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THE JOURNAL

of Conventional Weapons Destruction

Issue 21.1 | April 2017

WHAT'S IN A NAME?
IMPROVISED EXPLOSIVE DEVICE
IMPROVISED LANDMINE
VICTIM ACTIVATED
ARTISANAL
IED

Field Notes | Research & Development

Bosnia & Herzegovina: 20 years later

THE JOURNAL
of Conventional Weapons Destruction

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The Journal of Conventional Weapons Destruction is a professional trade journal for the humanitarian mine action and CWD community. It is a forum for best practices and methodologies, strategic planning, risk education and survivor assistance.

The Journal Editorial Board reviews all articles for content and readability, and it reserves the right to edit accepted articles for readability and space, and reject articles at will.

Authors who submit articles to *The Journal* are expected to do so in good faith and are solely responsible for the content therein, including the accuracy of all information and correct attribution for quotations and citations.

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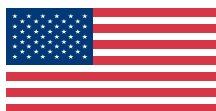
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Cover Photo
Landmines in Iraq are sometimes rigged with with booby traps, creating new challenges for deminers.
Photo courtesy of Sean Sutton, MAG.

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JAMES MADISON UNIVERSITY®

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FROM THE DIRECTOR

As we endeavor to make *The Journal* a forum of information and ideas for the conventional weapons destruction community, we look at the threat improvised explosive devices (IED) pose in countries around the world. Increasingly, humanitarian organizations are widening their scope to account for the prevalence of IEDs. The need for clear communication across humanitarian mine action and counter-IED (C-IED) operational lines is evident.

In this issue of *The Journal*, we feature the challenges that humanitarian organizations face when incorporating IEDs into their operational activities. Robert Keeley from Danish Demining Group (DDG) discusses the nuances of differentiating a landmine, a booby trap, and an IED and how overlaps between humanitarian mine action and C-IED can cause misunderstandings. Focusing on Somalia, Abigail Jones of the Danish Refugee Council explains the need to tailor risk education approaches for populations affected by IEDs, while Chris Loughran and Sean Sutton illustrate the work being done in the Middle East by MAG (Mines Advisory Group) through photos and express the need to distinguish between humanitarian and military involvement in conflict areas.

In celebration of the twentieth anniversary of mine action in Bosnia and Herzegovina, we spotlight the accomplishments, lessons learned, and future challenges for the region. In his article, Ian Mansfield examines the transition process that gave the country's government ownership of the Bosnia and Herzegovina Mine Action Centre. In addition, Gregor Sančanin explores the sociocultural aspects of the region and the remaining work to be done.

Looking back, Roly Evans from GICHD remembers the United Kingdom's coastal minefields during World War II and the techniques used by Royal Engineers to prioritize clearance and manage resources effectively. In addition, we highlight the Schonstedt Humanitarian Demining Initiative, a partnership between the public, private, and civil sector aimed at providing magnetic locators to the countries that need them most. In our Research and Development section, Milan Bajić, Tamara Ivelja, and Anna Brook write about the use of hyperspectral remote sensing technology and Ian McLean and Rebecca Sargisson present on the effects of weather on the detection abilities of giant African pouched rats.

After months of planning, the CISR team and Croatian Mine Action Centre implemented our third Regional Senior Managers Course in Biograd na Moru, Croatia, from March 20 to April 7. Moreover, our annual Post-Conflict Recovery Week featured Adnan Al Aboudi from Jordan's Higher Council for Affairs of Persons with Disabilities who spoke about his experience with campaigning for disability rights and Mona Abdeljawad from the Rights and Development Center in Jordan who spoke about the situation of Syrian refugees with disabilities in the Middle East. Lastly, CISR will be presenting on *The Journal* at the 14th International Symposium "Mine Action 2017" in Croatia in April, and will be on hand to speak with potential contributors. We hope to see you there!

Ken Rutherford
CISR Director

FEATURE

IMPROVISED EXPLOSIVE DEVICES (IED): A HUMANITARIAN MINE ACTION PERSPECTIVE

by Robert Keeley

Readers of this *Journal* need no schooling in the acceleration of the use of improvised explosive devices (IED) over the last 20 years. However, what has become obvious in the last few years is the degree to which the spheres of counter-IED (C-IED) and humanitarian mine action (HMA) now overlap. Danish Demining Group (DDG), for example, recently calculated that an estimated 67 percent of the countries where DDG is present also have an IED problem. In countries such as Afghanistan, IEDs are now the major cause of explosive-related casualties among the general population, the very constituents nongovernment organizations (NGO) and HMA sectors support. This raises questions of whether or not an NGO engaged in C-IED efforts can be classically impartial in circumstances where these IEDs are active. This is a significant difference for a sector primarily focused on dealing with the legacies of conflict that are explosive remnants of war (ERW). Yet, while undertaking a series of risk assessments to help identify an appropriate approach for an NGO active in HMA, it became clear that there was a need for better common terminology in order for HMA actors to identify the appropriate response. The aim of this article is to outline how this thought process evolved in DDG in order to set the ground for subsequent discussion of these risk-analysis processes.

What is an IED?

The name says it all. An IED is an explosive device that is made in an improvised manner. British parliamentarians currently define an IED as:

> *A device placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and designed to destroy, incapacitate, harass, or distract.*[1]

This term hides a multiplicity of variations: it might be a device based on a recycled item of unexploded ordnance
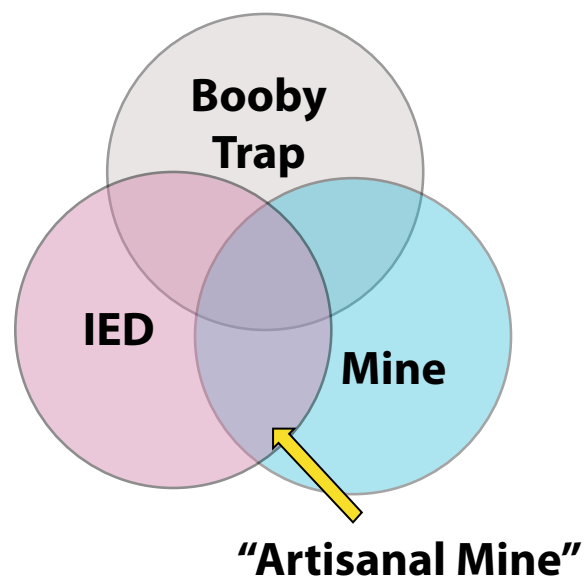
Figure 1. How IED terms overlap.
Figure courtesy of the author.

(UXO), or built around a repurposed item of abandoned explosive ordnance (AXO) found in an unsecured or raided ammunition stockpile. It might also be built from scratch from homemade explosives (HME). However, the common factor amongst these variations is that these constructions are improvised as opposed to factory-made, standardized weapons used for their intended purpose. In summary, the term IED is about **how the weapon is made**.

What is the difference between an IED, a booby trap, or an improvised mine? Not much, in some cases. A booby trap is defined as follows:

> *An explosive or non-explosive device, or other material, deliberately placed to cause casualties when an apparently harmless object is disturbed or a normally safe act is performed.*[2]

Security incidents are all enemy action (i.e. enemy-initiated direct fire and indirect fire i.e. mortar, rocket and artillery, surface-to-air fire, and explosive hazard) events to include executed attacks (i.e. IED explosion, mine strike) and potential or attempted attacks (i.e. IEDs, mines found & cleared, premature IED detonations, IED turn-ins) which are not included.

Security incidents do not include friendly action incidents such as direct fire and indirect fire that are initiated by friendly forces. Enemy-initiated attacks are all enemy action (i.e. enemy-initiated direct fire, indirect fire, surface-to-air fire) and explosive hazard events to include executed attacks only (i.e. IED explosions and mine strikes). Potential or attempted attacks (i.e. IEDs/mines found & cleared, premature IED detonations, IED turn-ins) are not included.

IED events comprise explosive hazard events, both executed (i.e. IED explosion/mine strike) and potential IED/mine attacks (i.e. IEDs/mines found & cleared, premature IED detonations, IED turn-ins).

A complex attack is an attack conducted by multiple hostile elements which employ at least two distinct classes of weapon systems (i.e. indirect fire and direct fire, IED, and surface-to-air fire) against one or more targets.

Figure 2. NATO weapons definitions from Afghanistan. Note that this does include reference to "legacy" incidents from explosive remnants of war.
Figure courtesy of UNMAS.

One can immediately see how easily these two terms overlap. It is possible to set up an IED to produce such a situation. Yet the term booby trap can also apply to non-explosive traps (e.g., punji sticks in Vietnam) and a command-detonated IED is not necessarily linked to the person carrying out an apparently harmless act. If the term IED is about how the device is made, the term booby trap describes **how the device is set up to function**.

Thirdly, one must consider how improvised or artisanal mines fit into this taxonomy. The 1997 *Anti-Personnel Mine Ban Convention* (APMBC) defined a mine as:

> *any munition placed under, on or near the ground or other surface area and designed to be detonated or exploded by the presence, proximity or contact of a person or vehicle.[3]*

Here we see another overlap. Mines are commonly factory-built, but it is quite possible to make a victim-operated IED. The mine definition is about **how the device is initiated**.

One could easily spend time wrestling with these definitions. Take any particular device: which one of these categories does it fit into? In many cases, a given device can fit in two, sometimes even three, categories at once. Because these terms developed from different historical roots, they overlap and describe different attributes of the device: the way it is constructed, the way it is set up, and the way it is initiated (Figure 1, page 5). If the terms aren't used correctly, there is a risk of over-reporting the problem. Secondly, because of their improvised nature, IEDs often require different training and equipment for counteractions; if the problem is misunderstood, the balance of training and other resources will also be wrong.

Moreover, there have been efforts to adjust the definition of **booby trap** to only cover factory-built devices. From the author's perspective, this attempt to square the definition circle is not helpful. The terms describe different attributes, and trying to make them fit a convenient perspective could simply add further confusion.[4] Perhaps a booby trap is not a separate type of weapon but merely another method of deployment.

How do IEDs fit into the spectrum of explosive incidents? In situations of counterinsurgency, asymmetric warfare, or internal security, the civilian population, civil power, humanitarian actors, and security forces face a range of different explosive threats, of which IEDs are only part of the spectrum. NATO's early work in Afghanistan helps to untangle the range of these threats.[5] Figure 2 was developed as a risk assessment carried out by the author on behalf of the U.N. Mine Action Service (UNMAS) in Mali in October 2015.

Figure 3 (page 7) helps clarify a number of points. First, current security incidents (case 2) can stand alongside incidents from legacy weapons (case 1). In fact, these legacy weapons led to the establishment of the HMA sector. Second, current and active security incidents can involve a range of weapons that are not IEDs, including direct fire, indirect fire from factory-built mortars, surface-to-air missile (SAM) attacks on civil aircraft, or placement of factory-built anti-tank mines—all of which are significant but not IED incidents. It should also be noted that, for clarity, the diagram does not include the range of criminal weapon uses that might be included under a wider definition of armed violence (case 3) such as armed robbery, inter-communal disputes, or even domestic violence.

How Do We Describe Different IEDs?

During the 20th century, simpler terms were in use such as letter bombs, parcel bombs, unattended bags, and car bombs.
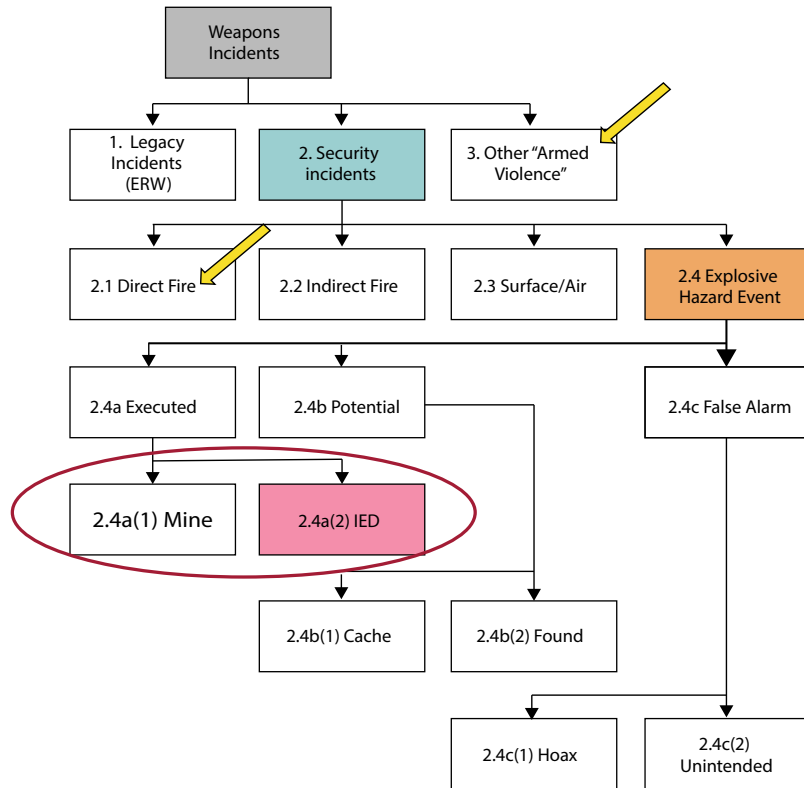
Figure 3. Description of IEDs.
Figure courtesy of the author.

These terms were not precise but counter-IED personnel knew what they meant. In recent years, there has been a significant proliferation of terms (particularly involving acronyms) intended to make our vocabulary more exact. However, this article argues that the opposite was achieved. We now have vehicle-born IEDs (VBIED), victim-operated IEDs (VOIED), command wire detonated IEDs (CWIED), suicide vehicle-borne IEDs (SVBIED), improvised rocket-assisted munitions (IRAM), etc. While it is comparatively easy to learn what these acronyms mean, perhaps they obscure what is actually needed for a fuller analysis.

These terms describe one or both of two main attributes of IEDs: the nature of the containment and the means of initiation. Thus a VBIED can be command detonated by wire (CWIED) or remote control (RCIED), it could be detonated on a timer, victim-operated (VOIED) or be operated by a suicide bomber (SVBIED). So, which one of these is it?[6]

Currently, organizations tend to use a reporting form with a list of boxes for each of these terms and ask reporting officers to select one. This fails the rule of lists, which requires a list to be both mutually exclusive and collectively exhaustive.[7] One-dimensional lists simply cannot consider something with two variable attributes without significantly more

letters. Yet an IED in a car initiated by a command wire could be reported by a peacekeeping contingent as a VBIED while another unit records an identical device as a CWIED. There are two implications. The security forces will be unable to correctly analyze the threat and design the appropriate response if the dataset is incomplete. Additionally, it will be harder to design appropriate risk education from the humanitarian perspective if both attributes are not clearly understood.

Risk is a precise mathematical term that considers both the probability of a particular incident occurring and the severity of its outcome. The containment of an IED and its size speaks directly to the severity of the potential outcome. A Unabomber-style letter bomb can potentially hurt one or two people: a van full of ammonium nitrate can bring down an entire federal building in Oklahoma, whereas the means of initiation speaks to the probability of the incidence.

Furthermore, good risk education processes discuss and suggest safe behavior. In order to do this, it is critical that the people designing the risk education programs have a good understanding of the typical means of initiation used in order to provide advice on indicators, safe behavior, and containment.[8]

As a result, a matrix is the suggested means of describing and recording IED incidents, rather than a simple list of terms (Figure 4, page 8).

Implications for Humanitarian Actors

There is clearly an overlap of IED, booby trap, and mine definitions. The terms are not interchangeable. The C-IED and HMA practitioners stand to benefit from recognizing this, as they set the basis for the rest of the taxonomy. Moreover, IEDs are only one part of a series of explosive and weapon-related hazards that might be faced in a particular country, including legacy ERW, attacks using factory-made weapons, and weapons used in other incidents of armed violence that are not terrorist or insurgency related. Classification of IED incidents, both in terms of containment and means of initiation, is important. By understanding the problem in terms of C-IED efforts, the community can appropriately target risk education messages with safe behavior.

As previously stated, while IEDs can consist of legacy weapons, they are unlike ERW (in the context of HMA) in that they are often active. While some countries may have fields of

Ser	Means of containment	Typical means of Initiation						Remarks
		Timer	Remote Controlled (RCIED)	Command Wire (CWIED)	Victim operated (VOIED)	Suicide	Other	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	Letter bomb				x			
2	Pipe bomb	x						
3	Person-born IED (PBIED)					x		Suicide vest
4	Mortar or rocket						x	May be an improvised weapon or factory-made weapon using improvised launcher
5	Buried bomb		x	x	x			Improvised mine when operated by victim
6	Box/briefcase/bag	x	x	x	x			Includes typical roadside bomb, such as palm oil container
7	Vehicle born IED (VBIED)	x	x	x	x	x		Could be divided into small, medium or large

Figure 4. DDG IED classification matrix.
Figure courtesy of the author.

legacy improvised mines such as Sri Lanka, these are still the exception rather than the rule. The entire HMA sector is based on the assumption that when a conflict is over, the population will be united in wanting ERW removed. In an active conflict, clearance of active IEDs by HMA actors may be seen as a hostile act. While it may be possible for commercial civilian operators to deal with this, it is difficult for NGO actors to take a similar position. NGO personnel must already deal with the dilemma that they cannot be truly impartial, and an NGO that clears active IEDs is effectively taking part in the wider counterinsurgency. The security implications for the staff of that NGO are significant. Yet, some donors are asking NGOs to undertake IED disposal (IEDD); thus a wider understanding and discussion of the issues are critical for everyone's clarity of purpose.

DDG has already looked at creating a more detailed risk analysis for organizations wishing to undertake IED risk education. Furthermore, DDG is working to understand the steps needed for a humanitarian organization considering whether or not to undertake IEDD as humanitarian action: both of which might merit further discussions in later papers. ©

See endnotes page 64

The original article first appeared in the Counter-IED Report, *autumn 2016 edition. It has been edited for* The Journal.

