC currently improves the tools developed under the FP7 TIRAMISU/D-BOX projects. The following table summarizes the most important operational tools and **promising C-IED tools** refers to the Points of Contacts (POC). Feel free to contact them for detailed information and possible implementation agreement. More on red lines: read www-link

T-IMS	torsten@sitescandinavia.se			
(SITE, Sweden)				
APT (UNIGE, Italy)	zoppi@dimec.unige.it			
(C-IED)	info@pierretra.com			
MINERVA (IDS,	l.nuzzo@idscorporation.it			
Italy) (C-IED)				
TR-LAUNCHER	geokecha@gmail.com			
(RMA, Belgium)	Yves.dubucq@ici-belgium.be			
Protective Equipment				
(ICI, Belgium)				
Hyperspectral	Nikola.pavkovic@ctro.hr			
detection tools	www.fp7-tiramisu.eu			
Neutralisation Set	Januszko@witi.wroc.pl			
	www.fp7-tiramisu.eu			
Mobile UXO	Januszko@witi.wroc.pl			
CONTAINER	www.fp7-tiramisu.eu			
Mine (IED) Risk	patfordemining@gmail.com			
Education for Adults				
Computer game	m.kacprzak@imm.org.pl			
for school children				
education on mine/				
IED risk				
Handbooks for	http://www.cbrneltd.com/			
CBRNE, Crisis	img_external/products/			
management,	ppe-thumb.png www.d-box-			
demining guidelines	projectieu			

#### 2. C-IED Descriptions

#### 2.1. T-IMS

The Information Management System (T-IMS)<sup>6</sup>, a mobile field data collection tool

<sup>&</sup>lt;sup>5</sup> European Program HORIZON focusing on the Security - In April 2015 the European Commission adopted the European Agenda on Security (EAS) for the coming five years. On the basis of the EAS, the Council adopted in June 2015 the renewed European Union Internal Security Strategy 2015-2020 confirming tackling and preventing terrorism, radicalisation to terrorism and recruitment as well as financing related to terrorism, preventing and fighting serious and organised crime and preventing and fighting cybercrime as the main priorities for European Union's actions

<sup>&</sup>lt;sup>6</sup> T-IMS : read further by: "From the field : mobile technologies for Mine Action; The Journal of Conventional Weapons Destruction"

EDs - experiences and methods of approach

for humanitarian demining, is a software application for C-IED operators and surveyors in the field. T-IMS optionally contains the Collaborative ORDnance Data Repository (CORD), hosted and managed by the Center for International Stabilization and Recovery (CISR) at James Madison University (JMU). CORD provides access to approximately 5,000 ordnance objects offline. Such system may easily been connected to IMSMA<sup>1</sup> proposed by the GICHD<sup>2</sup>. Compatible with the new IMAS IED<sup>3</sup>

#### 2.2. MINERVA

MINERVA is a vehicle-mounted ground penetrating radar (GPR) sensor for counter-IED and mine route clearance. It is a product of IDS's past experience in developing and manufacturing market leading GPR systems and its expertise in radar systems and antenna design. It uses from one to four modular antenna arrays to produce radar images of the subsoil, from 2D images to complex real-time high resolution 3D tomography.

#### 2.3. APT

A versatile adapted agricultural tractor was developed under the European Union's TI-RAMISU R&D project. The machine was subjected to multiple detonations at the CROMAC test centre and sustained only the most superficial damage. With no repair necessary, APT (Area Preparation Tractor) was then moved into a live minefield for acceptance testing<sup>4</sup>. After a brief period of Operator training with the remote controls, the APT was handed over to a Croatian demining team and moved into the minefield. A new Stage now involves the development of an alternative tool that shares the same rising and falling platform and extends APT for use as a C-IED robot.

#### 2.4. Fragment protective textile

The assessment of the resistance of a material under near simultaneous multiple impacts,

<sup>1</sup> Information Management System for Mine Action

<sup>2</sup> Geneva International Centre for Humanitarian Demining

<sup>3</sup>New Standard on initiative of UNMAS

as in a case of the fragmentation generated by IED explosion, can be roughly described by single ballistic impact tests. Therefore the Department of Weapon Systems and Ballistics of the Royal Military Academy, has developed a technique that takes into account the interactions of multiple near simultaneous impacts. This technique, called Triple Launcher, has certified the new fabric developed by Hotzonesolutions- ICI. A high strength and highly dense textile structure provides an ideal IED fragment protection. It prevents micro fragments such as dirt, sand and debris from penetration. The number of penetrating fragments is minimized and the penetration depth is reduced. The performance has successfully been tested according to STANAG 2920, with velocities up to 410 m/s

#### 2.5. Computer game for children education on IED risks

Great Rally on the Back of Electronic Tur*tles* is a board-type game, and rally through a terrain with mine /IED risks is its content. Electronic turtle, serving as a pawn in the game, is depicted as three-wheeled vehicle, equipped with camera and tiny intelligence - derived from cybernetic turtle that was designed for initial cybernetic experiments with artificial intelligence. The subjects of observation are different objects, situated on the path or past it, shoved with cybernetic turtle's camera. And just guizzes and observations, when correct answers and truthful observations bring needed grains, make up educative mechanism of the game. The game has been tested successfully in one school in Poland and in two schools in Croatia. Detailed description of the game, as well as methods and results of its testing, are presented in the Computer Games Journal (http://link.springer.com/article/10.1007/s40869-016-0026-z).

#### 2.6. BILLY GOAT RADIO

Billy Goat radio is a Risk Education (RE) tool aimed at enabling the operators living in mine and other explosive affected areas to write and produce short educational serial dramas which will be broadcast by radio and performed live by a team of local actors travelling through the interested region.

<sup>&</sup>lt;sup>4</sup> As required in IMAS 03.40, Test and Evaluation of Mine Action Equipment.

#### HIEDC (Humanitarian Improvised Explosive Device Clearance) & IEDD (Improvised Explosive Device Disposal)

## Risk Management by Response Training in HMA (Humanitarian Mine Action)

Philip Jowett MBE, IMCSE,

Benjamin Remfrey MBE, IMCSE, MI Exp. E

#### Abstract

In this short article MAT Kosovo will endeavour to convey a concept of operations for Humanitarian Improvised Explosive Device Disposal Clearance (HIEDC) from a humanitarian mine action (HMA) context. Considering recent changes to the threats faced by HMA clearance operatives from randomly seeded IEDs and booby traps (BT) it is imperative that processes and procedures are developed to ensure safe conduct of operations which reduce risk and mitigate threats.



Currently there is a requirement for a review of the IMAS Test and Evaluation Protocol 09.30/01/2014, Version 1.0, 30 October 2014 - Explosive Ordnance Disposal (EOD) Competency Standards and development of a robust set of Standard Operating Procedures (SOP), which will require ALL involved actors from within the HMA industry to come together and work in cadre to resolve this issue

*Index Terms -* HIEDC - Humanitarian Improvised Explosive Device Clearance. IEDD - Improvised Explosive Device Disposal. HMA - Humanitarian Mine Action. UAS - Unmanned Aerial Systems.

#### I. Concept of Operations

- 1. Conduct of HIEDC differs in many ways to CIED operations conducted by military personnel. Militaries operate within a non-permissive milieu. Their role is to utilise CIED techniques for:
  - a. Manoeuvrability.
  - b. Operability and force protection.
  - c. To gain intelligence.
  - d. Deny the enemy their resources and to gain convictions.
- 2. Military forces do not in the main conduct mine clearance operations, this is generally the role of Humanitarian Mine Action organisations (HMA) or in country militia. Although HMA are utilising military CIED search techniques these have been adapted to encompass International Mine Action Standard (IMAS) protocols and processes untimely leading to the release of land.
- 3. Within a HMA environment the ultimate objectives are to clear land of ERW to facilitate land release back to the populace. The key EOD philosophies within Humanitarian Mine Action being to:
  - a. Preservation of live.
  - b. Preservation of property and the environment.

- c. Return the situation to normality.
- 4. Differences in operational objectives, the environment in which HMA is conducted and the processes implemented for IED clearance are different in many ways from military operations, such as:
  - a. Clearance and Search within HMA deals with the clearance of legacy<sup>1</sup> / abandoned<sup>2</sup> IEDs and Booby traps and explosive Remnants of War (ERW) in a post conflict situation.
  - b. The focus of a threat assessment must look at the situation in the past tense. Whether conducting an initial threat assessment for planning or conducting a personal threat assessment on the ground the clearance operator must think "What was the target"? "What was the terrorist Modus Operdani (MO) of operation?
  - c. Over time any ground sign may have disappeared due vegetation growth and weather, such as rain washing away signs of disturbance.
  - d. Clearance assets work without authority to remove people and to establish cordons and are beholding to other agencies, such as Police or military assets to support their operations.
  - e. CIED techniques *should only be conducted* within a **permissive** environment and as such clearance teams should not be under external threat of attack or be targeted by hostile actors'.
  - f. CIED operations constantly place clearance assets in the highest possible threat areas for protracted periods to locate ALL threat items. This puts them at constant risk from devices which have been emplaced to specifically target other assets such as military, police and EOD clearance teams. Although clearance teams were/are not the intended target, they still face the same risks from secondary and

victim operated (VO) mechanisms whilst on operations.

- g. Clearance assets lack certain specialist equipment and high numbers of personnel which are often available to military assets which will make any task more onerous.
- h. Clearance assets do not conduct operations from within a protective cordon however, they will need to implement cordons when conducting the disposal phase of an EOD task to ensure the safety of others. They will be reliant on other agencies for support such as IEDD operators.
- i. HMA operations are conducted in accordance with IMAS, NMAA, organisational SOPs often under the remit of a National Mine Action Authority (NMAA) or UN. Clearance assets are accountable for your actions.
- j. HMA demining teams conduct clearance operation where aspects of that operation may or may not incorporate search procedures.
- k. Clearance assets must ensure the areas and environments cleared and searched are free from any explosive danger / ERW to enable land release processes to be implemented. This includes the implementation of IMAS marking systems and processes which enable subsequent Quality Checks (QC) of clearance operations to be implemented.
- 5. Clearance asset processes and procedures need to be systematic, thorough and documented to ensure compliance and accountability with IMAS land release processes.
- 6. CIED and Search operations within a HMA environment should not differ in approach to that of conventional disposal of mined and cluster strike areas. The build-up, planning, technical survey,

marking of CHA's, management of operations and documentation processes should be similar to that of IMAS for conventional clearance operations. The major difference HIEDC has from conventional demining is in the operational conduct and procedures of clearance within the confirmed hazardous area (CHA). The risks and identified threats require an alternate approach for the location and neutralisation of these seeded IEDs and boobytraps.

#### II. Implementation of other HMA capabilities

 Conduct of HIEDC will involve the implementation of current and advancing HMA capabilities within the phases of an operation, such as:



- a. Planning Previous military records, Use of Unmanned Aerial systems (UAS) for mapping of areas.
- b. Non-technical Survey Use of Unmanned Aerial systems (UAS) and ROV for remote reconnaissance, imagery, 3D modelling, thermal imprint, topography etc.
- c. Tech Survey -UAS / ROV / Mechanical assets / MDD/EDD: for area reduction and GIS, task monitoring (UAS).
- d. Clearance and Search operations -UAS / ROV / Mechanical assets / MDD/EDD: Implemented into the various procedures to reduce risk and mitigate threat to HMA operatives.

#### **III. CIED Operator Limitations**

8. It should be understood that HIEDC

trained personnel are not Improvised Explosive Device Disposal (IEDD) operators. IEDD operators have a greater level of training and equipment; providing a remote response capability such as; remote operated vehicles (ROV).