Dr. Robert Keeley
Chief Technical Advisor
Danish Demining Group

Dr. Robert Keeley is a former British Army bomb disposal officer who has worked in humanitarian mine action since 1991. His work has taken him to many countries including Afghanistan, Bosnia, Cambodia Croatia, Kuwait, Libya, Mali, Nigeria, Somalia, and Yemen. His work has encompassed a wide range of mine action and explosive ordnance disposal activities, including design and provision of mine risk education projects and victim assistance. Between 2002 and 2006, he researched and completed a Ph.D. in Applied Environmental Economics at Imperial College, London. His thesis was entitled "The Economics of Landmine Clearance." Since 2014 he has been the chief technical advisor for Danish Demining Group.

MAG: CLEARING IMPROVISED LANDMINES IN IRAQ

by Chris Loughran and Sean Sutton [MAG, Mines Advisory Group]

These women have just crossed the frontline in eastern Mosul, northern Iraq where hundreds of people are crossing every day. At the camps set up by MAG's humanitarian partners—often on land that was made safe from improvised landmines and unexploded ordnance by our teams—people who were displaced by the violence are provided with tented shelter and basic supplies. What they want most is to get home as soon as possible, once the violence has ceased. But people are losing lives, limbs, and livelihoods as they return to extensive contamination from landmines and booby traps in their homes, villages, and fields. We are in a race against time to get to these brutal, indiscriminate killers. In just three weeks in November 2016, in a single village east of Mosul, MAG cleared 250 improvised landmines. This could be 250 lives saved. Most of the improvised mines MAG found are powerful enough to rip apart a car but sensitive enough to be triggered by a child's footstep.
All photos courtesy of Sean Sutton/MAG.

MAG's recent experience in the Middle East has shown that clearing improvised landmines can be achieved even in the most complex humanitarian contexts. It is imperative that detail and specificity is given to discussions on improvised devices if we are to avoid negative repercussions for the safety of beneficiaries and humanitarian workers.

Munitions deployed on, under, or near the ground that are initiated by the presence, proximity, or contact of a person regardless of whether they are improvised or not are anti-personnel landmines, as defined by the *Anti-personnel Mine Ban Convention* (APMBC) and Amended Protocol II of the *Convention on Certain Conventional Weapons* (CCW).

One of the numerous landmines found close to houses marked off before it is defuzed and then destroyed. A destroyed Islamic State/Da'esh vehicle is in the background. Use of improvised or artisanal landmines is not a new phenomenon. MAG and other humanitarian NGOs have found improvised landmines in Afghanistan, Angola, Cambodia, and elsewhere for almost three decades.

Technical Field Manager Mohammad Salaam has worked with MAG for 24 years in countries all over the world. He has never seen a more heavily mined place than his home region in northern Iraq. "We find more every day" he said.
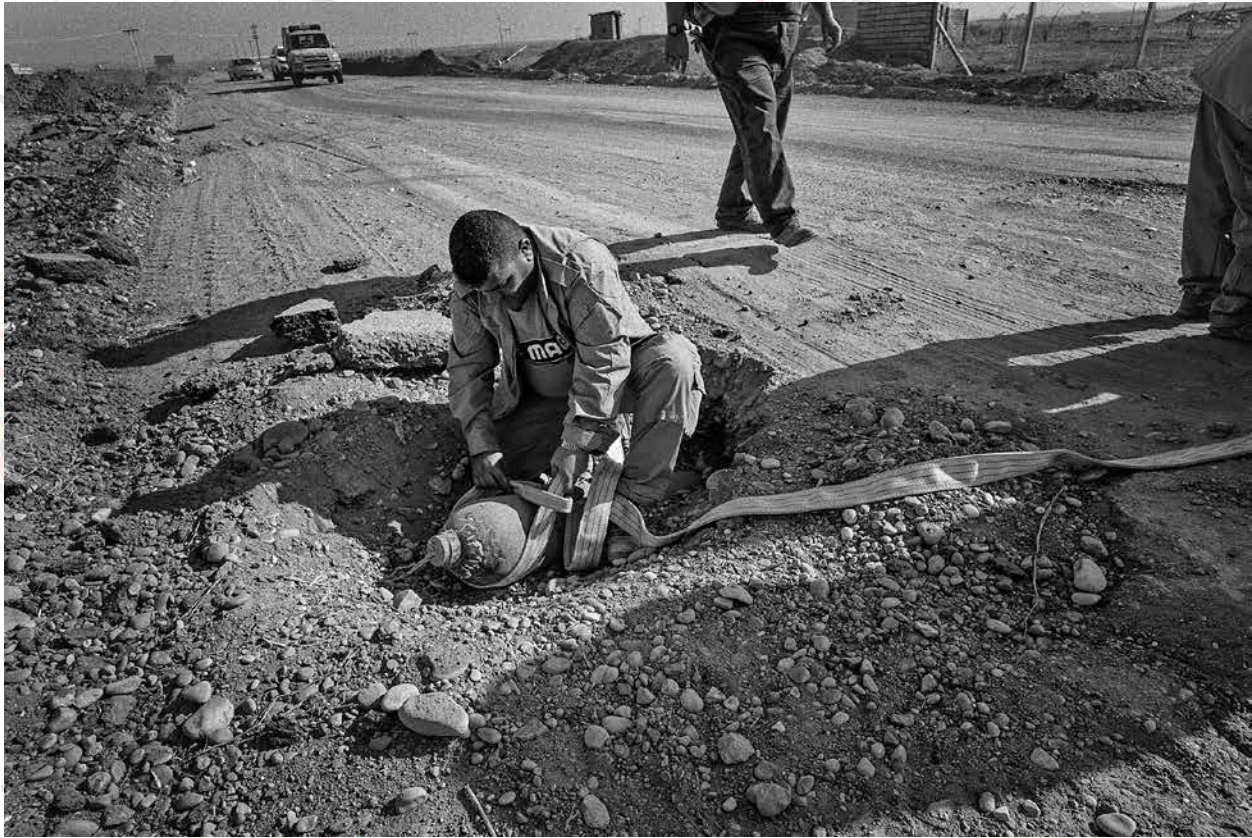
Deminers deal with explosive devices and landmines on the outskirts of Bashiqa, Iraq. Here the MAG team found six different items set up for command control and also pressure wires. Many vehicles passed over these explosives, very close to the pressure wires.

A week's haul of explosive items are taken for demolition near Bashiqa, Iraq.

It follows, therefore, that improvised landmines fall within the scope of the APMBC and states' commitment to uphold the highest standards of international humanitarian law.

When we call victim-activated improvised explosive devices (IED) what they are—landmines—it becomes clear that we can draw on the wealth of experience that exists within the mine action sector to tackle them in areas where the fighting has stopped. The humanitarian mine action community has addressed improvised landmines since the origins of the sector. Clearance of landmines—improvised or not—has been a part of MAGs' operational response from Angola to Afghanistan and Cambodia to Colombia.

This has given MAG the ability and tenacity to respond to new humanitarian emergencies, none more acute than the ongoing crisis in the Middle East. Since 2014, MAG has seen the systematic production and deployment of improvised landmines and booby traps by so-called Islamic State/Da'esh posing an immediate risk to civilians, especially returning personnel and displaced persons. The scale of contamination dictates that the humanitarian need and the need for additional mine action capacity will increase in the coming months, and urgent action is needed to prevent a large-scale landmine emergency.

MAG launched a major humanitarian operation in 2014 in response to evidence of improvised landmine use in areas of Iraq formerly occupied by Islamic State/Da'esh. From September 2015 to January 2017, MAG cleared more than 7,500 improvised landmines, booby traps, and other abandoned devices in Iraq and Syria alone. By the time this article goes to print, we expect the number to escalate. Improvised landmines account for over 99 percent of the

Rows of mines run through Tulluban village and other villages to the north, south, and east in Iraq.

After checking for booby traps in parts of the house still standing, a MAG technical field manager surveys the destruction caused when two villagers set off a booby trap when they opened a door. They were both killed.

improvised munitions cleared as part of MAG's humanitarian response in the Middle East.

MAG has updated standard operating procedures (SOP) and organizational policy to respond to this type of context and contamination, and we have recruited and trained additional staff. This includes additional capacity for when funding becomes available. Like any aspect of mine action, skills, training, equipment, and SOPs need to reflect the contamination profile. As always, there needs to be robust quality management systems in place. This is no different for contamination involving improvised landmines, booby traps, abandoned command operated IEDs, or explosive remnants of war (ERW) from improvised munitions.

The real areas of novelty arise from the nature and complexity of the conflicts in which we are seeking to meet humanitarian need. More than ever, conflicts span borders and some parties to conflict do not share the principles and value base that underpin humanitarian action. At the worst and unacceptable end of the spectrum, humanitarian workers are seen as legitimate targets. Inaction has consequences for people who are already enduring unimaginable suffering, so we must continue to develop policies and practices that further humanitarian efforts.

The nature of many current conflicts means that we cannot wait for the conflict to stop if we are to meet humanitarian need. Alongside our colleagues in the humanitarian sector, mine action NGOs undertaking emergency response programs must approach access in terms of areas where active hostilities have ceased. To achieve this requires robust risk and security management. Our continued access and the

Children discuss MAG risk education posters placed in the Khazir internally displaced person (IDP) camp near Mosul, Iraq.

safety and security of humanitarian workers and beneficiaries also depends on a clear and visible distinction between humanitarian and military or security action. This is why MAG and other NGOs continue to press for a clear distinction and vision of labor between humanitarian operations and counter-IED approaches.

The challenges are complex, but they are not insurmountable, and we are achieving results. We are enabling the safe delivery of shelter, food, and medical aid by our humanitarian colleagues, and we are saving lives. This is all part of the mine action sector's continued relevance, dynamism, and tireless work to prevent suffering, death, and injury. ©

Chris Loughran
Director of Policy
MAG (Mines Advisory Group)

Chris Loughran has more than 10 years experience working in the international nonprofit sector. Loughran joined MAG in 2006 and is currently director of policy for MAG, leading the organization's strategic influencing work on disarmament issues including landmines, illicit small arms and ammunition management. He holds a Bachelor of Arts from the University of Oxford (U.K.) and a master's degree in violence, conflict, and development studies from the School of Oriental and African Studies, University of London.

Sean Sutton
Communications Manager
MAG (Mines Advisory Group)

Sean Sutton is an award-winning photojournalist; his well-known pictures show the impact of landmines and explosive remnants of war on communities and have been published and exhibited all over the world. His book documenting how unexploded ordnance affect people in Laos was runner-up for the Leica European Publisher's Award. Sutton is MAG's international communications manager and has worked for the organization since 1997.

DO NO HARM: THE CHALLENGE OF PROTECTING CIVILIANS FROM THE IED THREAT IN SOUTH-CENTRAL SOMALIA

By Abigail Jones [Danish Refugee Council / Danish Demining Group]

In many countries, improvised explosive devices (IED), including improvised landmines, now constitute more of a threat to civilians than factory-manufactured landmines and other conventional weapons. The *Landmine and Cluster Munition Monitor* 2016 reported that the total number of casualties from victim-operated IEDs, which act in a similar manner to anti-personnel mines, increased from 1,075 in 2014 to 1,331 in 2015, the highest annual total of IED casualties recorded since 1999.[1] In response to this, humanitarian mine action organizations are expanding their scope of activities to include IED awareness for civilians either as a stand-alone activity or by integrating messages on IEDs into traditional mine risk education (MRE) sessions. This article explores the protection concerns related to the conduct of any educational activities on IEDs, with a particular focus on south-central Somalia. The article also discusses the challenges that exist for humanitarian organizations to successfully plan and implement IED awareness while upholding the principle of "do no harm." Furthermore, the article argues that there is a need to recognize that educational activities related to IEDs must be approached with methodologies, messages, and materials specific to these devices, as opposed to simply copying those that are considered to be effective for MRE.

Importance of Risk Assessments

As is the case with MRE, IED awareness should aim to reduce civilian casualties. However, a thorough risk assessment is the first step in identifying the realistic benefits of IED awareness and ensuring that they significantly outweigh the potential associated risks. This is due to the fact that IED awareness has the potential to create serious protection issues for the civilian population, many of which are outlined in the rest of the article. There is also a risk that organizations will be seen as taking sides in the conflict. Therefore, a thorough risk assessment is a key decision-making tool to help organizations understand the status of the device, the typical target,

the common scenarios of use, and the implications of implementing IED awareness for both the civilian population and the organization itself.[2] However, the risk assessment should also present concrete risk-mitigation strategies. Moreover, due to the complexities created by dynamic conflicts, risk assessments need to be made at regional or local levels in order to be relevant. The Danish Refugee Council/Danish Demining Group (DRC/DDG) has designed such a risk assessment process that is proposed as a framework for the drafting of a Technical Note on Mine Action in support of references to IEDs within International Mine Action Standards (IMAS).

Analysis of the Situation in South-Central Somalia

In south-central Somalia, IEDs are actively being deployed by armed opposition groups, such as Harakaat al-Shabaab al-Mujaahidiin, as well as by criminal gangs and during inter-\militant conflict.[3] These weapons bring the time, place, and method of attack fully under the operator's control, hence the high prevalence of use. There are very few cases of legacy devices because unused devices that did not detonate are typically retrieved and employed elsewhere.[4] Humanitarian organizations looking into the feasibility of conducting IED awareness in south-central Somalia should be cognizant of the fact that, in this context, IEDs are not the after-effects of conflict but a tool actively used by armed opposition groups to destabilize and attack the state.[5] Any organization getting involved in this issue, regardless of altruistic intentions, risks being perceived as siding with one party to the conflict over the other, and could therefore become a target for al-Shabaab or other IED users.

Data available from January to July 2016 demonstrates that 40 percent of IED attacks in south-central Somalia during this period involved command-detonated IEDs, four percent were victim-operated IEDs (VOIED), and 56 percent were unknown. The high percentage of devices listed as unknown is due to the challenges posed to carrying out post-blast forensic
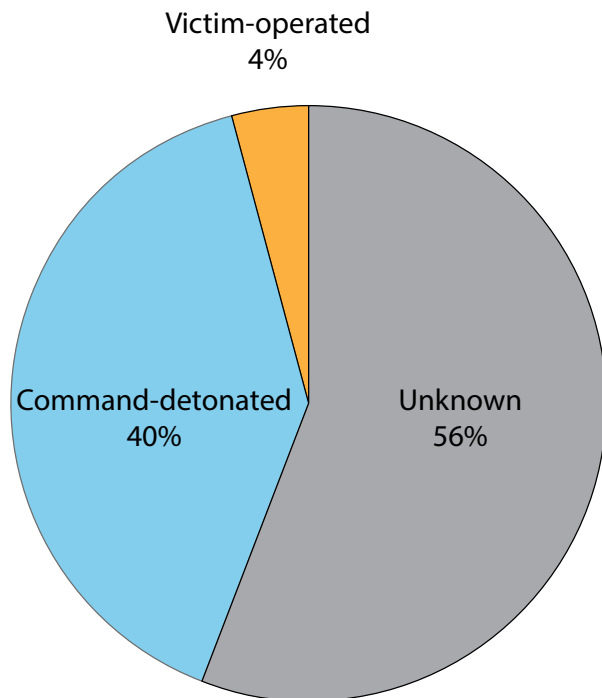
Figure 1. 2016 IED snapshot: South-central Somalia.
Figure courtesy of the author.

investigations at the explosion sites, and it also highlights the difficulty of compiling accurate data on types of IEDs used. It should be noted that Somalia is following the IEDs evolution trend, as was seen in Afghanistan and Iraq, with predictable increases in device complexity and explosive charge size.[6] However, Somalia is distinct from other countries due to the fact that a significant proportion of IEDs encountered in those countries are VOIEDs.

Overwhelmingly, IED attacks in south-central Somalia target government agencies and representatives such as security personnel or government officials. The majority of IED attacks target locations where government or security service personnel work, such as the July 2016 attack on the Criminal Investigation Department (CID) building in Mogadishu, and the two attacks on the SYL Hotel in Mogadishu where the government often hosts major conferences.[7] Incidents involving high-profile targets are typically complex attacks where vehicle-born IEDs (VBIED) or suicide VBIEDs (SVBIED) are used to initiate the attack, which is immediately followed by gunmen who wear suicide vests, also known as person-borne IEDs (PBIED). Complex attacks are also a tactic to intimidate the local population by showing that al-Shabaab can strike wherever and whenever they like, including in areas that are officially under the control of the Federal Government of Somalia. In addition, roadside IEDs are used to target military and police convoys, such as when a remote-controlled

IED (RCIED) exploded as a police vehicle passed it near the Black Sea neighborhood in Mogadishu on 11 November 2016.[8]

Armed opposition groups (AOG) commonly use IEDs to target representatives of the international community, particularly the African Union Mission in Somalia (AMISOM), the United Nations, and other representatives of the diplomatic community. In these cases, they are targeted because they are perceived as supporting the Federal Government of Somalia and therefore are not considered to have a neutral or impartial status, or—in the case of AMISOM—because they actively engaged in combat against al-Shabaab. A recent example is an attack that targeted AMISON troops in El-Ade in January 2016. The incident began with the detonation of a VBIED followed by al-Shabaab fighters storming the base.[9] Additionally, twin VBIED attacks were carried out near the airport in Mogadishu in July 2016 and reportedly killed ten people; the attack was claimed by the spokesperson of al-Shabaab to have targeted the headquarters of the African Union force.[10]

In 2015, there were 887 IED casualties in south-central Somalia, 454 (51 percent) of which were civilians.[11] Research indicates that in the majority of cases, civilian casualties are simply in the wrong place at the wrong time, caught in the

The Ambassador Hotel.
All photos courtesy of UNMAS Somalia.

initial blast or during the subsequent armed attack, such as when a roadside IED near Lafole town killed 18 civilians traveling in a mini-bus that was escorted by a vehicle carrying government troops.[12] In addition, there are increasing examples of deliberate attacks on public places that are considered too western and liberal, such as the three attacks on restaurants at Lido Beach in Mogadishu in 2016.

Gathering Information for IED Awareness

With civilians in south-central Somalia representing 51 percent of the casualties from IEDs in 2015, the protection implications of this are significant in Somalia. There is certainly a strong argument for further research into what could be done to provide civilians with the knowledge and skills to avoid being caught up in an IED attack. While many recognize that designing and implementing an effective educational program requires a thorough needs assessment to make informed programming decisions, this is problematic in the case of IED awareness.[13] There are many risks associated with data-gathering on an active IED threat that do not apply to factory-manufactured mines or explosive remnants of war (ERW). This raises important questions from a protection perspective.

In the context of south-central Somalia, information gathering on vulnerabilities at the community level to an active IED threat is extremely sensitive and likely to be perceived by the local population as intelligence gathering on behalf of government or security forces. The perception that humanitarian organizations are affiliated with the government would call into question the neutrality and impartiality of the humanitarian organization involved and could result in the organization and its staff being considered as legitimate targets for attack by AOGs. Humanitarian organizations should also be sensitive to the fact that, at this point, the IED threat in south-central Somalia is dealt with almost exclusively by state entities, which include the police, military, and intelligence services. Consequently, despite altruistic and protective intentions, efforts by international organizations to gather information on these issues are likely to be treated with suspicion and even hostility by state actors.[14] At the community level, anyone who is known or suspected to have provided information as part of such an assessment could be viewed as an informant. Considering that IED facilitators, as well as silent supporters of al-Shabaab live within the communities, there is a very real threat of retribution at the community level.[15]

This analysis raises questions on whether it is possible to carry out information gathering on IEDs in south-central Somalia while upholding the principle of "do no harm." In

The Nasa Hablood Hotel.

this context, DRC/DDG believes that employing participatory approaches to needs assessments—for example carrying out key informant interviews, focus group discussions, and individual interviews with members of affected communities—has the potential to do great harm not only to the humanitarian organization but also to the beneficiary community. Hence, developing new methodologies and tools for analyzing the vulnerabilities of the civilian population to IEDs is prudent, and mine action organizations should avoid relying on those that have been used for traditional MRE needs assessments.

Implementing the IED Risk Education Awareness Campaign

If moving forward with an IED awareness campaign, organizations would do well to approach south-central Somalia's situation with methodologies, messages, and materials that are specific to IEDs as opposed to those that are effective for traditional MRE.[16] First and foremost, pictures of IEDs serve little purpose due to the fact that the manner in which IEDs are deployed implies that they remain hidden or disguised. If information regarding the appearance of IEDs or the context

where they are placed is disseminated in communities, the groups that fabricate these weapons will potentially react by changing the devices' appearance, components, and locations. Another risk involved in using pictures of IEDs is that everything could potentially look like an IED. This would inevitably contribute to an unnecessary fear of everyday objects among the civilian population and intensify the psychological suffering already experienced by the Somali population.

Similarly, while significant work was done to develop IED awareness curricula for military personnel deployed in conflict-affected environments, this information may not be appropriate for civilian audiences. For military personnel, IED awareness may delve into detail of how an IED is constructed and deployed, which is intended to supplement what they know about tactics, techniques, and procedures. This is reminiscent of the early days of mine action, when beneficiaries were provided with irrelevant information, e.g., the name of the weapon, the amount of explosive inside, and the functioning principle by which the mine operated. In the case of landmines and ERW, these unnecessary details were eventually deemed inappropriate and discarded. However, at this stage, the humanitarian community presently runs the risk of repeating the same mistakes in addressing IED-related threats.

Humanitarian organizations who share this level of detail with civilian audiences in south-central Somalia may inadvertently encourage people to approach suspected IEDs or, worse still, try to move them to protect others.[17] Moreover, experience from counter-IED efforts illustrate that IED users regularly adapt their emplacement or targeting methods to thwart counter-IED measures. The implication of this for IED awareness is that materials and messages could quickly become irrelevant as the nature of IEDs evolve. Finally, if humanitarian organizations are seen disseminating information on how to make IEDs and how they work at the community-level, serious questions may be asked by the host government as to the purpose of educating people on this.

All educational activities on IEDs for civilians in south-central Somalia should therefore focus on what the civilian population needs to know, which is distinctly different from that of military personnel. IED awareness at the community-level must emphasize improving situational awareness and the ability to recognize the IED indicators as well as those of an imminent attack. Depending on the results of the risk assessment, sessions could elaborate on the typical scenarios in which civilians become casualties and on what to do if

civilians come across a suspected IED, are in the proximity of an explosion, or are caught in gunfire following an explosion. Asking the civilian population to "report" IEDs in a context like south-central Somalia is inappropriate.

Looking Toward the Future

This article (1) explores the concerns relating to any educational activities on IEDs for the civilian population, with a particular focus on south-central Somalia. This article also discusses (2) the challenges that exist for humanitarian organizations wishing to plan and implement IED awareness successfully whilst upholding the principle of "do no harm." Furthermore, the article argues that (3) there is a need to recognize that civilian-focused educational activities on IEDs must be approached with methodologies, materials, and messages specific to these devices.

The case of south-central Somalia is used to highlight the fact that despite the high number of civilian casualties and the altruistic intentions behind engaging in IED awareness, if appropriate risk-mitigation strategies are not in place, related activities have the potential to do real and long-lasting harm to organizations and beneficiaries. As a result, supplementing the necessary tools and best practices in dealing with IEDs is vital for the safety and effectiveness of mine action work in current conflict environments. A new Technical Note on Mine Action is a sound first step in this direction; however, to ensure that they "do no harm" the issue will require organizations to proceed with caution. ⓒ

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in the SPOTLIGHT

BOSNIA AND HERZEGOVINA

20 years later

The Early Years of Demining in Bosnia and Herzegovina: Transfer to National Ownership

by Ian Mansfield

Ian Mansfield stands in front of damaged apartments in Sarajevo. *Photo courtesy of the author.*

After the signing of the Dayton Peace Accords on 14 December 1995, the newly formed Government of the Federation of Bosnia and Herzegovina requested that the United Nations set up and manage a mine clearance program. However, it soon became clear that the government should take responsibility and ownership of the program.

The war in Bosnia and Herzegovina took place between April 1992 and October 1995. While the causes of the war and what happened are extremely complicated, Bosnian Serbs encircled Sarajevo and imposed a blockade, while 'ethnic cleansing' operations were undertaken by all sides in towns and villages throughout the country.

As a result of the Dayton Peace Accords, the fighting stopped, and Bosnia and Herzegovina was to remain one country; however, it was divided into two entities: the Republika Srpska and the Muslim-Croat Federation. The country was to be governed by the Council of Ministers, consisting of one representative each from the Bosnian Croats, Bosnian Serbs, and Bosniaks (Bosnian Muslims). These representatives would

share the presidency on a rotating basis, and elections were to be held to elect a parliament. Each entity was allowed to keep its own army, but a large, international military force called the Stabilization Force (SFOR) was deployed throughout the country to enforce the peace.

The Landmine Problem

As the fighting was intended to drive people out of their homes, landmines were used extensively throughout the conflict to keep people away from villages. Large, front-line areas developed along the boundaries between different ethnic groups, and mines were also laid in vast numbers to protect these areas.

The majority of the known minefields in Bosnia and Herzegovina were located along the 1,000 km (621 mi) long Inter-Entity Boundary Line, which divided Republika Srpska. The Muslim Croat Federation Records of over 18,000 minefields were available but toward the end of the war, many mines were laid without being recorded, and it was estimated that these maps represented only 50 to 60 percent of the minefields in the country. At the time when the Dayton Peace Accords came into effect, many believed that there could be up to one million landmines laid in Bosnia and Herzegovina, along with an unknown number of unexploded ordnance (UXO) waiting to be cleared. Accurate casualty figures were difficult to obtain, but there seemed to be general agreement that about 50 civilians were killed or injured by landmines or UXO every month since the end of the war in 1995.[1]

Initial Response

In January 1996, the fledgling Bosnian government requested United Nations' assistance with setting up a mine action program. The responsibility fell to the United Nations Mission in Bosnia Herzegovina (UNMIBH), which established the

United Nations Mine Action Centre (UNMAC) in June 1996. As part of the transition of the mine action program to national ownership, a rather complex set of organizational changes were agreed upon by the Council of Ministers and the United Nations in October 1997. Responsibility for the mine action program was planned to transfer from UNMIBH to the government on 1 January 1998. However, the government was not ready, and the United Nations Development Programme (UNDP) took over the interim responsibility. The government set up the Commission for Demining, the role of which was to keep the Council of Ministers informed on the progress of demining in the country, to approve national mine action plans and standards, and to oversee the work of UNMAC. The Commission for Demining consisted of three members: a Bosnian Serb, a Bosnian Croat, and a Bosniak; and they effectively performed the role of the national mine action authority.

UNMAC would transition to become the Bosnia Herzegovina Mine Action Centre (BHMAC) and it would be responsible for managing all central database records, setting priorities and issuing task orders, overseeing quality management or standards of work being done, and raising funds. The Republika Srpska and the Muslim-Croat Federation would set up their own offices to supervise and undertake mine clearance.

Mine Clearance Actors in Bosnia and Herzegovina

However, UNMAC was not the only program in the country. Beginning in 1996, foreign governments began bilateral support for demining in Bosnia, with Norway funding Norwegian People's Aid (NPA). As the first civilian organization to work in Bosnia, NPA focused on clearing important infrastructure projects, cultural heritage monuments, and damaged houses and apartments in support of refugee settlement programs in Sarajevo. The German government funded the trial of two demining machines, and a German bomb disposal school trained Bosnian refugees in Germany. The Belgium government funded two technical advisers to the Demining Commission.

In 1997, via the entity governments, the World Bank financed mine clearance operations by international commercial companies, all of whom had established subcontracts or joint venture arrangements with local commercial mine clearance companies. This was the first time the World Bank had funded mine clearance work, and it was not without its difficulties. Over US$10 million was made available to commercial companies, leading to the sudden formation of 40 local companies.

Norwegian People's Aid deminer in Bosnia and Herzegovina.
Photo courtesy of the author.

Fourteen contracts were awarded, but the majority of the money went through two international companies: MineTech and RONCO. Both were reputable companies and had established partnerships with some Bosnian companies, one for each of the three ethnic groups. However, in early 1998, MineTech pulled out of Bosnia, and—due to a disagreement with the World Bank—the United States withdrew its funds from the World Bank and gave the money directly to RONCO.

A debate occurred regarding the merits of using commercial companies for mine clearance as opposed to nonprofit organizations, like nongovernmental organizations (NGO) or government agencies. The pro-commercial argument was that commercial companies were more efficient because they were in a competitive environment. The counter-argument was that commercial companies only assumed easy tasks, and it was alleged that the local Bosnian companies cut corners and compromised on safety to keep their costs down. On the other hand, the NGOs said that they focused on house clearance, which was slow but necessary in Bosnia, as refugees needed to be able to return home. The various commercial companies and NGOs endeavored to produce figures to estimate their clearance costs per square meter. However, it is the author's opinion that the figures were neither accurate nor convincing.

In the former Yugoslavia, a government body called the Civil Protection Organization (CPO) dealt with natural disasters like fires and floods, and was also responsible for civilian bomb disposal. In Bosnia, the CPO still existed albeit in a much weakened state. It fell under the purview of the Ministry of Defence, which made it difficult for the United Nations and World Bank to engage with the organization. In 1997, the European Union decided to support the CPO, funding training and providing equipment and vehicles for 12 mine clearance teams and nine bomb disposal teams. In the urgency to get things moving in Bosnia, little thought went into project

Diana, Princess of Wales, at the Bosnian Mine Action Centre.
Photo courtesy of J.J. Van der Merwe.

sustainability. In early 1998, the CPO could not afford to take on the teams who were trained. As a result, hundreds of deminers were laid off, and equipment sat idle while waiting for more funds from the European Union.

Frustrated at the slow pace of house clearance in Bosnia, the United Nations Refugee Agency (UNHCR) decided to fund its own clearance teams. In 1997, UNHCR trained and equipped a total of 240 deminers. These teams worked on house and apartment clearance in the two entities, but it was agreed that the project would come under the overall umbrella of the national program.

Finally, under the Dayton Peace Accords, the respective armies of the two entities were required to undertake mine clearance work. Under the supervision of the international military contingents from SFOR, if the entity armies undertook certain tasks like mine clearance, they earned credits, which allowed them access to funding, new weapons, or certain training opportunities. The entity armies had previously undertaken what they called "mine lifting" tasks, which involved using a minefield map to remove only the mines that were marked on the map. Sadly, as the work was undertaken by recently conscripted troops who did not check for any additional mines outside the mine lanes that may have been laid subsequently, there were a high number of injuries and deaths. No central records were kept of this work, and no one was confident that the areas involved were completely cleared. While the entity armies certainly had the potential to speed up the national mine clearance effort, this seemed to be a wasted endeavor.

Transition Process

Although the Commission for Demining was notionally the government authority in charge of all mine action, it only had varying influence over the seven different groups or projects outlined. In Bosnia and Herzegovina, the government was weak, and a range of significant mine clearance activities were already underway without any coherent national plan in place. At the coordination level, there were only a few Bosnians in the BHMAC who had been identified as suitable to take over management roles.

The demining commissioners said they did not think that the government could meet the 1 July 1998 deadline for the transition of the mine action program from United Nations to government control. In many ways, the government was not ready; however, it had to be done. At the next Commission for Demining meeting in May 1998, UNDP announced that the handover would take place as planned on 1 July 1998, without the possibility for an extension.

To assist with the handover, the 'Bosnia and Herzegovina – National Mine Action Plan – 1998' was developed with the cooperation of the World Bank and European Union. The program aimed to reduce the number of civilian landmine and UXO casualties, clear houses for returning refugees and internally displaced persons, and make land safe for agriculture, reconstruction, and development activities. The key elements of the plan detailed the transition to government control and outlined what the U.N. components would do. The amount of confirmed or pledged funding came to US\$18 million total for 1998. With another \$22 million requested, this total amounted to US\$40 million for the year. Deminers' salary costs were one of the main reasons for the large figures. In Afghanistan and Laos, deminers were paid US\$100 per month. In Bosnia and Herzegovina, because of the European cost of living, the rate was around US\$800 per month.

As the Dayton Peace Accords attracted significant international attention, many high-level visitors came to see the mine clearance work in Bosnia and Herzegovina. The most famous visitor was Diana, Princess of Wales, who visited the U.N. Mine Action Centre in Sarajevo in early August 1997, just weeks before her death. Other notable visitors at the time included Canadian Foreign Minister Lloyd Axworthy, Japanese Foreign Minister Keizo Obuchi, and the head of UNHCR, Mrs. Sadako Ogata.

Preparing for the Handover

In preparation for the handover of responsibility, a two-day workshop was arranged at the Marshall Tito Barracks from 11 to 12 June 1998. Over 100 demining supervisors from a variety of organizations from the two entities attended. Getting people into Sarajevo from all over the country involved detailed logistical planning, and U.N. vehicles were dispatched to ensure safe passage for many attendees.

The meeting went extremely well. The participants, many of whom were former combatants who had probably fought against each other, discussed technical issues cordially. Despite political tension amongst participants, the meeting was a success overall and helped clarify the national program's way forward. Because of its technical nature and obvious benefits to

communities, the mine action sector showed that it could be part of the peace-building efforts in Bosnia and Herzegovina.

The use of the Bosnian entity armies in mine clearance was another issue that needed to be addressed. These armies were a huge, under-utilized resource with the capacity to provide future clearance. The military had previously resisted taking tasking orders from a civilian body or having their work inspected by civilians. As the team leaders' meeting involved some personnel from the entity armies, they left with a better understanding of the national program. Following subsequent meetings with entity armies, SFOR representatives, and donors, significant agreements were reached.

The international military contingents from SFOR agreed to train and equip the entity army deminers according to the new international standards, and the United States announced that they would set up three training centers. The entity armies agreed to accept clearance tasks from BHMAC and to allow civilian inspectors to accredit army units and check their work. Due to civilian sensitivities remaining from the militaries' actions during the war, the military would focus on clearing areas around military bases, airfields, and industrial sites, as opposed to clearing houses. The one sticking point was extra insurance to cover the army deminers, but Canada and Norway agreed to provide funds to cover these costs.

Local candidates were identified to head the new BHMAC, entity centers, and other key posts within the offices. However, quite a few positions would still have to be filled by U.N. staff, and there would be a reliance on donor funding for many years to come.

Transition Ceremony

On 1 July 1998, a day of ceremonies marked the handover, as the United Nations transitioned ownership of the BHMAC to the government, and the new Bosnian managers were sworn in. The entity armies were to sign agreements that fell under the umbrella of the national program, but at the last minute, some alleged inequality was raised that halted proceedings. The signature of these agreements eventually took place on 6 July 1998. The transition to national ownership of the mine action program was complete—at the political level at least.

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Ian Mansfield AM CSC
Mine Action Consultant

Ian Mansfield has worked in mine action for the past 25 years. Between 1991 and 1998 he was the United Nations program manager in Afghanistan, Bosnia, and Laos. Mansfield then worked as the UNDP mine action team leader in New York for four years, followed by nine years as the Deputy Director of the Geneva International Centre for Humanitarian Demining (GICHD). He now works as a consultant based from his home in Australia and recently published *Stepping into a Minefield* about his experiences in the early days of mine action.

Bosnia and Herzegovina:
ITF Enhancing Human Security Perspective 20 Years After the Conflict

by Gregor Sančanin [ITF Enhancing Human Security]

A deminer and mine detection dog enter a minefield above the town of Konjic.
All photos courtesy of ITF Enhancing Human Security.

ITF Enhancing Human Security has worked in Southeast Europe's post-conflict countries since 1998. In states affected by the break-up of Yugoslavia such as Bosnia and Herzegovina, ITF works to support the country's fulfillment of the *Anti-Personnel Mine Ban Convention* (APMBC).[1]

With a history of nationalistic antagonisms, a series of armed conflicts, secessions, and major political and state structural reforms stemming back to the turn of the 20th century, the history of the former Socialist Federal Republic of Yugoslavia (SFRY) is intertwined with the history of religious and ethnic groups in that area.