 HIEDC level 3 qualified operators (team leaders) will have the same levels of capability for the disposal / render safe of explosive hazards as that of a IMAS EOD Level 3/3+ clearance operator, in that they are cable of:



- a. Blow in Place (BiP).
- b. Low Order Techniques (LOT).
- c. Thermite disposal (drip or pyro torches).
- d. Pulling.
- e. Tracing of trip wires and gagging of fuses.
- f. Excavation of an explosive target.
- g. Limited manual techniques Detonator removal. (untapping from detonating cord).

## No differently from conducting RSP within a demining, BAC task site or conducting Spot tasks.

- 10. Any disposal or render safe deemed beyond the scope of HIEDC trained personnel will be dealt with by a fully qualified IEDD operator, these include:
  - a. Vehicle Clearance (opposed to vehicle search on base security operations).
  - b. Advanced electronic trigger mech-

anisms such as, PIR, light sensitive, prototyping board activated devices.

- c. Body clearance (suicide belts) secondary devices and other complex IEDs.
- d. Support to Building/compound Clearance.



#### IV. Other limitations include:

- a. CIED techniques are not structured to deal with mines (except for IED mine belts) or sub-munition clearance. Where there is a threat of mines or sub-munitions conventional IMAS demining clearance procedures are to be used.
- b. IMAS EOD level 3 qualified personnel to be employed as Team Leaders (TL) who have successfully completed a level 3 HIEDC training course or equivalent.
- c. Only the TL to render an IED inoperable utilising those techniques taught through training.
- d. Manual render safe procedures are not to be carried out unless specific in theatre training has been undertaken.
- e. Where possible a qualified IEDD operator / No2 should be in support of HIEDC operations. This may be as a deployed asset with the clearance teams or as an on-call response asset should an IED be located.
- f. IEDC techniques are not structured to deal with mines (except for IED mine belts) or sub-munition clear-

ance. Where there is a threat of mines or sub-munitions conventional IMAS demining clearance procedures are to be used.

- g. IMAS EOD level 3 qualified personnel to be employed as Team Leaders (TL) who have successfully completed a level 3 HIEDC training course.
- h. Only the TL to render an IED inoperable utilising those techniques taught through HIEDC training. Manual render safe procedures are not to be carried out unless specific in theatre training has been undertaken.
- i. If an IEDD operator is in support of HIEDC operations the asset is to conduct all render safe procedures.
- j. Clearance teams may assist in the collection of intelligence and forensic evidence however, this is not the remit of the clearance assets and should be the focus of other national assets. Operation should not be compromised or place clearance assets in danger for the collection of intelligence or forensic evidence.

#### V. CIED planning

- **11.** *Operational Planning* If clearance and search operations are to be successful they must be well planned, coordinated and managed effectively. It is the remit of the planner to coordinate agencies and assets. Operations should be based on the perceived threat from IEDs, boobytraps and ERW at the time of placement as this will dictate the operational required and identify requirements for resources and personnel. The level of response should be considered to avoid wasting key assets to minor tasks.
- **12.** *Clearance and Search Capability* Operation Managers / Commanders should consider carefully the assets and equipment they require in a theatre of opera-

tion to ensure the CIED assets are able to respond and meet the demands of the task. A CIED training cadre should cover the following disciplines:

- a. Clearance and Search Doctrine, Policy.
- b. IED and Boobytraps / Methods of Operation / Threat Assessment.
- c. Base security / Op security and Actions On. **(optional)**
- d. Person Search. (optional)
- e. Vehicle Search. (optional)
- f. Area Clearance. (IED seeding and rubble areas).
- g. Building Clearance Disruptive and Assurance (VIP) Search. **(optional)**
- h. Route Search / checks / VPs.
- i. Compound Clearance.
- j. Clearance of built up areas.
- k. Clearance of human remains.
- 1. Clearance of collapsed buildings.



#### VI. HIEDC recommended levels of training

- 1. Personnel attend a tiered training programme of 3 levels of CIED training. Given the nature and inherent danger involved in IED clearance the following prerequisites are suggested:
  - a. IMAS Level 1 HIEDC Clearance and Search Team Member. Role: Team

Member (TM). Prerequisites: IMAS EOD level 1-2 with 6 months experience.

- b. IMAS Level 2 HIEDC Clearance and Search Team 2i/c. Role: Team 2i/c. Prerequisites: IMAS EOD Level 2-3 with 6 months experience.
- c. IMAS Level 3 HIEDC Clearance and Search Team TL. ROLE: Team Leader: Prerequisites - IMAS EOD Level 3 with 6 months experience.

#### VII. IMAS IEDD Operator

- a. IEDD Operator and No2 Separate qualification and training required. Recommendation that IEED are international with minimum of 2 years' experience.
- b. IMAS Level 3+ and have attended a HIEDC course with a minimum of 6 months experience as a HIEDC TL.

#### VIII. In Summary

CIED is an effective tool to identify and locate legacy/abandoned IEDs, boobytraps ERW and render inoperable; ultimately providing a safe environment for QA/QC and land release. They are not procedures that are implemented where there are minefields or sub-munitions. If areas are identified through Non-technical and technical survey to contain mines or sub-munitions conventional mine clearance techniques should be implemented. Where possible IEDD assets should always support HIEDC operations.

#### References

[1] Explosive Ordnance Disposal (EOD) Competency Standards. Test and Evaluation Protocol, 09.30/01/2014, Version 1.0 30, October 2014.

[2] www.mineactionstandards.org International Mine Action Standards.