By the early 1990s, rising ethnic tensions led to an outbreak of armed clashes as the Yugoslav republics of Bosnia and Herzegovina, Croatia, Macedonia, and Slovenia seceded from the SFRY. Today, some of the former SFRY republics are still contaminated with high concentrations of landmines and unexploded ordnance (UXO), Bosnia and Herzegovina being the most heavily affected in the region.[2]

Historical Context

Bosnia and Herzegovina's declaration of sovereignty in October 1991 was followed by a referendum for independence

A deminer checks the soil for a potential mine in the ground in Konjic municipality.

from the former SFRY in February 1992.[3] Three and a half years after the ethnic- and religious-based armed conflicts in Bosnia and Herzegovina began in April 1992, a peace agreement was reached on 21 November 1995 in Dayton, Ohio, and officially signed in Paris, France, on 15 December 1995, bringing years of interethnic civil strife to an end.[4] The Dayton Peace Accords retained Bosnia and Herzegovina's international boundaries and created a joint, multi-ethnic and democratic government, the state itself being composed of two largely autonomous constitutional and legal entities.[5,6]

Mine action in Bosnia and Herzegovina began in 1996, with the establishment of the United Nations Mine Action Centre (UNMAC), created for the purpose of building a local management structure and operational mine action capacity. All available minefield records were gathered through SFOR, and a central minefield database was established as a basic tool for further planning.[7] During the initial years, demining operational activities were conducted mainly through U.N. and World Bank programs, with the engagement of a variety of international commercial and nongovernment organizations (NGO).

Bosnia and Herzegovina signed the APMBC on 3 December 1997 and ratified it on 8 September 1998. In July 1998, national structures took over more responsibility for demining activities, but still with continued financial, expertise, and technical assistance from the international community.

At the time two mine action entities were established, namely the Republic of Srpska Mine Action Centre (RSMAC) and the Federation Mine Action Centre (FMAC), as well as the joint coordination center: Bosnia and Herzegovina Mine Action Center (BHMAC). The APMBC came into force on 1 March 1999 with obligations on Bosnia and Herzegovina to clear all known mined areas by March 2009.

In 2002, the central structure was established at the state level, and the BHMAC—until then only a coordination body—was authorized by the Ministry of Civil Affairs. Foreign agencies initially implemented humanitarian demining activities, but the process of building local capacities was underway. At that time, the main responsibility and authority was that of the Council of Ministers and both entity governments, which ensured coordination, improvement, planning, and recording of mine action programs.

The Demining Commission and Ministry of Civil Affairs prepared the first demining law in Bosnia and Herzegovina, which was adopted by parliament in February 2002.[8] The adoption of the law helped to make demining a priority in the country.[9] In the same year, the first Mine Action Strategy was made for the period of 2002 to 2009, significantly improving the functionality of the structure, quality assurance, and the effectiveness of the overall process. At the end of 2004, an evaluation of the program concluded that the vision of the first strategy was too optimistic and the size and complexity of the

The view over a minefield during a presentation in Konjic.

problem greatly exceeded available funding, technology, and general support to implement the program. The adoption of a revised Mine Action Strategy for the period of 2005 to 2009 introduced a more realistic approach. At the same time, the Council of Ministers made a decision to start the preparation of a new strategic document for the period of 2009 to 2019, which would provide the basis for an extension of Bosnia and Herzegovina's APMBC clearance deadline.

Previous experience indicates a significant discrepancy between needs for mine action in Bosnia and Herzegovina and realistic funding and technical possibilities. The Bosnia and Herzegovina Mine Action Strategy 2009–2019 was adopted by the State Ministry Council on 24 April 2008.[10] Nevertheless,

A deminer digs the soil in search of mines amidst the steep forest area in Doboj municipality.

considering the extent of the mine and UXO contamination, the available funding for its resolution, and the slow pace of clearance activities, it is clear that a new amended demining strategy with a new deadline beyond 2019 will need to be adopted in the near future.

Contamination

The presence of mines and UXO in Bosnia and Herzegovina will continue to be a priority for years to come. Threatening the physical safety of its residents, this contamination is an obstacle for country reconstruction, economic development, social society building, and the overall human security environment. Demining is an initial precondition for reconstruction and development projects, their successful implementation, and for the safe return of refugees and displaced persons.

Commercial companies, NGOs, the Bosnia and Herzegovina Armed Forces demining battalion, and entities' Civil Protection demining teams are the four officially recognized categories of operators directly involved in the mine clearance process in Bosnia and Herzegovina. The Demining Commission requires that all demining agents be accredited by BHMAC prior to receiving approval to work in the country. In 2016, BHMAC accredited 27 operators to conduct humanitarian demining operations and monitoring in Bosnia and Herzegovina, the majority of which are national and locally-based organizations.[11]

The initial estimation after the survey executed in 1996 indicated the mine and UXO suspected land-surface area was around 4,200 sq km (1,622 sq mi), presumably containing

up to approximately 1 million mines and UXO.[12] Currently, there is 1,118 sq km (442 sq mi) of suspected hazardous areas, which accounts for 2.2 percent of Bosnia and Herzegovina's total land area.[13] Based on BHMAC systematic survey operations, it is estimated that 81,000 mines and explosive remnants of war (ERW) are spread throughout 9,018 locations in Bosnia and Herzegovina. Of the suspected hazardous areas, 7.3 sq km (2.8 sq mi) spread over approximately 200 locations is believed to contain approximately 2,000 cluster submunitions.[14] Lives and livelihoods of an estimated 545,600 local residents are still directly affected by mines, UXO, and cluster munitions, while 1,398 communities in 129 towns and municipalities are identified and defined as impacted.[15,16] Since 1996, there have been 1,742 mine/UXO victims, including 608 fatalities.[17] Thus far, approximately 61,440 anti-personnel mines, 8,380 anti-tank mines, and 54,930 UXO were found and removed in Bosnia and Herzegovina.[18]

Based on assessment of the residual mine problem, the general impact of landmines has been significantly reduced, and as much as realistically possible, in accordance with strategic goals, financial, operational, and resource planning. However, the May 2014 floods caused additional setbacks, complicating implementation plans for 2014 and halting prospective strategy planning for the future.

Floods of 2014

The May 2014 floods were the worst in the last 120 years, causing massive damage in the northern, eastern, and central parts of the country that border Croatia and Serbia. Meanwhile, Bosnia and Herzegovina was still recovering

from consequences of the 1992–1995 armed clashes, where much of the population continued to suffer from poverty and unemployment. The natural disaster affected 25-to-33 percent of the state territory and approximately one million people, with severe damage to urban, industrial, and rural areas. Electricity and clean water were unavailable for days and, in some cases, weeks. Many houses, infrastructure, schools, hospitals, private facilities, and farms were completely destroyed. This caused a deterioration of public services, local economies, and agriculture activities.[19,20]

Initial concerns were raised about massive mine displacement as an estimated 70 percent of the flooded area was in or around mine contaminated areas.[21,22] Fortunately, the

A mine detection dog team operates in steep forest terrain in Doboj municipality.

A mine detection dog works in a forest situated in minefields in Šamac municipality.

final recovery needs assessment concluded that the original mine migration was relatively small compared to initial estimates. Unfortunately, the fencing and warning signs around many minefields were destroyed and urgently needed to be replaced to avoid additional casualties. Landslides caused further mine migration within suspected hazardous areas as well, which meant that mines and UXO in some cases became more deeply buried in the soil. For this reason, areas needed to be resurveyed, re-marked, remapped, and in some cases even re-cleared.[23] Local populations in the flooded areas needed to be constantly informed of the additional mine/UXO risk.

The initial estimation of the floods' affected area consisted of approximately 920 sq km (355.2 sq mi), which included more than 3,000 landslide locations, prompting a landmine awareness campaign to make the local population and relief workers aware of the dangers from mines and UXO that may have been unearthed or repositioned by water erosion and landslide subsidence. From the initial 920 sq km (355.2 sq mi) of flooded areas, approximately 300 sq km (115.8 sq mi) was further assessed to be potentially in mine affected areas.[24] BHMAC also identified that approximately 105 sq km (40.5 sq mi) of the flooded area could potentially contain mines and UXO that migrated from the suspected hazardous areas. Within that 105 sq km (40.5 sq mi), a total of 40 sq km (15 sq mi) was finally designated suspected hazardous areas.[25] The 2014 floods therefore additionally burdened and delayed the demining process in Bosnia and Herzegovina.

ITF Support in Bosnia and Herzegovina

Established by the Government of the Republic of Slovenia in March 1998, the initial purpose of ITF was to assist Bosnia and Herzegovina in the implementation of the Dayton Peace Accords by providing assistance and support for post-conflict rehabilitation.[26, 27]

By the end of 2016, more than 77 sq km (47 sq mi) of land in Bosnia and Herzegovina was demined through more than 2,444 ITF projects, removing over 20,830 mines and almost 18,000 items of UXO.[28,29,30] ITF has also provided rehabilitation to 829 mine accident survivors, provided mine risk education (MRE) to over 180,000 children and adults, and secured socioeconomic support projects for over 5,000 mine accident survivors in Bosnia and Herzegovina.

Future Challenges

Bosnia and Herzegovina undergoes a steady, albeit slow demining progress. One must understand that Bosnia and Herzegovina has highly complex political and decision-making systems. Demining is of crucial importance for all spheres of daily life as well as the national development strategy. Hence, the realpolitik should unanimously define national needs, ensuring a better future for coming generations. 🌐

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ITF Enhacing Human Security

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Field Notes

Public, Private, and Civil Sector Partnerships Bolster Humanitarian Demining Efforts

by Bob Ebberson and Wendy Hart [Schonstedt Instrument Company]

UNMAS assesses explosive threats at a future MINUSMA campsite in Gao, Mali, February 2014.
Photo courtesy of UNMAS.

Schonstedt Instrument Company is a small manufacturing company located in the eastern panhandle of West Virginia, about 70 miles (112 km) from Washington, D.C. Schonstedt makes instruments that locate underground objects. These include pipe, cable, and magnetic locators that find and trace underground utilities and ferrous metals such as boundary markers used by surveyors. Magnetic locators have proven to be successful in locating unexploded ordnance (UXO) and other explosive remnants of war (ERW). In looking for ways to grow this market,

Schonstedt recognized an opportunity to support humanitarian demining throughout the world. Determining that the sale of a pipe and cable locator would financially support the donation of a magnetic locator, Schonstedt implemented a program in 2007 that would be sustainable over time and created the Schonstedt Humanitarian Demining Initiative.

Needing partners who could identify and prioritize populations for which clearance would otherwise be impossible without a donation, Schonstedt partnered with the United Nations Mine Action Service (UNMAS). To date, UNMAS

UNMAS assesses explosive threats at a Malian army camp in Timbukktu, December 2013.
Photo courtesy of UNMAS.

An operator with The Development Initiative uses a magnetic locator to conduct battle area clearance activity at the Malian army camp in Timbukktu, December 2013.
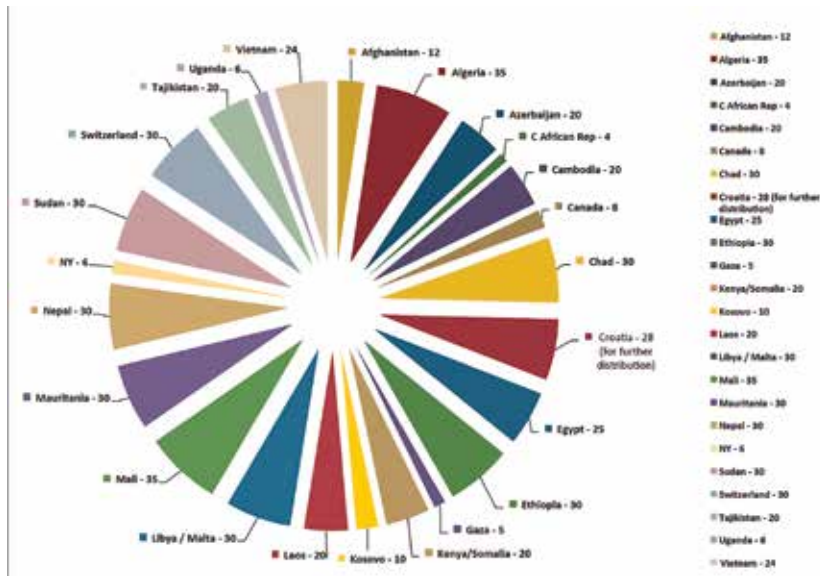*Photo courtesy of UNMAS.*

Figure 1. Between 2007 and 2016, the Schonstedt Humanitarian Demining Initiative deployed more than 500 donated locators to more than 20 countries in need.
Figure courtesy of Schonstedt Instrument Company.

in a one-to-one match by Schonstedt, thereby allowing two locators to be donated in that person's name. The donor base has grown to include associations, businesses, church groups, service clubs, and individuals, all of whom appreciate the fact that 100 percent of their contributions go to shipping equipment directly to trained humanitarian deminers in the field, with Schonstedt absorbing all administrative costs. Individual donors from the Religious Society of Friends donated three of the 10 units sent to Tajikistan and provided funding for 24 units to Vietnam. Donors are recognized with letters of appreciation from Schonstedt, UNMAS, PM/WRA, and the in-country recipient of the equipment whenever possible, e.g., the Croatian Mine Action Centre or the International Mine Action Training Centre in Nairobi, Kenya.

Schonstedt locators have contributed to clearance operations in numerous countries. For instance, the Tajikistan Mine Action Centre reported finding complete cluster bombs, each containing hundreds of submunitions. Most were broken open and their contents relocated down the mountain. In one gulley, ten submunitions were found by eye, while another seventeen were found using the donated detectors. And as reported by the Mine Action Programme for Afghanistan (MAPA) and The HALO Trust, over 80 tons of ammunition

has facilitated the donation of 508 tools (priced at US$1,041 each) to U.N.-supported deminers in 26 countries, including but not limited to Algeria, Azerbaijan, Cambodia, Chad, Croatia, Egypt, Ethiopia, Gaza, Kenya, Laos, Lebanon, Libya, Mauritania, Nepal, Somalia, Tajikistan, Vietnam, and the Darfur region of Sudan. The Office of Weapons Removal and Abatement in the U.S. Department of State's Bureau of Political-Military Affairs (PM/WRA) has also assisted in identifying areas most in need of support. Together with UNMAS in New York, Schonstedt Instrument Company equipped U.N.-supported humanitarian demining teams in locations that would not otherwise have benefited from mine clearance. This expanded capacity meant fewer losses of lives and limbs, and contributed to the vision of a mine-free world.

The Mechanics

The program evolved over time. Initially, one magnetic locator was set aside for every sale of a pipe and cable locator. A Schonstedt partner might put in a request for 20 units to be sent to Cambodia and provide a point of contact there. To evidence a true need and encourage a shared stake in the process, Schonstedt required that recipients bear the cost of shipping. On receipt of those funds, the donated equipment would ship.

As the program became more prominent, individuals began approaching Schonstedt, wishing to contribute to the effort. They asked if they could buy a magnetic locator and donate it. In response, Schonstedt modified the program so that whenever someone donated a magnetic locator, it would result

The Croatian Mine Action Center (CROMAC) employed the Schonstedt GA-72Cd locators on clearance projects along the power line in eastern Croatia near the Osijek city in very difficult terrain.
Photo courtesy of CROMAC.

Daniel Craig, U.N. Global Advocate for the Elimination of Mines and Explosive Hazards, demonstrates the use of the Schonstedt magnetic locator.
Photo courtesy of the U.N Photo/Manuel Elias.

are destroyed in Afghanistan each month. Schonstedt locators play a part in the location and destruction of these explosive items.

Many of those who donate to Schonstedt are reoccurring donors and welcome the opportunity to make a difference in the lives of people they will never meet. In addition, employees of Schonstedt have the satisfaction of knowing that what they do on a daily basis has a far reaching effect and contributes to the well-being of others in some of the world's most mine-contaminated countries. ⬤

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Field Notes

World War II Coastal Minefields in the United Kingdom

by Roly Evans [Geneva International Centre for Humanitarian Demining]

While not widely appreciated today, there were once 1,997 minefields in the United Kingdom containing between 338,500–350,000 landmines.[1] If you were to walk today on a beach suitable for amphibious landing on either the south or east coasts of the United Kingdom, chances are that you would be walking on a former 1940s minefield. This article briefly explores the story of the United Kingdom's coastal minefields, from their hasty installation through their costly clearance. Many of the lessons from this period remain relevant today, as countries seek to apply land release principles to reduce the risk of explosive contamination to tolerable levels.

In June 1940, the U.K. government believed it faced the imminent threat of invasion. The authorities immediately began fortifying the ports and potential landing beaches alongside inland defensible features. The British Army had lost equipment during the Battle of France and would have possibly struggled to defend a long and exposed coastline had Operation Sealion, the German invasion plan, been launched.[2] Fortifications and obstacles were seen as a means of evening the balance against what was feared would be an irresistible *blitzkrieg* invasion force. In such circumstances, many minefields were laid in great haste. The *Corps of Royal Engineers Journal* states that "the laying of minefields was the first large scale practical experience the British Army had had in this branch of warfare. Lack of experience, and hurried operation, led to many mistakes being made which were to cause much trouble to units and members of the Corps later."[3]

Minefields were typically combined with other obstacles such as wire entanglements, scaffolding, dragon's teeth to destroy landing craft, anti-tank ditches, and anti-tank blocks. Some—but by no means all—minefields were to be covered by machine gun fire, usually from a protected pillbox or a trench system. Around 28,000 pillboxes were built in Britain in 1940 alone.[4]

Figure 1. B Type C mine.
Photo courtesy of Imperial War Museum.

A number of different mines were used in 1940. These included the B Type C from Royal Navy stores that contained 11.4 kg (25.1 lbs) of explosive, usually Amatol. The B stood for **beach mine**, although the mines were sometimes colloquially referred to as **mushroom mines**. While the mine had enough explosive to destroy a tank or a vehicle, it could also be initiated by a person. This mine required as little as 22.7 kg (50 lbs) of weight to initiate the fuze, which consisted of a striker separated from a cartridge primer by a simple bow-shaped spring. The bow spring was prone to becoming weaker as the mine corroded, often making the mine more sensitive to pressure. The device effectively functioned as both an anti-personnel and anti-tank mine. The B Type C mine would become infamous during the subsequent clearance efforts.

A soldier based in Suffolk in August 1942 remembers "I was attached to the Essex Regiment. We were involved in laying mines from the Minsmere Sluice to where the power station is now. We would dig a round hole and put in it a sort of
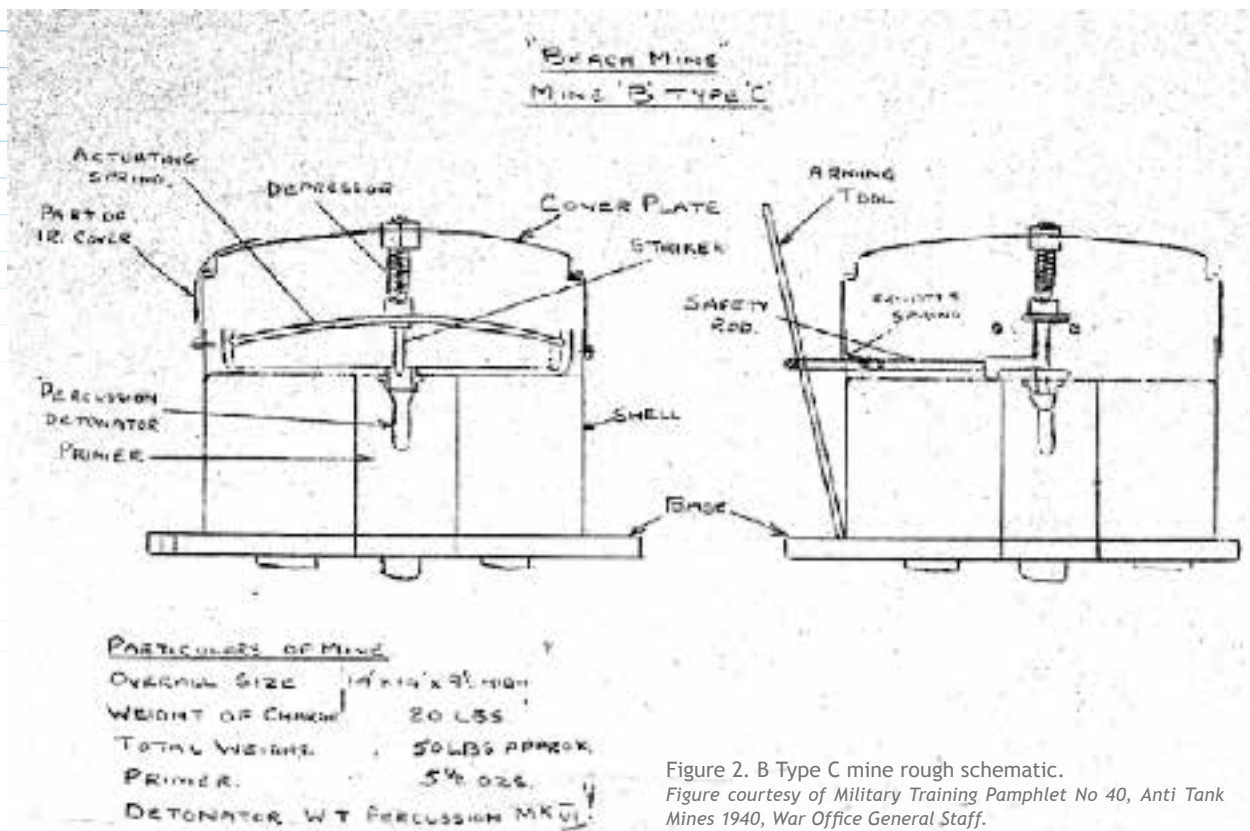
Figure 2. B Type C mine rough schematic.
Figure courtesy of Military Training Pamphlet No 40, Anti Tank Mines 1940, War Office General Staff.

biscuit tin with a hole in it. Into that you would put the detonator, then gently replace the lid, and very gently cover the mine with sand. We meticulously marked every spot we put a mine on a map, so that they could be lifted later. Both sides of the belt of mines were protected by wire to prevent people straying into the area accidentally. Sometimes a sheep would get through the wire and would be blown up."[5]

Generally the Royal Engineers were tasked with laying, cordoning, and recording minefields. For example, the War Diary for 558 Field Company, Royal Engineers for November 1940 records that "nearly 2700 A/T Mines MK1V were laid, armed, and mapped, protected, and carefully recorded." The same phrase is used for 4,500 mushrooms (B Type C mines) and 30 RE No.1 Mines.[6] While effort was taken to fence off minefields and record mine locations accurately, anecdotal evidence suggests that this practice was not as universal as desired. Inaccuracies in record keeping, combined with changes caused by the tides, inhibited some of the later clearance efforts.

Some of the minefields in which this Essex Regiment soldier worked are visible in Figure 3, page 35. Figures 4, 5, and 6 (pages 35 and 36) show where the minefield from Figure 2 would have been in 1945 prior to removal and what is there today: the largest nuclear power station in the United Kingdom.

Some efforts were made to improve on the hasty minefield laying as early as late 1940. When properly planned and executed, beach minefields would be laid above the high water mark, and mines would be secured in place by recovery wires. Recovery wires linked mines and held them in place, assisting later clearance efforts greatly. Clearance of minefields without recovery wires would often prove problematic, since mines would be more prone to migration.

In the autumn of 1940, the 125th Infantry Brigade took over a stretch of Suffolk's coastal defense. They noted that "mines have also been placed on the beaches, but the sea sucks them out to sea up to 50 yards out from the mine fields as marked on the maps. Anywhere near the sea side of the mine fields is dangerous. The mine fields are very well marked on the maps, but of course they are moved by the action of the sea."[9]

Sergeant Fred Hinton of the Royal Engineers remembers "just after Christmas (1940) we moved to Deal in Kent and billeted in empty boarding houses. My job, with a section of men, was to take up 2 rows of beach mines that had been laid in the shingle beach between Deal and Sandwich and replace them with 4 rows wired together and mapped. The 2 rows we picked up had been laid 7 paces apart one row staggered behind the other. The land was sand dunes with sand leading
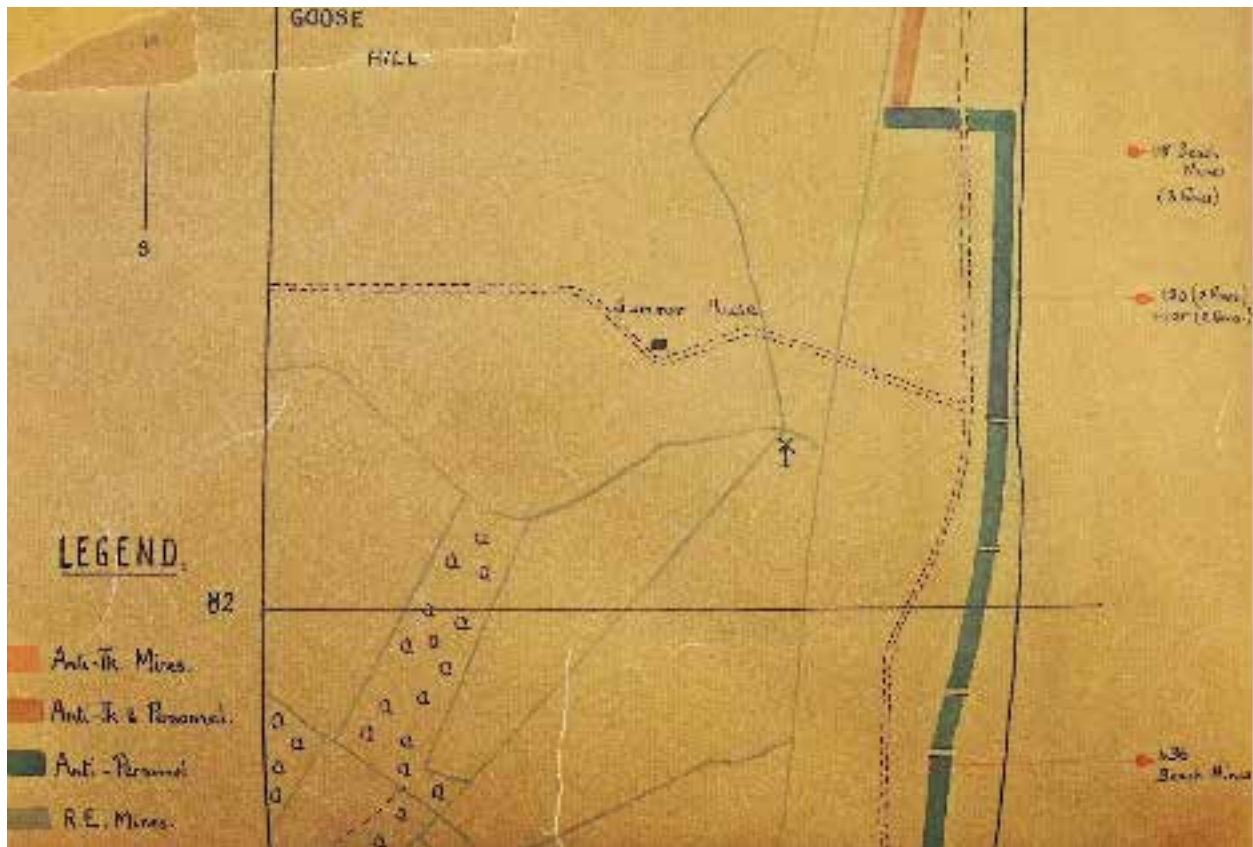
Figure 3. A 1942 image of the minefields north of Sizewell on the Suffolk Coast, United Kingdom.
Figure courtesy of The National Archives.

Figure 4 (left). A 1945 aerial view of Sizewell Nuclear Power Complex. Figure 5 (right). A 2014 aerial view of Sizewell Nuclear Power Complex. Both figures show the immediate coast to the north indicating the minefield from the 1942 diagram shown in Figure 3 and believed location of the minefield continuing to the south.[7]
Figures courtesy of Google Earth.

Figure 6. Instructions for laying beach mines, diagram 2. Method of connecting to recovery wires.
Figure courtesy Chief Royal Engineer, 44th Division.[8]

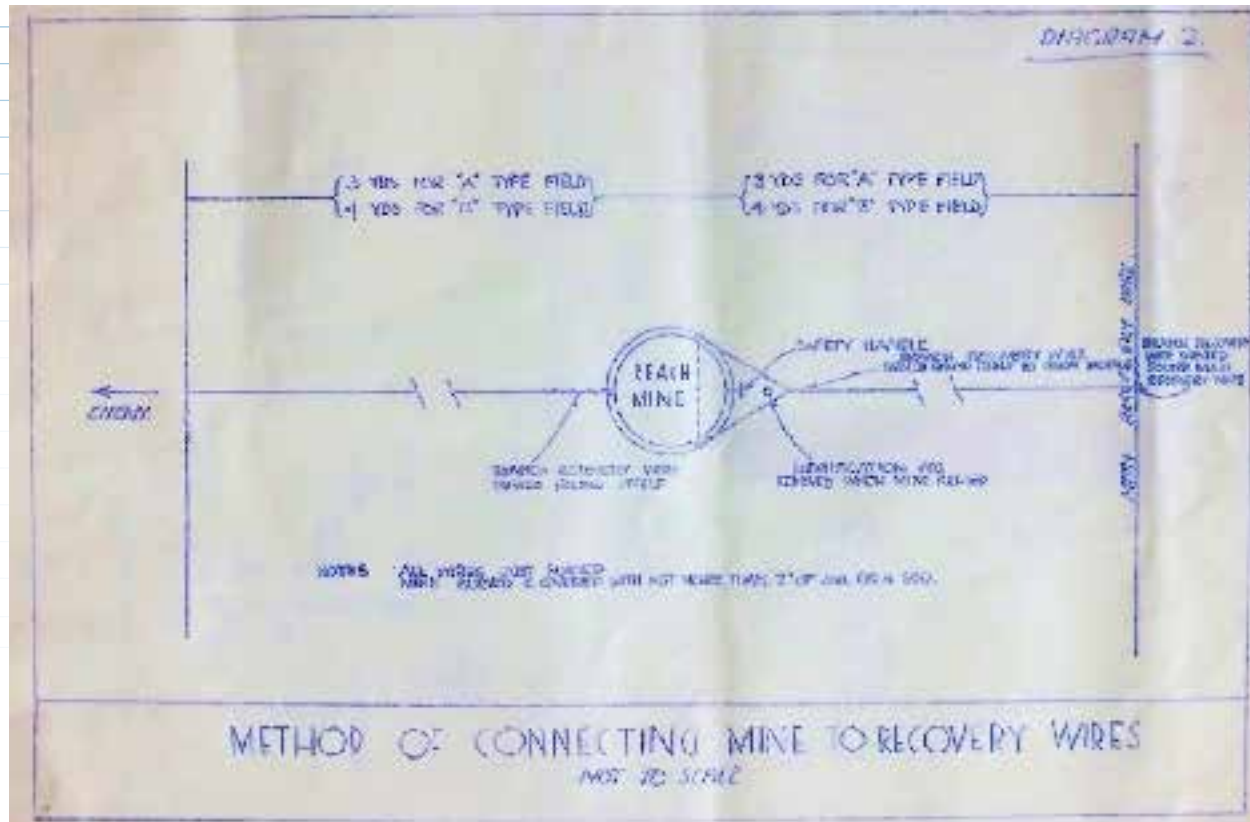down to a shingle beach… We lost 2 men early on before adopting a 3 mine distance rule. After that, we had a minimum of men on the beach and those carrying the mines from the beach keeping well clear of the 2 finders. Each day a stretch of beach would be cleared and wired off, 4 rows dug and new mines laid, wired together and mapped. I was on the job for about 11 months. We took 3500 mines up and re-laid 7000. This was mainly on the beach of the Sandwich Golf Course."[10] The Royal St. George's Golf Club is now one of the courses used to host the Open Golf Championship.

Some of today's major tourist attractions, even quintessential images of England, were mined. Cuckmere Haven on the Sussex coast is one such example. This beach has since been used in a number of Hollywood films. In 1940, an extensive system of pillboxes and anti-tank defenses overlooked six minefields containing 1,532 landmines (556 B Type C mines and 976 General Service anti-tank mines).[11] The Cuckmere minefields claimed lives during the war. In September 1940, three Royal Engineers were killed by a B Type C at Cuckmere.[12] There were more casualties in 1942.[13]

Clearance of the U.K.'s minefields commenced in earnest in late 1943, once it seemed certain that the threat of a German invasion had receded. Clearance certificates were carefully worded and plainly stated that mines were only removed from specified areas. Often certificates would end with a subheading titled "Opinion as to safety." It is noteworthy that many certificates in the archive include the phrase "no guarantee can be given that the area may be considered safe." Sometimes the "Opinion as to safety" noted that "the area may be considered safe except for the possibility of mines being washed up on to the beach from other minefields."[14]

While few realize that Britain once had extensive minefields, fewer know that significant casualties were sustained during the clearance efforts. The Corps of Royal Engineers History puts total casualties for all Bomb Disposal duties (including mine clearance) in the United Kingdom during World War II at 55 officers and 339 other ranks killed, and 37 officers and 172 other ranks wounded.[15] During the immediate post-war years, a further 151 Royal Engineers died clearing Britain's beaches.[16] To put that figure into context, the United Kingdom lost a total of 1,078 during the Korean War, and 255 were killed in the Falklands War. Some estimates place the total number of fatalities that occurred on Britain's beach minefields at approximately 500 civilians and military personnel.[17]

Figure 7. Cuckmere Haven from the west.
Photo courtesy of the author.

Causalities continued into the 1950s. One notable incident occurred in May 1955 in the town of Swanage in Dorset; five boys were killed after tampering with a mine that the coroner later stated likely washed up on shore.

The minefield at Swanage was laid in 1940. A clearance operation of the relevant section was undertaken in 1945. It was repeated in 1947 and again in 1949. Eventually, a clearance certificate was issued on 17 February 1950. The original minefield record and the subsequent clearance records show that 117 mines were originally laid, of which only five were lifted in clearance. There was some evidence of small craters where 54 other mines had been. Minefields consisting of B Type C mines were known to be prone to significant sympathetic detonations; an animal initiating one mine could set off many more. The remaining 58 mines were unaccounted for. It is possible some of these mines were laid without recovery wires and may have washed away during the course of the war. One of the men who survived the incident, Robert Key, later became a Member of Parliament. During the debate on ratifying the *Convention on Cluster Munitions* in March 2010, he called for parts of the Dorset coast to be re-cleared. He noted that the officer in charge of the clearance task in 1950 had

refused to issue a certificate of clearance but had been overruled.[18] Issues of liability and the difficult decisions involving risk assessment of challenging clearance sites are nothing new to mine action.