[3] Libya IEDD Top 20, Edition 1 (31 March 18)

[4] Libya IEDD SOP 1.0, Edition 1 (31 December 16)

[5] www.homelandsecurityqualifications. co.uk - National Occupational Standards (NOS) In Munition Clearance and Search (2002 / 2006)

[6] MAT Kosovo – Humanitarian Improvised Explosive Device Clearance (HIEDC) Course Material, (January 2018)

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Phil has gained a wealth of operational and project management experience, which he has taken into the commercial workspace, developing and conducting Security and EOD training to the civil and military sector, specifically in the UK, USA, Libya, Kosovo, Bosnia, Ukraine, South Sudan and Syria. With over 10 years' experience within HMA both operationally and in the training environment; Phil now leads on all course design, QA, QC and training delivery at MAT Kosovo Training Centre. Email: phil@pcm-erw.com

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Ben's vision of improving standards and focusing on training excellence has resulted in the growing reputation of the Kosovo based EOD & ERW Training Establishment, a valued member of the PCM Group of Companies.

Having been awarded the MBE by Her Majesty Queen Elizabeth II and being made a Paul Harris Fellow by Rotary Club International for the work of the lifesaving work of the organisations he has led. Ben was a former NCO in the British Army's Royal Engineers, spending much of his service with 59 Independent Commando Squadron Royal Engineers.

Email: <u>ben@pcm-erw.com</u>

# Natural disasters / crisis situations and mine action

# (Explosions of ammunition depots, fires, floods)



# Natural disasters / crisis situations and mine action

## Shifting Mines: Countering "New" Legacy Contamination in Flooded Areas using 2D Hydraulic Models

Lior Asaf, Matan Biederman, Leonid Grinis, Michael Heiman

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#### Abstract

Along the Israeli borders, large areas of land have been designated as SHA's as a result of the potential mobilization of Anti Personal Mines (PRBM-35 and no10 types) by major floods over the last 50 years. A new methodology to reduce the size of the Suspected Hazardous Areas (SHA) and manage the risk in these areas by predicting the potential transport of the mines following seasonal flood events that took place in the last 50 years is presented.

The method was developed for the first time for INMAA (Israel National Mine Action Authority) and applied in five demining projects in Israel. Lab experiments and 2D hydraulic model predictions were verified independently in the field using data collected from the INMAA, and from mines removed at the Sapir site. Ninety seven percent (97%) of the 379 mines that were found at the Sapir site were located in areas calculated to have a risk Category of 4 (high). The other 3% of the mines were found to be located in risk Category 3 (medium) areas. No mines were found in risk Category 1 (very low) areas or risk Category 2 (low) areas. This methodology proved to reduce the work and risk associated with mine removal operations (50 % decrease in SHA areas), save valuable resources, improve safety, and significantly cut costs (over 100 million US\$ in IMMAA projects).

#### 1. Introduction

Along the Israeli borders, large areas of land have been designated as SHA's as a result of the potential mobilization of Anti Personal Mines (PRBM-35 and no10 types) by major floods over the last 50 years. In an attempt to save costs, minimize the damage to natural values and reduce the safety risks of implementing such actions, Ecolog Engineering Ltd. (Ecolog) was requested by INMAA to develop a methodology to reduce the size of the SHAs and manage the risks at these sites by predicting the potential transport of the mines using hydrological and hydraulic modeling following large flood events (Figure 1).



Figure 1 : SHA's sites

#### 2. Methods and Materials

The concept is simple analysis of the terrain (natural and manmade), and flow conditions

(Water depth and velocity), during past floods by hydraulic models to allow the determination

of different risk levels for mine transport in SHA - Suspected Hazardous Areas. During the first phase of the project, a conceptual model including assessment of risk zone based on the results of 2D hydraulic simulation for past flood events was developed (Table 1).

Category	Risk	Description	Color
1	Very low	Areas where no water flow occurred during the past flood events	
2	Low	Areas that have been flooded by some event, but have no hydraulic connection to the minefields	Blue
3	Mediu m	Areas that have been flooded by some event, but have low energy (flow) regime which has low chance to mobilize mines (V<0.3 m/sec or D< 0.1m )	Yellow
	High	Alone where were done recorded to only the and frank some out were estimated to have from ready of free contributions are manifed the result (were subject to the contribution)	

Table 1: Categories for risk zones for mine hazard in SHA sites.

#### 3. Lab Experiments

Since literature and research data regarding boundary conditions for mines movement during floods was not available, we developed lab experiments to determine the flow conditions for mines initial movement and deceleration under various slopes (0 %-8%) and terrain material (e.g. Small Pebble, Medium Pebble, Small Gravel and Grable) (figure 2). The lab experiments were not planned to reconstruct a specific river or stream but to rather to analyze the general boundary conditions for mine movement under natural flow. During the experiment we preformed 7943 measurements of Anti Personal Mines (PRBM35 and No. 10 types in 1:1 scale) transport in various flow, slope, and terrine conditions. The Lab result for 0 % are presented in Figure 3. From the lab results we can predict the hydraulic conditions that can transport Anti Personal Mines like PRBM35 and No. 10 under natural flow at various bed material. The minimum velocity is around 0.3 m/sec for small gravel (blue squares) and the corresponding water depth is around 0.1 m.



Frame, (2) Pump , (3) Flow meters , (4) water valve
water tank # 1 (6) flow experiment tunnel (7) water tank # 1
Figure 3. Flow experiment setup

Figure 2: Flow experiment setup



Figure 3: Initial movement for M35 mine at % slope as a function of gravel bed material (blue, green and red lines are Minimum, Mean and Maximum velocity values respectively

#### 4. 2D Hydraulic Simulation

Digital Elevation Models (DEM) were constructed using aerial photographs, satellite and LIDAR measurements while examining natural morphological and man-made changes undergone at the stream at the investigated areas, in recent decades. The DEM's were used as the basis for the hydrological models for past major floods since the installation of the minefields in 1968. Rain statistics from 1944-2016 were used to determine rain intensity and accumulated rain for past major flow events. Following the hydrological survey and determination of the flood hydrographs for the major floods event (from 1970, 1975, 1987, 1993, 2004 and 2010), a 2D numerical flow model (by TUFLOW software) was developed to calculate the two-dimensional velocity and water depth raster's across the SHA to determine the feasibility of mine movement. The simulation calculated the velocity and water Natural disasters / crisis situations and mine action

depth for each 5m\*5m cell throughout the flow event in each of the SHA sites. A typical model grid is for 4-25 km<sup>2</sup> corresponding to 160,000-1,000,000 cells. Figure 4 presents the maximum velocity raster for the 2010 flood event at the Sapir site. Based on the results of the 2D hydraulic model, the SHA was divided into four levels of risk based on the hydraulic conditions during the flow event (Table1) from Category 1-very low risk, to Category 4 - high risk). Model predictions were verified independently using data collected from the INMAA, from mines evacuated at the Sapir site. Figure 5 presents the location of mines at the Sapir site over the risk zone map. It's important to indicate that the location of the mines were unknown to us during the production of the risk zone.