The rush to defend Britain's coast in 1940 resulted in difficulties in clearance from 1943 onwards. Even in 1940, Eastern Command reminded corps staff that "unless accurate records are kept of locations it will be impossible to recover mines on termination of hostilities, and many casualties during recovery will result."[19] Not only were accurate records required, but so too was the stringent use of recovery wires to prevent mines from moving. In 1945, the MP for Evesham was well aware of the problem and urged Prime Minister Atlee that "in various parts of the country some land mines have been overlooked, will he instruct the Service Departments to issue a questionnaire to serving and non-serving personnel asking them to notify any special knowledge they may have regarding the location of these undetected mines, in view of the danger to children and the general public?" It appears an evidence based approach to survey of minefields is nothing new. The Prime Minister rejected the appeal and asked "whether [the] questionnaire suggested would provide any useful
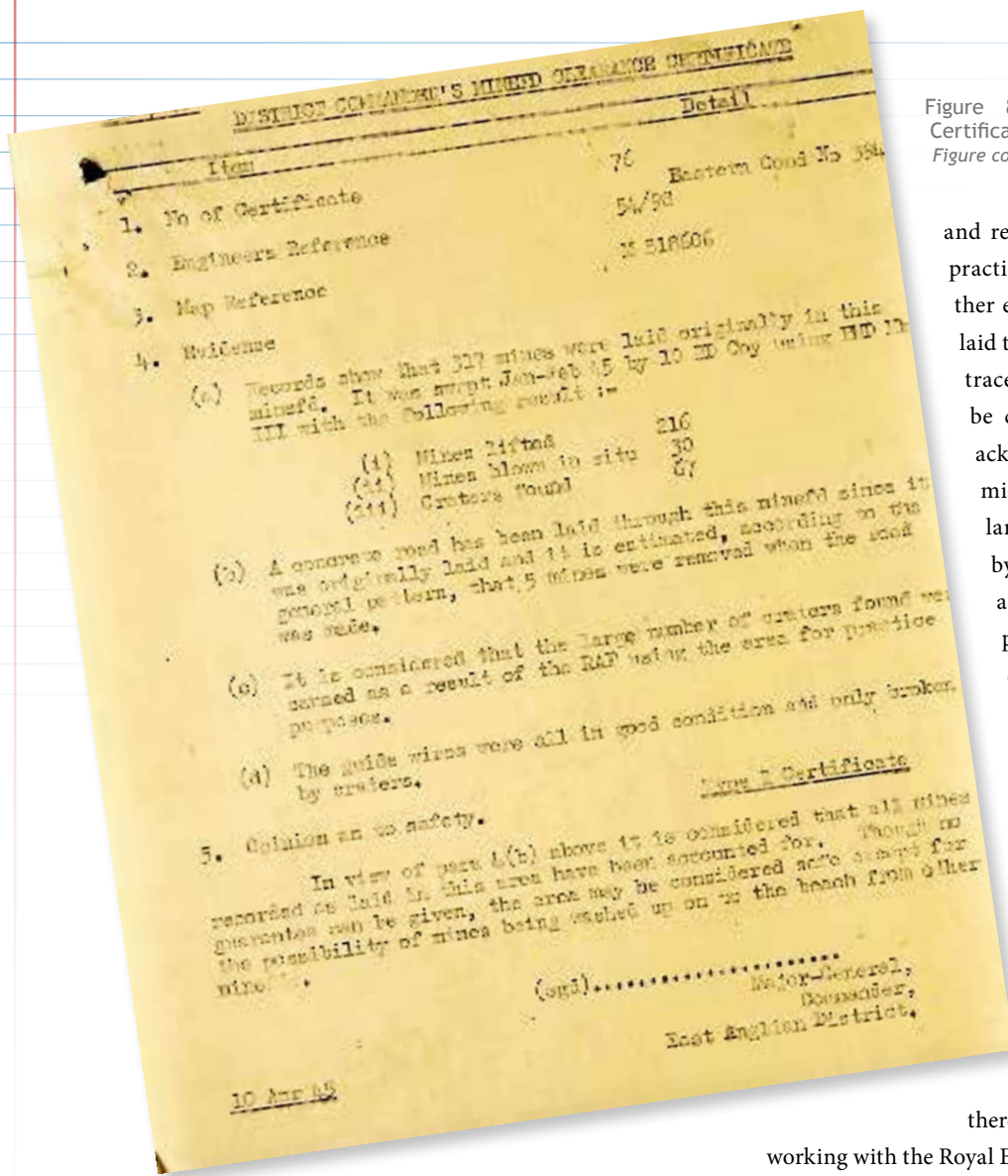
Figure 8. Eastern Command Clearance Certificate No.76, April 1945. WO 199/98.
Figure courtesy of The National Archives.

and reliable assistance. It is already the practice, where necessary, to seek further evidence direct from the men who laid the mines. Such men can readily be traced through record offices and can be cross-examined on the spot." He acknowledged that, "the location of mines is a difficult problem, particularly as many may have been shifted by tides and soil movements, and, although the work is being actively pursued, I am afraid that complete clearance may take a long time."[20]

As in other European countries, many prisoners of war (POW) were co-opted into the dangerous clearance efforts. In 1946, around 1,200 Ukrainian POWs were employed as deminers in the United Kingdom. Although all were eligible for repatriation by 1948, some chose to stay as civilian employees of the Royal Engineers. By 1962, there were still 113 Ukrainian civilians working with the Royal Engineers in a unit called the Mixed Service Organisation. Some would remain working with the Royal Engineers into the 1980s. Innovative clearance methods were developed that included the use of bulldozers and water jets to move sand and even shingle. The water jets would expose mines and often detonate them. Ultimately, areas swept by this process would be subsequently searched by electronic detector.

All mines used on Britain's shores had a high metal content and were relatively easy to find if they were within the confines of the minefield perimeters. From late 1943 until late 1948, a total of 1,986 minefields consisting of 338,500 mines were cleared, mostly by the Royal Engineers.[22]

Eleven other more complex and difficult minefields were cleared by 1972.[23] The last mined beach at Trimmingham in Norfolk was finally released to the public in 1972. In 2004, a memorial was unveiled nearby at Mundesley to commemorate the 26 Royal Engineers killed while clearing the beaches in this area alone.

Figure 9. Royal Engineers make use of water jets while clearing Saunton Sands in Devon, 1947.[21]
Figure courtesy of British Pathe.

Figure 10. Beach defenses near Aldeburgh in Suffolk, United Kingdom, photographed by the RAF on 17 December 1941 where B Type C mines are believed to have exploded.
Figure courtesy of Historic England RAF Photography.

Cleared minefields did not just return beaches to public use. By the 1960s, certain sites became nuclear power stations. Figures 12 and 13 (pages 40 and 41) show the minefields protecting Dungeness in December 1941. Part of that minefield ran straight through the current super structure of a nuclear power station.

While many efforts were made to clear minefields, the residual risk remained. In 1961, for example, a Royal Engineers Bomb Disposal Team was tasked to re-clear the beach at Sandgate near Folkestone, because the local council wished to replace the beach groynes (ocean shore barriers designed to limit the movement of sediment). A remaining B Type C mine was found. Such instances were relatively common. In June 1967, the Royal Navy had to re-clear an area of Slapton Sands in Devon of 32 anti-tank mines. The beach was originally cleared in 1948.[25] The last recorded, deliberate clearance of B Type C mines was in Whitsand Bay in Cornwall in 1998. As late as December 2011, a beachcomber group on the beach

Figure 11. The memorial to the Royal Engineers who died clearing minefields near Mundesley, Norfolk, United Kingdom.
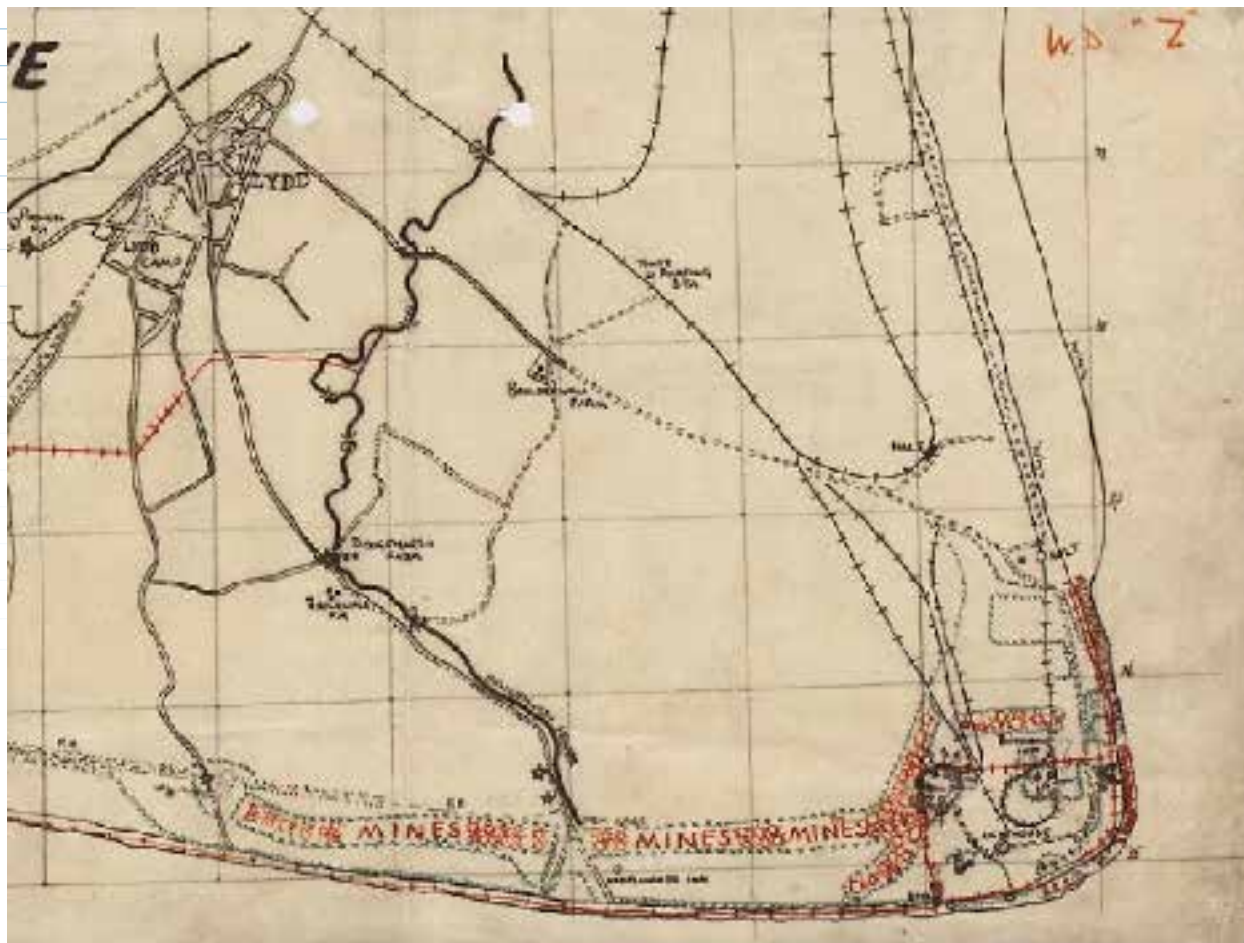*Figure courtesy of Tour Norfolk.*

Figure 12. A 1941 image representing defenses at Dungeness, Kent, from the War Diary 8th Royal Fusiliers.[24]
Figure courtesy of The National Archives.

at Seaford just west of Cuckmere Haven called the police having found a very weathered B Type C mine.[26] Other instances are relatively frequent.[27] For instance, landmines have been found in fishermen's nets.[28]

In February 2014, the U.K. Ministry of Defence replied to a Freedom of Information (FOI) request that asked for "details of WW2 beach minefields for North East Scotland, either maps or clearance certificates from post war demining." The Army Secretariat rejected the FOI on the basis that certain individuals might attempt "to locate and unearth these munitions, potentially leading to serious harm to themselves and others in the vicinity." Interestingly, the secretariat added that "another consideration is that the accuracy of this information is not guaranteed, nor is it considered comprehensive."[29] It would appear that the implications of the hasty installment of minefields on the U.K. coastline remain with us and are relevant today. In October 2015, a suspected landmine washed ashore in

Aberdeen and was subsequently destroyed.[30] It will likely not be the last to be found on U.K. shores.

The United Kingdom's experience with clearing minefields is still applicable to current ongoing efforts to clear minefields and battlefields. Firstly, it is noteworthy that the United Kingdom quickly accepted that clearance resources were insufficient to guarantee zero risk from explosive hazards. An all reasonable effort approach to target resources effectively was adopted. Those who have promoted land release since 2005 would recognize this approach. The most difficult minefields were left to the end and cleared over a prolonged period, allowing quicker clearance of more straightforward areas. In general, it appears that prioritization of clearance was appropriate and successful. The United Kingdom also led the development of mine clearance technology, including 4A mine detectors, Electrical Research Locators, and techniques such as the use of water jets. Moreover, along with many other countries in Europe, the United Kingdom developed realistic

Figure 13. Aerial image of Dungeness, Kent, as it appears today.
Photo courtesy of Google Earth.

capabilities to deal with the inevitable residual contamination. It is not known whether any national clearance program has managed to clear all contamination. Residual contamination can typically be minimized but not eliminated completely. The solution is to develop reasonable risk management and legal frameworks backed by a sustainable professional clearance capacity. This model is seen in a number of countries including many in Europe as well as Japan. The challenge for countries with more recent contamination is to develop a suitable and viable national capacity that can effectively manage the ongoing risks of residual explosive hazards.

See endnotes page 65

The author would like to thank Wendi Pedersen for helping to prepare figures 5 and 6 of this article.

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Roly Evans is an advisor in land release and operational efficiency in the risk management division at the GICHD. He also covers conventional explosive ordnance disposal (EOD) and training issues. He has worked in the fields of mine action, EOD, and physical security and stockpile management in Africa, Europe, the Middle East, South Asia, and Southeast Asia.

R&D

Research and Development

EFFECTS OF WEATHER ON DETECTION OF LANDMINES BY GIANT AFRICAN POUCHED RATS

by Ian G. McLean, Ph.D. and Rebecca J. Sargisson, Ph.D.

Although APOPO has trained mine detection rats for many years, no published data exist on how weather parameters relate to detection accuracy. Using data taken during routine training, we show that there was little relationship between the detection success of rats and rainfall but find that rates decreased, on average, with increasing temperatures and increased with higher humidities. Individual rats vary in terms of sensitivity to temperature in that

1. a small number of rats appear to work better at higher temperatures, and
2. most rats showed relatively low sensitivity to temperature at normal training temperatures. However,
3. there was a proportion of rats for which temperature sensitivity may be affecting detection reliability, and identifying these rats relatively early in training should aid decision making about operational deployment.

Dogs and other animals function as odor-detection tools for an increasing array of detection applications outside the laboratory. Examples include the scat of endangered species, humans in collapsed buildings, cadavers, accelerants at fire scenes, contaminated land, weeds, landmines, and there are many more.[1–8] It is broadly assumed that biological odor detectors working outdoors will be affected by environmental variables such as temperature, humidity, and wind.[7–10] However, as also noted by Reed et al., we found surprisingly little empirical exploration of odor-detection success for animal detectors in relation to varying environmental conditions.[11]

Little or no effect of local weather conditions was found for dogs locating scats of mustelids or bears in a temperate forest environment in the Eastern United States.[12] However, detection success improved with increasing number of days since precipitation, and increasing relative humidity for dogs searching for carnivore scat.[11] For dogs searching for tortoises in a desert environment, significant effects on detection success were found for temperature (higher temperatures = better success), humidity (lower relative humidity = better success), and wind speed (increasing wind speed = better success).[13] In a study in a cool temperate forest environment, detection success improved with increasing temperatures, but humidity had no effect.[14] The temperature and humidity

ranges experienced in these last two studies were quite different, being relatively hot and dry in Long et al. study, while relatively cool and moist in Sargisson et al's study, possibly explaining some of the differences.[13,14]

Limited research is available regarding the effect of weather variables on the success of landmine- or explosives-detection dogs, who typically work outdoors and often under extreme environmental conditions. Sargisson et al. explored the effect of temperature, humidity, and rainfall on landmine detection by dogs in Afghanistan during trials spanning a full operational season for the dogs.[8] All data were gathered during normal operational conditions. No effect was found for temperature on detection success (i.e., hit rate), and some evidence was found for a negative relationship between humidity and hit rate. As humidity declined under the dry conditions experienced in Afghanistan, hit rates increased, and a strong effect was found for rainfall. Afghanistan had experienced four years of drought prior to the study, and most of the dogs were not likely to have experienced rain or have ever worked over moist ground. Significant rain fell early in the study, hampering detection success by increasing the number of false alarms and reducing the hit rate due to runoff spreading mine odor across the minefield.

The scant research on how weather parameters impact the odor-detection success of dogs shows mixed results, possibly because success is linked to normal operational and training experiences. If the weather moves outside those parameters as it did during the Afghanistan study, the dogs may struggle.[8] For rats, we have found no published research investigating the effects of weather variables on odor-detection, probably because most work with rats is undertaken in laboratory conditions. We know of only one program in which rats serve as field-based odor-detectors: the use of giant African pouched rats (Cricetomys gambianus) by *Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling* (APOPO).[15] These rats are trained for landmine detection in Morogoro, Tanzania, which lies at 6 degrees 49 min south latitude and 37 degrees 40 min east longitude, and is situated at elevation 504 m above sea level. They are currently working operationally on the Mozambique-Zimbabwe border, and in Angola and Cambodia, all areas with warm, temperate to tropical climates.[16,17] Thus, the

Figure 1. Rats undergoing training in the APOPO landmine-training field in Morogoro, Tanzania. The handlers (in blue) have a line attached to one leg, spanning the width of the box. The rat is wearing a harness that is attached to the line, allowing it to move back and forth along the line. The supervisor is in white.
Photo courtesy of APOPO.

rats are operational in weather conditions that are similar to, but somewhat more variable than, the conditions under which they were trained.

In this study, we undertook a retrospective analysis of data collected by APOPO in its training minefields to explore the effects of temperature, humidity, and rainfall on detection success of giant African pouched rats searching for landmines in Morogoro, Tanzania.

METHODS

APOPO supplied a file of information on the performance of rats during training and testing up until August 2016 in a minefield containing about 800 boxes. A box is a marked area of land between 60 and 400 sq m, contains zero to seven buried mines, and is surrounded by safe lanes. The search of one box represents one row of data. The file contained the details of each box: date, search time, rat identification, number of mines present (0–7), number of mines found, number of false alarms, and various administrative details. We calculated the proportion of mines found (p = number mines found / number present, range 0–1), average search time of the box (time of start and end were both listed), and logit p as per Equation 1.

Eq.1 $$\text{Logit } p = \log_{10}\left(\frac{p + 0.01}{(1-p) + 0.01}\right)$$

No weather variables were recorded by APOPO, and we obtained these separately as described below.