*Figure 4: Velocity flow raster for the 2010 event (850 m3/sec) at Sapir Site* 



*Figure 5: Location of mines at the Sapir site over the risk zone map* 

#### 5. Results and Discussion

Ninety-seven percent (97%) of the 379 mines that were found at Sapir site were located in areas calculated to have a risk Category of 4. The other 3% of the mines were found to be located in risk Category 3 (medium) areas. No mines were found in risk Category 1(very low) areas or risk Category 2 (low) areas. Figure 6 summarizes the results for the risk zone from the five SHA sites. In each site the final polygon for each risk zone was produced in ArcGIS was the base for future demining operation and the final clearance of the SHA sites. The overall area of Category 1-2 is between 17% at Sapir site to 86.9 % at Naama site. The total low risk area is around 12,000,000 m<sup>2</sup> (51.3 % from total area). If we considered based on the actual evacuation cost the total saving would be over 100 M\$ for the Israeli National Mine Action Authority. Therefore quite a significant cost saving of around 50 % from initial demining operation estimation was achieved using the risk zone approach. The methodology applied in the project received the 2017 first prize for invention in the Israeli Civil Service Sector.



Figure 6: Categories for risk zones for mine hazard in SHA sites

#### 6. Conclusions

- 1. New methodology to reduce the size of the Suspected Hazardous Areas (SHA's) by predicting the potential transport of the mines using hydrological and 2D Hydraulic modeling was newly developed.
- 2. The model was tested in 5 sites in Israel adjacent to major dry wadies in the Arava Valley, the Dead Sea and Jordan Valley region (Naama, Tamar, Zin, Sapir, Tsofar and Tzukim sites).
- 3. The total low risk area is around 12,000,000 m<sup>2</sup> (51.3 % from total SHA area).
- 4. Ninety-seven percent (97%) of the 379 mines that were found at Sapir site were located in areas calculated to have a risk Category of 4 (high). The other 3% of the mines were found to be located in risk Category 3 (medium) areas.
- 5. No mines were found in risk Category 1 (very low) areas or risk Category 2 (low) areas.
- 6. This methodology proved to reduce the work and risk associated with mine removal operations (50 % decrease in SHA areas), save valuable resources, improve safety, and significantly cut costs (over 100 million US\$ in IMMAA projects).
- 7. The methodology developed during this project is now available for use in other SHAs worldwide.

#### Cultural Heritage in Mine Suspected Areas: A GIS Data Base

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#### Introduction

Every armed conflict is primarily an intensive spatial practice. The military engagement creates separate relations in space or the space is mobilised in a military manner. Lines are established along with demarcation zones, military positions, roads etc. which together cut through the common social space of the civilian life. Upon the cessation of an armed conflict, the military installations are in a direct collision with the everyday lives of the people. The contamination of space with the UXO (unexploded ordnance) and ERW (explosive remnants of war) is one of the most long-lasting and real negative consequences of an armed conflict. Such a contamination presents the most significant obstacle for people returning to a space or resocialization of space. Negative consequences of armed conflict together with UXO and ERW are numerous and properly identified, especially those which concern the basic needs of people and communities.

The focus of this paper is still inadequately discussed topic of cultural heritage in MSA (Mine Suspected Areas). The destruction of cultural heritage in the context of an armed conflict, as well as the necessity to protect the cultural heritage in such an eventuality, has been identified a long time ago.<sup>1</sup> The first proper international legal framework whose focus is the protection of cultural heritage in an armed conflict is The Hague Convention, 1954.<sup>2</sup> Although the Convention establishes a

framework for protection of cultural heritage in an armed conflict,<sup>3</sup> the emphasis is primarily on the deliberate destruction and looting and not on the destruction of cultural heritage generally, which inevitably takes place in an armed conflict.<sup>4</sup> However, it is precisely the "incidental" infliction of damage which is the most common. This form of damage is not obvious as is the case with the first-class monuments and properties with the level of protection at the international scale such as The Old Town in Dubrovnik, for instance. The prevailing damage inflicted upon the cultural heritage most commonly occurs within the actual practice of warfare: by cutting through the space measuring in hundreds of kilometres and encompassing extremely large areas of space which are the subject of building the military infrastructure, the placement of landmines included. Hence, the space is cut through with the whole historical stratification and historical depth of that space enveloped in the process: numerous archaeological sites, landscapes and other monuments are affected, known and unknown, formally protected and unprotected.

The estimation of the total, that is the real damage inflicted upon the cultural properties demands enormous painstaking work and research because such estimates must be founded upon the actual spatial data. Now-

<sup>&</sup>lt;sup>1</sup> For history of the protection of cultural heritage in an armed conflict see: Johannot–Gradis 2015.

<sup>&</sup>lt;sup>2</sup> Convention for the Protection of Cultural Property in the Event

of Armed Conflict, Hague (Netherlands) 1954, First protocol 1954, Second protocol 1999.

<sup>&</sup>lt;sup>3</sup> For the history of legislation on protection of cultural heritage in an armed conflict see: Techera 2007.

<sup>&</sup>lt;sup>4</sup> *The military necessity is integrated in The Hague convention which is a subject of numerous discussions, for instances: Frulli* 2011., *Techera* 2007.

adays, such a project is most certainly conceivable with the use of landscape archaeology methods including the analysis of aerial and satellite imagery, LiDAR data with the assistance of GIS etc. The proposed approach demands accounting for all military engagements in a certain area. In this context it is important to note that UNESCO recently published a military manual for the protection of cultural property.<sup>5</sup> Military engagement is commonly defined in broad and general terms as types of military action that might interfere with cultural properties. The placement of anti-personnel mines and other explosive devices as a means of negative action against the cultural heritage during and consequently long after the armed conflict is not cited once. The issue of the MSA and cultural heritage is neither sufficiently recognized nor systematically addressed as a means of inflicting damage in an armed conflict.

#### Cultural Heritage in the MSA in Croatia: A Background

As early as 1991, Croatia adopted several legislatives acts<sup>6</sup> concerning war damage.<sup>7</sup> Naturally, the assessment of war damage on cultural properties and sites was included in the acts. The work on the estimation of war damage on cultural properties was conducted under aegis of Ministry of Culture. The reports produced by these efforts clearly demonstrate that the focus was placed on religious architecture and other well-known and emblematic registered cultural monuments and sites which were a part of inhabited areas and subjected mostly to the acts of deliberate destruction.<sup>8</sup> Not a single instance of inflicting direct or indirect damage to archaeological sites or other cultural properties

was listed in the declaration of war damage,<sup>9</sup> either by placing landmines or building military obstacles or other installations. This inevitably brings us to a conclusion that such actions were not considered in the assessment of war damage. According to a formal response issued by the Ministry of Culture at our request, the estimation of war damage conducted by the Ministry did not include archaeological sites or other cultural properties in the MSA, the record of such properties or sites are not kept and the Ministry did not participate in any capacity in the process of demining such places.<sup>10</sup> This fact has to be considered and evaluated in the context of the circumstances at the time. The tools, data and software solutions at our disposal today were not available at the time which would enable different and more efficient management of a post-conflict situation at the level of the entire space with every regard to security issues.

The MSA is a pressing problem which demands numerous stakeholders, whose purview is some aspect of managing space, as part of the solution to that problem. The article 7<sup>11</sup> from the Law on the Mine Action clearly states as much where the Ministry of Culture is listed<sup>12</sup> among the stakeholders involved in demining efforts. All cultural properties on the territory of Republic of Croatia fall under the direct jurisdiction of the Ministry of Culture. The legal framework is defined by countless laws and international conventions, of which the Republic of Croatia is a signatory state. This legislation elaborates on various aspects and means of protecting and safeguarding of cultural heritage, han-

<sup>&</sup>lt;sup>5</sup> O'Keefe et al. 2016.

<sup>&</sup>lt;sup>6</sup> Zakon o utvrđivanju ratne štete (NN 61/91).

<sup>&</sup>lt;sup>7</sup> Uputa za primjenu Zakona o utorđivanju ratne štete (NN 54/93).

<sup>&</sup>lt;sup>8</sup> The data in this paper are presented by the counties with the overall elaboration of the types and the extent of damage and restoration: Ukrainčik, Uršić 1998/1999.

<sup>&</sup>lt;sup>9</sup> Ibid.

<sup>&</sup>lt;sup>10</sup> An official information provided by the Ministry of Culture, Republic of Croatia, at the request of the co-author (February 22<sup>nd</sup> 2018).

<sup>&</sup>lt;sup>11</sup> Law on the Mine Action (Zakon o protuminskom djelovanju, NN 110/15).

<sup>&</sup>lt;sup>12</sup> The Ministry of Culture has already been integrated as a stakeholder in the article 4. The Law on the Humanitarian Demining (Zakon o humanitarnom razminiranju, NN 153/05) no longer in force, it is substituted by Law on the Mine Action (Zakon o protuminskom djelovanju, NN 110/15).

dling of archaeological finds, the execution of works etc.<sup>1</sup> The inclusion of the Ministry of Culture in the demining legal framework is easily comprehensible when the problem is viewed from a spatial perspective. The MSA arbitrarily encompass enormous tracts of land including every aspect of spatial content that may be present in that area. Although it is abundantly clear that the demining process falls exclusively under the jurisdiction of Croatian Mine Action Centre (HCR), other stakeholders listed in the law on the demining action<sup>2</sup> are direct stakeholders in space. Their participation in the process could and should be in the form of inter-institutional cooperation in defining measures, categorisation of areas afflicted by the ERW, defining demining priorities and standards, providing funds, defining consequences of contamination with UXO and ERW etc. We find it plausible to claim that the legislation on demining which included all stakeholders with some stake in management of space, comprehended the issue of MSA with full implications and reach in mind. However, the corresponding practice of cooperative problem solving appears to be missing completely in this particular instance.

#### Cultural Heritage in the MSA in Croatia: The Aftermath and How to Deal with It

The estimated damage on cultural properties is not fully accounted for simply because all manners of destructive actions are not taken into consideration as well as the entire scope of military engagement. This claim appears all the more valid from the current perspective when new technologies, tools and perspectives are available which enable a more comprehensive treatment of the problem. Nowadays, the fact that a whole range of significant archaeological sites is affected by various forms of military engagement such as building military positions and other installations, the placement of landmines etc. seems quite straightforward. The elaboration of the relationship between cultural heritage and MSA clearly demonstrates that years after the cessation of armed conflicts numerous unforeseen consequences of wars are encountered. It is reasonable to claim that actual damage has never been fully assessed and analysed. The same is true for various agents of destruction, whether their deployment is direct or indirect or what negative impact of such actions may be. Consequently, the damage inflicted upon the cultural heritage during the course of the Homeland war is yet to be fully assessed, according to any assessment criteria as are the various means of inflicting damage and the repercussions this might have for cultural heritage.