We rejected boxes for which there were obvious data-entry errors (such as time inconsistencies, missing data, or where $p > 1$), all boxes searched outside the standard training period of 06:30 to 09:30, very short or very long searches (< 10 min, > 45 min), and all searches where boxes contained no mines. The edited data

set consisted of 6,798 boxes for 217 rats and was further reduced to 4,723 boxes after rejection of any box described as a blind test (there were relatively few of these per rat), any rat that searched fewer than 10 boxes all together, and all data before 2015. Larger sample sizes per rat were available in 2015 and 2016 than were available for earlier years. For a small number of boxes, some data were removed as there were a few days for which we could not obtain reliable weather data.

The final data set contained information on searches of more than 10 boxes during training for each of the 86 different rats for the period 5 January 2015 to 10 August 2016; the average number of boxes per rat was 35.6, with a 95% confidence interval (CI) [30.82, 40.38]. Some rats were still in training, while others had completed training and were either deployed operationally or otherwise lost from the program. Following the criteria above, we included all rats for which data were available; we did not reject rats that died or failed accreditation.

TRAINING PROGRAM

When searching at the outdoor training field, a rat works on a line between two handlers who operate a running lead to keep the rat moving in the correct direction (Figure 1). The average time for a rat to complete a standard 100 sq m box is 19 min, 44 sec (n = 4,779) for training. If a supervisor is present, he or she will record indications as reported by the handlers. If no supervisor is present, no data are recorded. The availability of a supervisor to record data appeared to be entirely independent of the factors we were studying, and we do not regard the missing data as relevant to this study.

Rats receive initial training at the APOPO laboratory. Once they are deployed to the field, they go through three training stages:

1. **3 m boxes** are 60 sq m, contain a high density of mines (4–7), and have a 3 m axis on one side;
2. **5 m boxes** are of varying sizes up to 100 sq m, contain a medium density of mines (3–7), and have a 5 m axis on one side; and
3. **advanced boxes** are also of various sizes with dimensions up to 400 sq m, these contain a low density of mines (1–4).

Boxes containing no mines can be used at any stage of training. The number of boxes searched at each stage of training in the final data set was quite variable across rats, often including no boxes for one stage, and we ignored stage of training in this analysis. Searches involving boxes with zero mines were rejected, because we were analyzing for the effects of weather variables on proportion of mines found.

In training, handlers know where all mines are in the box and reward most correct indications (i.e., found mines) by the rats. As
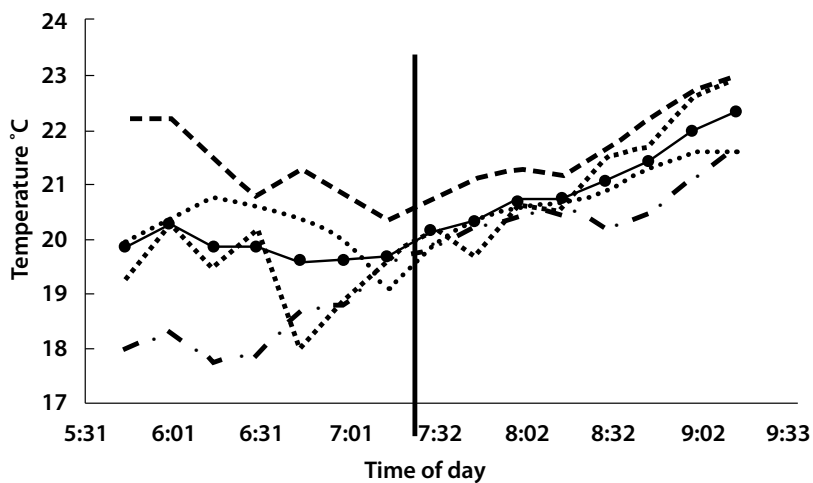
Figure 2. Temperature change through the morning from 05:45 to 09:15 on four days in the third week of August, 2016. The average values used in modelling are shown as a solid line. The vertical line is the time when the sun hits the ground.
All figures courtesy of the authors.

handlers are not blind to the location of the mines, they can aid the rat in finding a mine by adjusting the criteria to accept a hit, or by gently manipulating the running line. However, there were still a large number of missed mines in the data set, and we hypothesized that a proportion of those misses were linked to variation in weather variables.

WEATHER DATA

Obtained from a government-run weather station 1 km from the training site, weather data were available for every day in the 2015–2016 period; however, the reported details were inconsistent. Temperature and relative humidity were usually reported at 06:00 and 09:00, and sometimes also reported for 07:00, 08:00, and 10:00. Rainfall was reliably reported as a total for the whole day, but information on specific times of rainfall was rarely reported. Wind speed and direction were rarely reported and were ignored. Rats work close to the ground and were not worked in windy weather, thus they are unlikely to be affected by wind. Nor were they worked if the grass was wet or the ground boggy due to their tendency to stop constantly to groom.

Needing more precise weather information than was available from the station, we built models using the available data in order to predict temperature and humidity at the precise times that rats searched the boxes. For rainfall, we estimated rain (in mm) in the 24 hrs before each training day using Equation 2.

Eq. 2   (mm of rain on day before the search) +
         (1/2 mm of rain on day of search)

Equation 2 was adjusted if any information on when rainfall occurred in the day was available, e.g., if all rain that fell on the day of the search fell after the time of the search, then none of that rain was included for the day of the search. When such information

was not available, we used half the rainfall as an estimate of what may have already fallen at the time of the search in the morning. Rats did not undergo training if rain fell during the usual training period but were trained if overnight rain had been light or was threatening and had not yet fallen.

In order to build the weather models, we recorded temperature and humidity every 15 min from 05:45 to 09:30 on 17 (temperature only), 19, 20, and 21 August 2016. It rained early on 17 August 2016, and was dry overnight with initial clear skies (at 07:00), while the other three days experienced increased cloud cover. We used the patterns recorded on those days to predict the pattern of temperature and humidity change on all other days of the year for which training data were available, using the available weather records at 06:00 and 09:00 on each day to anchor the models and adjust them for seasonality. The model then predicted the temperature and humidity at the precise (average) time that the rat was searching a box on that day. As most boxes were searched in less than 30 min, the average time of the search approximates to the timing of an indication within 15 min or less.

The general pattern for temperature recorded in August (Figure 2) was a decline from 06:00 to a low point (between 06:30 and 07:15), followed by a steady increase to 09:15. For humidity, the pattern was an increase to a peak (between 07:00 and 07:45) followed by a steady decline to 09:15 (Figure 3, page 46). There was some variation in scale and timing of the low or high point on the days that the detailed patterns were recorded, which we minimized by using values averaged across the three to four days of detailed data (solid line in Figures 2 and 3). The sun hit the ground at 07:20–07:25, which is consistent with the switch to increasing temperature and declining humidity in the data.

Due to the low latitude and the variability in this small data set, we did not attempt to adjust the models for the time of sunrise at other times of the year. Rather, we depended on the data from the weather station at 06:00 and 09:00 to anchor the models, and accepted that the estimates of temperature and humidity used in the analyses here are subject to error that is controlled for, but not eliminated, in the models.

Being tropical, weather variation at Morogoro is influenced as much by rainfall and humidity as by temperature. There are two wet seasons: November and April (the April wet season is longer and with more rain), and winter temperatures are only a few degrees cooler than summer temperatures. Across a full year, the minimum and maximum temperatures measured at the Morogoro station were 14 and 28 C respectively for 06:00 and 09:00, with a typical range of 3–4 C on any day. Thus, in August,
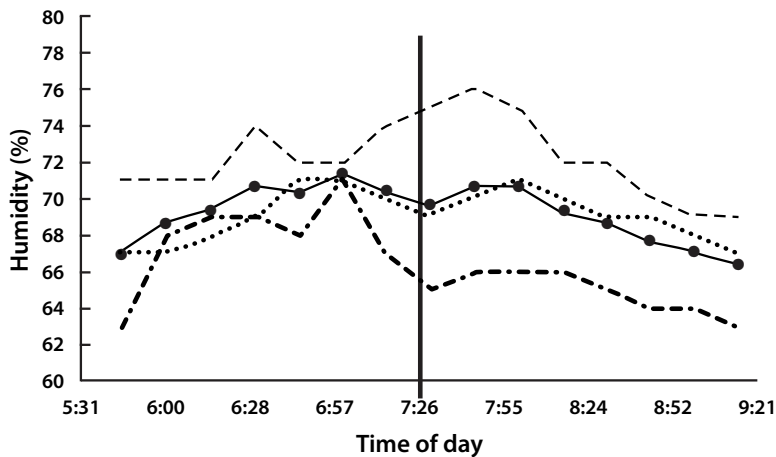
Figure 3. Humidity change through the morning from 05:45 to 09:15 on three days in the third week of August, 2016. The average line used in modelling is shown as a solid line. The vertical line is when the sun hit the ground.

a typical temperature range was 17–20 C, and in January, it was 22–25 C. We are confident that the models predicted temperatures with reasonable accuracy, especially after 07:00 when most of the boxes were searched.

Humidity was considerably more variable than temperature on a day-to-day basis (Figure 3). Model predictions were therefore likely to be of lower accuracy than for temperature. However, these predictions still give the best available estimate of humidity at the time of the search.

ANALYSES

We analyzed the data in two ways. First, we determined the effects of each of the three independent weather variables (temperature, humidity, and rainfall) on the dependent variable (proportion of mines found; here converted to logit *p*, see Equation 1, page 44) using linear mixed modelling. Second, a descriptive analysis was essential to understand the patterns in the data, and we give examples of those analyses here to provide background for the study. All analyses used each rat as the subject that delivers the dependent variable. Thus, the reported sample size for any analysis was the number of rats, with any variation in sample size of rats (*n*), caused by missing weather data resulting in the rat being excluded from a particular analysis.

The number of search boxes available for each rat ranged from 10 to 80. That large range created difficulties for statistical analyses exploring variation across rats in a repeated-measures design. We therefore collapsed the data for each rat in two ways.

First, for each rat we collapsed *p* (Logit *p*) data into categories by calculating mean values for weather variable units: for temperature, data were collapsed into 1 C units (range <15–27+ C, giving 14 categories); for humidity, data were collapsed into 2.5% units (range <67.5–100%, giving 14 categories); for rainfall, data were collapsed into unit ranges of increasing size with increasing

rainfall (details in **Results**), giving 10 categories. The maximum *n* of 14 or 10 unit categories was usually less for each rat, as no data were available for some unit ranges for most rats, even if the original sample size was large (as described previously, the uncollapsed *n* was 10–80). Analyses were then performed on those partially collapsed measures.

The proportion of mines found (*p*) is bound by the values 0 (none found) and 1 (all found), and is therefore not appropriate for parametric statistical analyses, which require unbounded dependent variables. Therefore p was converted to logit *p* as per Equation 1. The conversion creates an unbounded value for *p*, where a *p* of 0.5 = 0, a p of 1 = 2 or more, and a p of 0 = -2 or less. The adjustment of 0.01 avoids incalculable logit p values when *p* = 1 or 0.

Second, for descriptive purposes, we calculated Pearson's correlation coefficients (*r*) across all boxes for each rat between each of the three weather variables (temperature, humidity, and rainfall) and proportion of mines found. Pearson's *r* approximates the slope of the regression line for the rat in relation to the weather variable, and serves as a proxy measure enabling comparison across rats using a single value. A large number of correlation coefficients were calculated, and our purpose was descriptive, thus we do not report significance. Pearson's *r* ranges from -1 to +1. If *r* is positive, *p* increased as temperature, humidity, or rainfall increased. If *r* is negative, *p* declined as those variables increased. If *r* is close to zero, *p* can be considered to be unaffected by the weather variable. As *r* becomes larger, i.e., approaches +1, detection success by the rat is increasingly likely to be influenced by the weather variable. However, interpretations based on the scale or significance of that influence should be cautious and supported by further analysis.

RESULTS

Individual rats potentially contributed an accuracy score at each of 14 different temperature or humidity units and 10 different rainfall units, introducing a repeated measure into the analysis.[18] Additionally, as not every rat contributed an accuracy score for every weather unit, there was incomplete data. Therefore, we ran three separate linear mixed models, one for temperature, one for humidity, and one for rainfall, using rat name as a random effect variable and the relevant weather variable as a fixed effect. For simplicity, all models were run using a homogeneous covariance structure with compound symmetry.

The model for temperature was significant, $F(1, 13) = 4.78$, $p < 0.001$, showing a significant relationship between temperature and logit *p*. Figure 4 (page 47), which displays the estimated marginal means for logit *p* at each of the 14 temperature units, shows
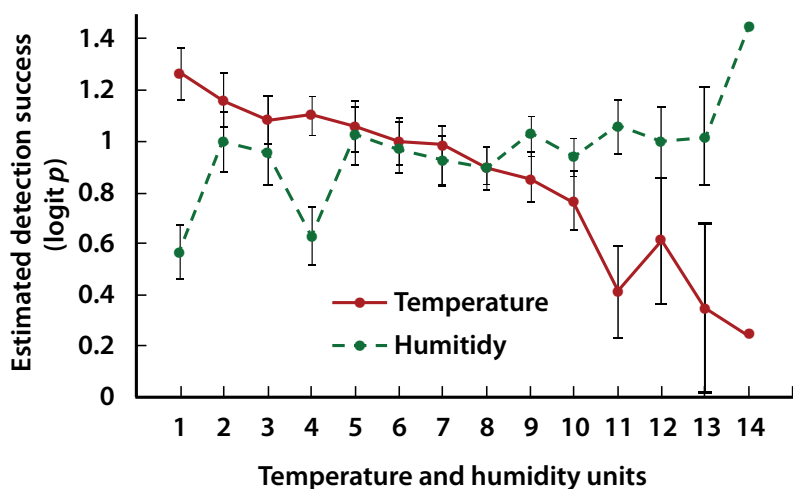
Figure 4. Estimated marginal means for logit p based on increasing values of temperature and humidity (in units). Error bars show the standard error of the mean.
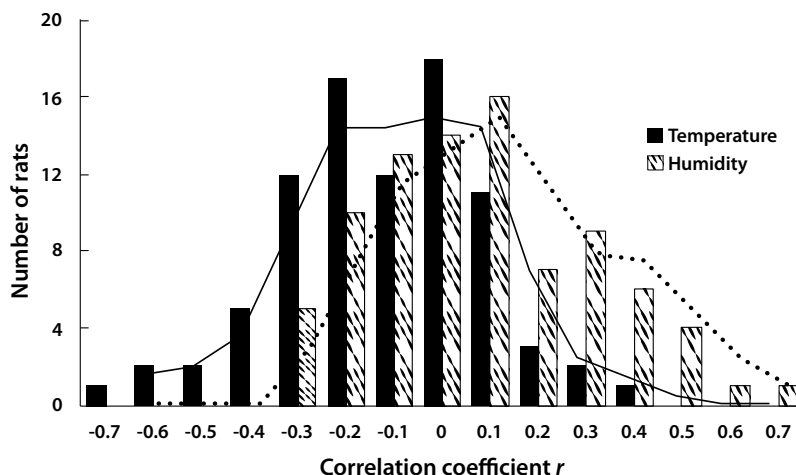

Figure 5. Distribution of Pearson's *r* for the relationship between temperature (solid bars), humidity (dashed bars) and *p* during field training to find landmines for 86 rats. Value on x axis gives the middle of the count range; e.g., the count for "0" is for the range >-0.05 to +0.05.

that logit *p* decreased with increasing temperature. The model for humidity was also significant, $F(1, 13) = 3.807$, $p < 0.001$, showing a significant relationship between humidity and detection success. Figure 4 shows that although detection success generally increased with increasing humidity, the pattern was slightly more variable than for temperature. The model for the relationship between rainfall and detection success was not significant, $F(1, 13) = 0.63$, $p = 0.76$, and the estimated marginal means showed no consistent relationship with logit *p*, and therefore these means are not shown in Figure 4.

The correlation coefficients for each rat were linked to temperature, humidity, and rainfall at the time of the search. Weather variables influence each other and are only partially independent. During the weather modelling, we noted that temperature and humidity were inversely related, whereas any relationship of either of these variables with rainfall was not readily discernible (in part

because there were many days with no rainfall). Our analyses consistently indicated that temperature was most strongly related to rat detection success, humidity was less strongly related, and there was no detectable relationship between detection and rainfall. We therefore emphasized temperature and included the descriptive results for humidity, but not for rainfall.

For temperature, the ratio of negative to positive *r* values was 61:25 (total *n* = 86) and the average *r* was -0.12, 95% CI [-0.08, -0.16] (Figure 5). Thus, for most rats, detection success declined with increasing temperature, and there was a negative relationship with temperature for the average rat. The relationship between temperature and performance should be minor for rats with *r* values close to 0, and for 55 of the 86 rats (64%) *r* was within the range -0.2 to +0.2. Of the 31 rats with a stronger negative *r* than -0.2, seven had a very strong value (below -0.4) indicating a relatively high negative sensitivity to temperature. Four rats had a positive *r* over +0.2, suggesting that their detection success improved with increasing temperature. Of these, one was only trained at lower temperatures (below 20 C) and the positive *r* should be discounted for this animal. However, two were trained within the typical range of temperatures (17–25 C), and one was only trained at relatively high temperatures (21–27 C). Thus, while the main effect of temperature on detection accuracy is negative, there appears to be a small proportion of rats for which performance improves at higher temperatures.

For humidity, the ratio of negative to positive *r* values was 35:51 (total *n* = 86), and the average *r* was 0.07, 95% CI [0.02, 0.12]. Thus, the detection performance of rats tended to improve as humidity increased (Figures 4 and 5), with some rats showing a strong relationship between humidity and detection success (eight rats had an *r* > 0.4).

There were four rats with strong sensitivity to both temperature (*r* < -0.4) and humidity (*r* > +0.4). Of these four, one showed a steady improvement on training trials with no evidence of struggling in summer; one showed a steady overall training improvement, but its performance declined in summer; one struggled in late summer, after which its performance improved as the weather cooled, and one did not have enough data to interpret. We give these examples primarily to demonstrate how the sensitivity of individual rats can be explored if appropriate data are available.