The problem of cultural heritage in the MSAs will be illustrated by a case study from the Zadar hinterland. The area under discussion in geomorphological terms is a region where karst poljes and limestone ridges alternate in a regular succession. The entire area is extremely rich with various remains from the past. However, a single class particularly stands out: monumental drystone wall architecture dating from Later Prehistory, the Bronze and Iron Ages. This architecture is often coupled with burial mounds from the same period. Such assemblages are commonly placed on limestone ridges and their position is, as a rule, prominent and dominating. Such sites are labelled hillforts in the professional literature and they constitute the most ubiquitous and emblematic class of sites on the entire eastern Dalmatian coast and the hinterland. The immense size of the hillforts enables their easy detection from the air, on

<sup>&</sup>lt;sup>1</sup>akon o očuvanju i zaštiti kulturnih dobara RH (NN 69/99, NN 151/03; NN 157/03, NN 87/09, NN 88/10, NN 61/11, NN 25/12, NN 136/12, NN 157/13,NN 152/14 i 44/17), Pravilnik o uvjetima za fizičke i pravne osobe radi dobivanja dopuštenja za obavljanje poslova na zaštiti i očuvanju kulturnih dobara (NN 74/03, NN 44/10), Pravilnik o arheološkim istraživanjima (NN 102/10), Pravilnik o određivanju kulturnih predmeta koji se smatraju nacionalnim blagom država članica Europske unije (NN 38/04), Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property, 1970, Paris (Ratification law NN 12/93), European Convention on The Protection of The Archaeological Heritage (Revised), Valletta, Malta 1992., (ratification law NN 4/04, 9/04), Convention on the Value of Cultural Heritage for Society, Faro, 2005 (ratification law NN 5/07) etc.

<sup>&</sup>lt;sup>2</sup> Zakon o protuminskom djelovanju (NN 110/15).

aerial and satellite imagery which are readily available for over a decade. The sites themselves are well known from the seminal and basic scientific literature.<sup>3</sup> Numerous such sites find themselves in the MSA (Fig 1.). fects. The final step is the definition of standards or protocols for demining activities at archaeological sites which are in accordance with proper legislation concerning both protection and safeguarding of cultural heritage



Fig 1. Prehistoric hillforts in Zadar and Šibenik hinterland in the MSA, base map: geoportal.dgu.hr, MSA data provided by HCR, March 2018 (made by authors)

The case study presented in this paper is not comprehensive in terms of presenting complete spatial information available on the cultural properties or specifically in this case archaeological sites in the MSAs. It is more of a heuristic device to illustrate an example of managing such a situation. One aspect of management may be formulated through the definition of the scale of negative impacts. The first level includes the actual inflicted damage as well as its forms and manifestations at the level of each individual site. Potential general negative impact is defined at the second level which stem from the fact that archaeological sites are found within an MSA. Such areas are subjected to demining activities by default. The next step in management is defining goals and corresponding measures in order to mitigate negative efand mine action.

The damage at the level of each individual cultural property<sup>4</sup> effected through the impact of ERW can be defined as direct through the infringement upon the material integrity of the site (Table 1.). The damage to the site takes place on two occasions: first, when the explosive devices are placed and then when they are removed. Since demining activities are inevitably carried out using metal detectors, metal artefacts are removed which constitutes selective and hence biased removal of archaeological finds from the cultural layers. This practice decreases the scientific value of site as it the cause of permanent loss of scientific information. The discovery of archaeological finds during demining works is not uncommon. That much is demonstrat-

<sup>&</sup>lt;sup>3</sup> For instance: Batović 1987., 1990., 1990.a, Brusić 1976.

<sup>&</sup>lt;sup>4</sup> The criteria for defining the damage on cultural properties is formulated after Sirovica 2015.

ed by the exhibition under the title "Pars pro toto – Archaeology in the Minefield" ("Pars pro toto – Arheologija u minskom polju") organized by the Lika Museum in Gospić and opened in November 2017. The exhibition was produced as a result of cooperation between deminers and an archaeologist and it presented archaeological finds discovered during demining works.<sup>1</sup> The indirect damage may be formulated as inaccessibility of the cultural property for scientific research, valorisation and development of cultural products and tourism (Table 1.). The demining of archaeological sites and other cultural properties ensues for more than 20 years with no participation whatsoever of institutions whose direct jurisdiction are cultural monuments.

Cultural heritage in the MSA				
The form of damage	Criterion	Damage type and description		
Direct damage Indirect damage	Material integrity	The placement of anti-personnel mines infringes upon the material integrity of ar- chaeological sites and other cultural properties		
		Demining disturbs the material integrity of archaeological sites and other cultural properties		
		Demining permanently alters the content of cultural layers by removal of metal and other archaeological finds		
	Scientific	The loss of information on context and content of cultural layers by removal of metal and other archaeological finds		
		Inaccessibility of a cultural property for scientific research		
	Economic	Inaccessibility of a cultural property for valorisation		
		Inaccessibility of a cultural property for development and integration into cultural/ tourist product		
GOALS				
1. CONTROL AND REDUCTION OF DAMAGE ON CULTURAL HERITAGE				
2. ENABLEING ACCESSABILITY OF HERITAGE				

Table 1. An example of defining criteria for war damage on cultural heritage in the MSA

Table 2. An example of measures for reduction of damage on cultural heritage in the MSA

<sup>&</sup>lt;sup>1</sup> Kolak 2017., https://muzejlike.hr/2017/11/27/otvorena-izlozba-pars-pro-toto-arheologija-u-minskom-polju/, visited 26.02.2018.

Therefore, it is impossible to adequately estimate the effects of the general negative impact which can be formulated as gross loss of heritage value and scientific data in Croatia. The loss is caused by the undeniable necessity of conducting demining work and just as necessary use of the metal detector which simultaneously results in a selective removal of metal artefacts which were once an integral part of the site. imperative that the activities are conducted jointly and in an atmosphere of compromise. The first step in that direction presents the integration of spatial data on cultural heritage in MSA into the Mine Information System of Croatian Mine Action Centre (MIS HCR).

Vector data with the area of each individual cultural property simultaneously present the "cultural heritage" category which is equivalent to other categories such as agricultur-

Cultural heritage in the MSA					
Integration of data on cultural properties into MIS HCR					
Category "cultural heritage"		Spatial data "cultural heritage"			
Priority "cultural heritage" The zone of application of special demining stan- dards		Zone 1	Zone 2		
		The area of site	The area surround- ing the site		





Fig 2. Hillfort Gradina near Vukšić, an example of the spatial category "cultural heritage", base map: geoportal.dgu.hr, MSA data according to HCR, March 2018. (made by authors)

General goals may be formulated in relation to the negative effects: control and reduction of damage and enabling access and availability of heritage (Table 1.). The reduction of damage may be formulated through multiple measures (Table 2.) which demand the participation of the institutions with proper jurisdictions, namely the Ministry of Culture and Croatian Mine Action Centre (HCR). The jurisdictions of these institutions inevitably overlap in such situations. Therefore, it is al land, settlement, protected area etc. or a type of demining priority<sup>2</sup> (Table 3., Fig 2.). Cultural heritage as a category can further present a basis for a development measure "demining of cultural heritage" and a means for securing funds for demining actions. It is important to note that spatial data "cultural

<sup>&</sup>lt;sup>2</sup> After the priorities defined in the National Program of Mine Action Program, Republic of Croatia 2009-2019 (Nacionalni program protuminskog djelovanja Republike Hrvatske 2009.-2019., NN 120/09.).

heritage", apart from the category and the priority, simultaneously presents a zone of special demining standards (Fig 2.).

The articulation of standards during demining activities<sup>1</sup> is precisely the area of compromise. Special standards should be formulated depending on the particularities of each individual situation. However, the general principle always must be that safety of deminers takes precedence over all other issues. The standards are necessary and present a measure whose direct intention is to reduce the damage on a cultural property. This primarily refers to handling of archaeological finds which are inevitably removed from their original context. Archaeological sites are often places of high intensity of metal detector signal and metal and other archaeological finds are removed in the process of demining. Since it is virtually impossible to apply the norms defined by the legislation concerning protection and safeguarding of cultural heritage, it is necessary to define measures for handling of archaeological finds. This may be formulated as through collecting the archaeological finds and handing them over to the proper museum institution authorised to store such material. For that purpose, it is necessary to conceptualize outreach programs and open communication channels between the stakeholders involved in order to reach common ground on the importance and significance of cultural heritage as universal value in need of care and protection. Such programs would also present a means to control and reduce the damage which is in this case unfortunately necessary. The spatial data on the overall demining efforts should be integrated into ISKB Teuta<sup>2</sup> of Ministry of Culture in order to re-evaluate the war damage on cultural properties, particularly at archaeological sites where metal detector was used. It is an extremely important information for all demining actions already conducted which were not under the supervision of authorised institutions for protection of cultural heritage.

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#### Bibliography

Aldrich, L., Fiederlein, S., Rosati, J. 2015. Clearance at Cultural Heritage Sites, The Journal of ERW and Mine Action, Vol. 19, Issue 1, Article 10., http://commons.lib.jmu.edu/cisr-journal/ vol19/iss1/10.

Batović, Š. 1987. Liburnska grupa, Praistorija Jugoslavenskih zemalja V, Željezno doba, Sarajevo, 339–390.

Batović, Š. 1990. Benkovački kraj u prapovijesti, Radovi Filozofskog fakulteta u Zadru, 16, Zadar, 5–142.

Batović, Š. 1990. Novija istraživanja prapovijesti u biogradskom kraju, Biogradski zbornik 1, Zadar, 85–195.

Brusić, Z. 1976. Gradinska utvrđenja u šibenskom kraju, Materijali SADJ 12, Zadar, 113–126.

Frulli, M. 2011. The Criminalization of Offences against Cultural Heritage in Times of Armed Conflict: The Quest for Consistency, European Journal of International Law, Volume 22, Issue 1, 2011, 203–217, https://doi.org/10.1093/ejil/ chr002.

Johannot–Gradis, C. 2015. Protecting the past for the future: How does law protect tangible and intangible cultural heritage in armed conflict?,

<sup>&</sup>lt;sup>1</sup> Special standards were deployed in demining projects conducted at a World Heritage site at Afghanistan and two sites on the tentative list for consideration as World Heritage sites (in Georgia and Laos), see: Aldrich et al. 2015.

<sup>&</sup>lt;sup>2</sup> ISKB TEUTA is presented in Križaj 2007. and the data which is accumulated are compatible with the MIS HCR.
*International Review of the Red Cross (2015), 97 (900), 1253–1275.* 

Kolak, T. 2017. Pars pro toto – arheologija u minskom polju, Muzej Like Gospić, studeni 2017. – siječanj 2018., Katalog izložbe.

Križaj, L. 2007. Informacijski sustav kulturne baštine RH TEUTA, Muzeologija 41/42, 196– 204.

O'Keefe, R., Péron, C., Musayev, T., Ferrari, G. 2016. Protection of Cultural Property: Military Manual, UNESCO Publishing, Sanremo.

Sirovica, F. 2015. Ocena izgube vrednosti in znanstvenega informacijskega potenciala pri uničenih arheoloških depozitih, Ljubljana, Filozofska fakulteta, Univerza v Ljubljani, unpublished PhD thesis.

Techera, E. J. 2007. Protection of Cultural Heritage in Times of Armed Conflict: The International Legal Framework Revisited, Macquarie Journal of International and Comparative Environmental Law (2007) Vol 4, 1–20.

Ukrainčik, V., Uršić, B. 1998/1999. Ratne štete na spomenicima kulture, Godišnjak zaštite spomenika kulture Hrvatske 24/1998/25/1999, 7–55.



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