For rainfall, the ratio of negative to positive *r* values was 41:44 (total *n* = 85) and the average *r* was -0.01, 95% CI [-0.05, +0.05].

The relationship between rainfall and detection overall was small, with only a few animals performing more or less accurately in wet conditions. However, the rainfall analysis was dominated by dry days, with about two-thirds of the searches undertaken after zero rainfall in the last one and a half days, and most others experiencing relatively little rainfall. There were only a few days in the year when substantial rain fell, and the rats were not usually trained on those days (although they might be trained the next day when a heavy rainfall would be included in the data). Overall, the number of searches on which significant rain fell was only a small proportion of the overall data set, and our ability to detect any relationship between detection and rain was therefore limited.

DISCUSSION

Overall, these results give confidence in the ability of most rats to cope with weather variation under the conditions experienced at the training fields. However, the greatest relationship between detection success and weather was found for temperature, which is frequently an issue in the places where animals (including rats) are used to search for landmines. Temperatures at ground level in environments in which there is little vegetation can rise more quickly than air temperature measured by a weather station would suggest.[8] APOPO is aware of this issue, and the trainers reported to us that lethargy could appear quickly if rats were working over bare ground, even if air temperatures were within the normal working range. Ground vegetation buffers the heating effect of direct sun, giving a longer operational time, and cloud cover is more likely when humidity is high. It appears that the most appropriate locations for these rats to work outdoors are those where humidity remains relatively high, and there is ground vegetation. We cannot comment from these data on whether there are minimum temperature limits for operational use of rats.

A small proportion of rats showed a strong enough relationship with temperature and/or humidity and detection performance to suggest that APOPO could benefit from monitoring performance in relation to weather parameters. Perhaps most importantly, it should be possible to identify those individuals for whom performance is strongly positively related to temperature and deploy them preferentially to operational theatres where temperature is likely to be an issue. Individuals whose performance is strongly negatively related to temperatures might be deployed to laboratory-based detection tasks, such as tuberculosis testing, where temperature and humidity are controlled.

A concern for APOPO is that apparently well-trained rats may still fail accreditation testing, which is a single event undertaken following the U.N.-approved mine action standards. Failure on that test could delay opportunities for operational deployment, and has resulted in individual rats being held back in their training programs. While the standards must be adhered to, the results

from this study suggest that temperature may be a factor in some of those failures, and consideration of the relationship between performance of individual rats in relation to weather parameters for both testing and the proposed deployment theatre might be appropriate. ©

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Developing a Hyperspectral Non-Technical Survey for Minefields via UAV and Helicopter

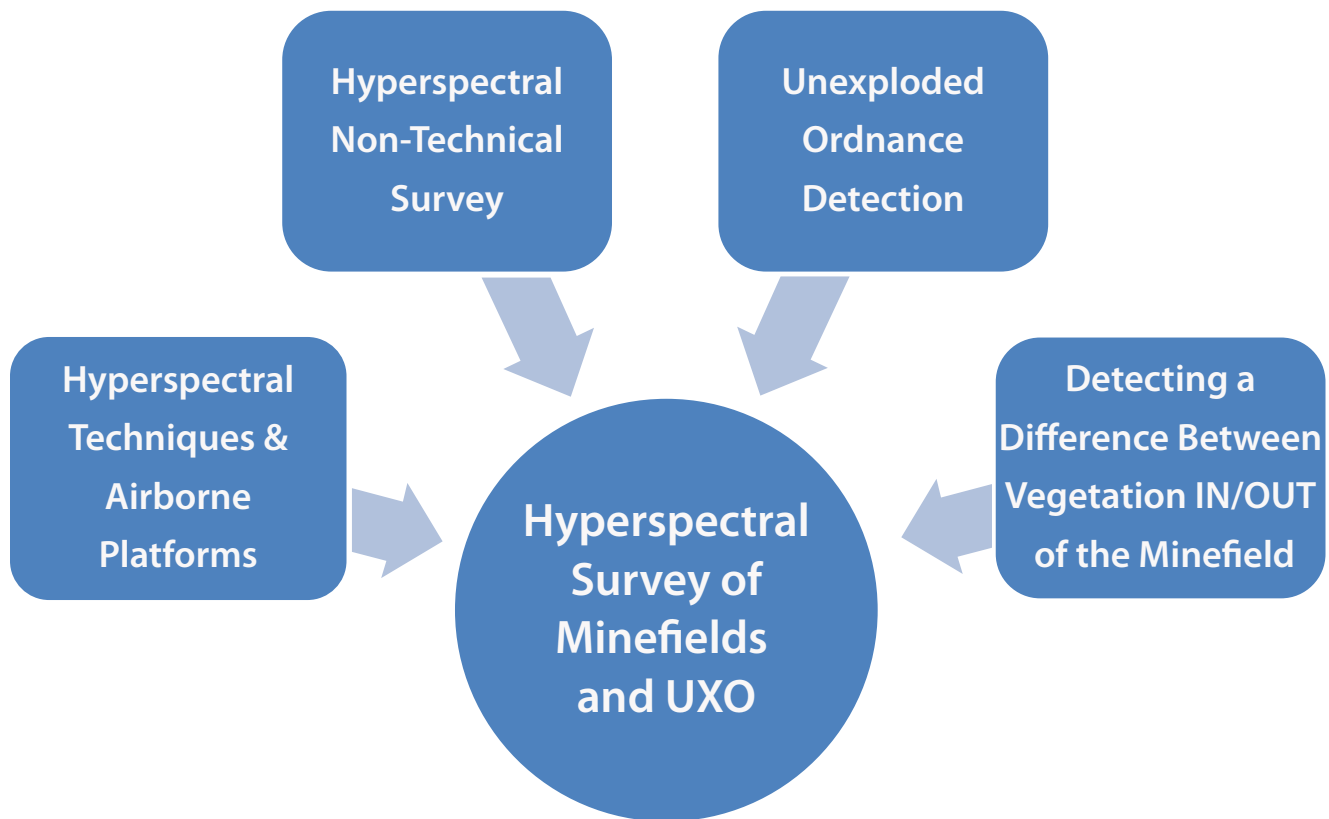**By Milan Bajić, Ph.D., Tamara Ivelja, and Anna Brook, Ph.D.**

Figure 1. The considered topics.
Figure courtesy of the authors.

The main topic discussed in this paper is the research, development, and implementation of hyperspectral remote sensing technology in humanitarian mine action (HMA), mainly for non-technical survey (NTS) from aerial platforms (Figure 1).[1] NTS should be conducted to determine whether landmines or unexploded ordnance (UXO) exist in considered areas and whether clearance is needed and if so, in what scope. The availability of the hyperspectral sensors (2011–2012) that are suitable for use with multi-engine unmanned aerial vehicles (UAV) enabled the development of systems for HMA. While large and costly airborne hyperspectral systems have been available for over two decades, they had little to no impact on HMA.[2] Optical spectroscopy brought out interest in the relationship between vegetation and explosives, and this relationship is considered herein. Therefore, we briefly analyzed the state of

landmine detection via hyperspectral technology, particularly the efforts to detect the mines due to the influence of explosives on vegetation reflectance spectra.

The Croatian Mine Action Centre for testing, development and training Ltd. (HCR-CTRO) contributed to the development and implementation of hyperspectral technology in mine action and is also discussed here. Our activity in the domain of HMA started with the European Commission FP5-IST project ARC and continued to the European Commission's Framework Programme 7 (FP7) project: TIRAMISU.[3,4] In this program, the Specim ImSpector V9 hyperspectral line scanner was integrated as a push broom mode acquisition system for surveying minefields and UXO-contaminated areas, as well as for other purposes.[5–12] In 2015, a full frame hyperspectral sensor, the Cubert UHD-185, was applied.[4,13] Both types of sensors (line scanner and full frame sensor) were

integrated into aerial acquisition and navigation systems on board a UAV and a Bell-206 helicopter, as well as on ground vehicle platforms in technically simpler versions. These were involved in the intensive data collecting campaigns over the minefields.
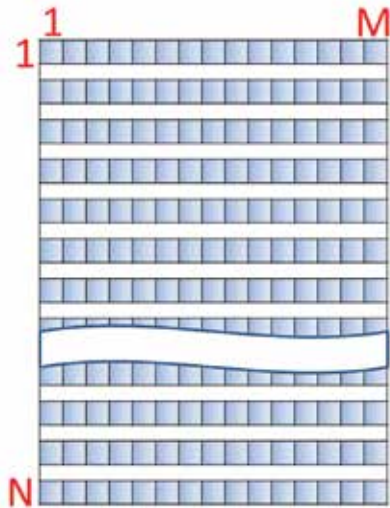
The basic operational features of the considered hyperspectral sensors are explained in Figure 2. Line scanners (2a) collect hyperspectral data for W wavelengths in successive lines. Technically complex, line scanners produce results that are available after time-consuming processing. Near real-time, full-frame sensors (2b) include images in visible wavelengths (blue), sharpening the spatially coarser hyperspectral image (red) at W wavelengths of the same area. The intrinsic hyperspectral spatial resolution is Q times coarser (e.g., $Q = 20$). Near real-time control of collected hyperspectral data is possible. Near real-time sensors (2c) provide hyperspectral data at any K of W selected wavelengths, $K < W$ (typical $K = 30$, $W = 300$) at full spatial resolution.

Besides the development of a hyperspectral survey system suitable for NTS, our goal was to implement the methods and technology for NTS in minefields by applying spectroscopy. The initial goal was to analyze and verify the vegetation indices that show differences between the mixture of grassy vegetation inside (IN) and outside (OUT) of the minefield. For this purpose, minefields in Croatia, near Benkovac (Figure 3) and Murgići, near Lički Osik (Figure 4, page 53) were surveyed.
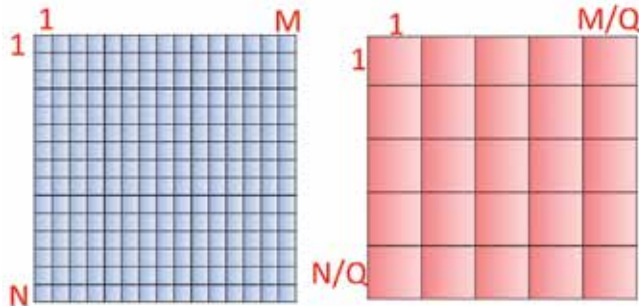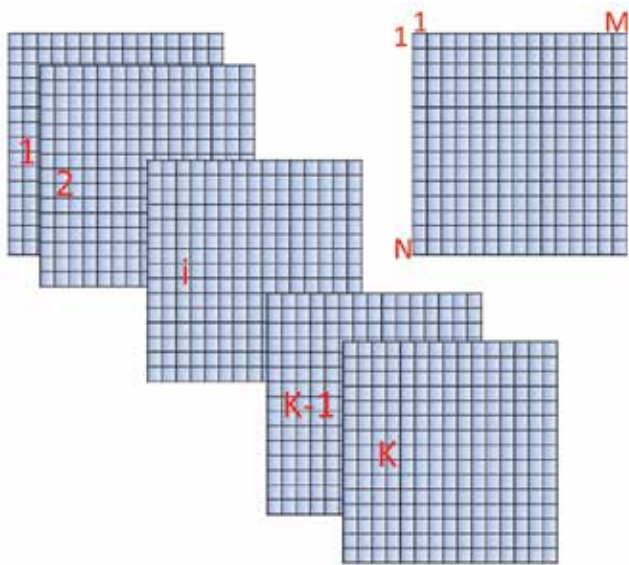
Figure 2a.

Figure 2b.

Figure 2c.

Figure 2(a-c). Modes of hyperspectral data collecting at W wavelengths, typical $W > 90$.
Figure courtesy of the authors.

IN - Minefield Benkovac - 10,000 sq m
Blind test area - 5,900 sq m
Public data area = 1,600 sq m
OUT = 43,323 sq m
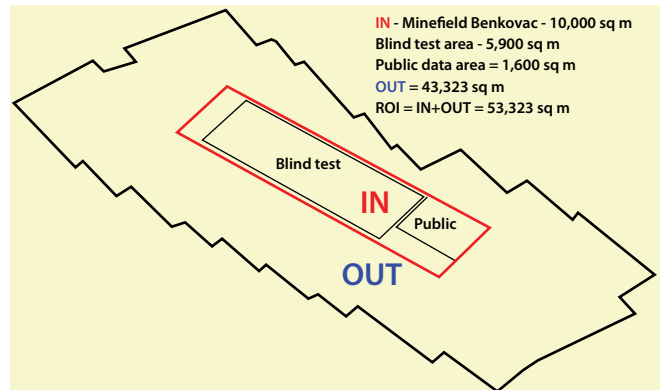**ROI** = IN+OUT = 53,323 sq m

Figure 3a. The hyperspectral detection of the difference between grassy vegetation IN and OUT of the minefield.
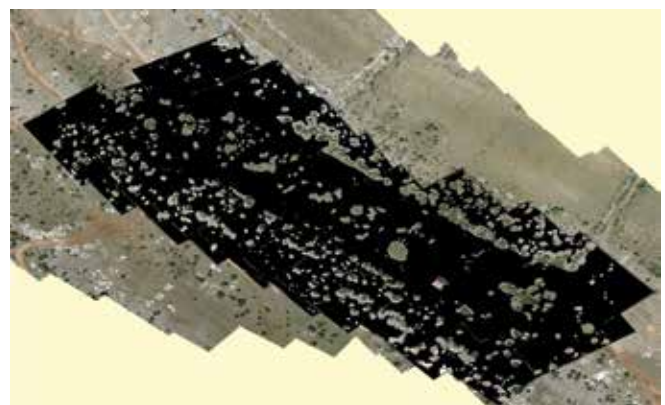*Figure courtesy of the authors.*

Figure 3b. Bushes and trees are excluded from hyperspectral data.
Figure courtesy of the authors.

Hyperspectral data (Figure 3a) were collected simultaneously on the OUT (43,323 sq m) and IN (10,000 sq m) areas of the Benkovac minefield (containing 1,000 mines), where 5,900 sq m of the minefield is aimed for the blind statistical tests. Public-use data on the location of 150 mines exists for part of the minefield. Bushes and trees hyperspectral data were excluded manually from data of the IN and OUT areas.

In our approach, the features and characteristics of the particular vegetation types were not analyzed. Instead, a grassy vegetation mixture (IN and OUT) of the considered area was taken into account. This is a crucial fact on which we continued our research and development. Differences in the vegetation's spectral reflectance (both IN and OUT) were perceived and confirmed in a case of the Benkovac minefield. After this step, vegetation indices were analyzed, and we confirmed that indices values from the IN area differ from those of the OUT areas.[4,10,13]

Besides the references linked to our work, a large amount of valuable information on hyperspectral topics exists. Used for military applications, this technology can analyze the variability of terrain signatures, produce hyperspectral images for data fusion, and detect anomalies.[14–18]

HYPERSPECTRAL DETECTION

Some of the earliest information on hyperspectral detection of buried mines via the spectral changes in vegetation was presented in 1997 (McFee, Ripley), 2007 (McFee et al.) and later in 2010 (Yoresh).[19,20,21] In 2007, McFee et al. reported that "The detection of buried mines using a CASI hyperspectral imager from personnel lift at 5 m distance, under various vegetative covers and bare soil at various times from 1 2/3 to 15 1/2 months after burial. Short vegetation gave better detection results than bare soil which gave better results than medium length vegetation. Probability of detection (Pd) was typically in the range of 55 to 94 percent and False Alarm Rate (FAR) varied from about 0.17/m2 to 0.52/m2."[20] In 2010, Yoresh stated that "Processing of the imagery was applied into a mosaic of the geometrically rectified 125 channels HyMap, data which was atmospherically corrected. It allows identifying suspected minefields, in the size of 30 x 30 meters from satellite photo, and of smaller size of 1 x 1 meter from aerial photos."[21]

The longwave infrared (LWIR) hyperspectral method of detecting buried mines is based on sensing soil surface changes.[22] The extremely high cost of LWIR hyperspectral sensors limits their application when compared to the prices of visible, near-infrared, and shortwave wavelength sensors.

The hyperspectral method of detecting mines on the surface in visible, near-infrared light and shortwave infrared light is described by McFee et al. as "Individual mines [that] could be distinguished from backgrounds in all seasons and times of day between sunrise and sunset, even when they were partially obscured by vegetation. High spatial resolution airborne imagery of real and surrogate minefields has also been obtained from the helicopter (0.1 m x 0.1 m at 75 m altitude to 0.2 m x 0.2 m at 150 m altitudes). Analysis yielded Pd of nearly 100 % with FAR of 0.0003 per sq m and 0.004 per sq m. Real-time analysis, necessary for military applications, has been demonstrated from low speed ground vehicles and recently from airborne platforms. Down-welling radiation sensors are necessary to allow detection of mines independent of natural illumination, since calibrated panels are not practical in the field."[20]

The process of using hyperspectral imagery to detect unexploded ordnance (UXO) that has been scattered by unplanned explosions of munition stockpiles is discussed in (Foley, Patterson 2007), (Bajić et al. 2013), (Yvinec et al. 2015). The wide area assessment of UXO distribution at and around ammunition depots post explosion can be obtained by combining aerial hyperspectral and very high spatial resolution visible (VHR VIS) images. A similar approach was applied where hyperspectral samples were collected by ground based system and VHR VIS sensors attached to helicopters and UAVs.[8,24] For TIRAMISU 2012, we collected hyperspectral and VHR VIS data and images of UXO, soil, and vegetation relevant to unplanned explosions of munition stockpiles.[4]

Assessing former military test sites with hyperspectral imaging to detect the UXO and abandoned ordnance (AXO) on or below the surface was considered in 2007 (Foley, Patterson).[8,23,24] Researchers concluded that the wide area assessment of UXO distribution in the former military test range could be obtained by combined aerial hyperspectral and VHR VIS images.[23] The Geneva International Centre for Humanitarian Demining (GICHD) observed a similar approach that was applied to a former military shooting range and concluded that the statements about probability and reliability of results are not strong enough and are not supported by evidence.[25]

Using hyperspectral imaging to detect residual contamination on military test sites that will be used for civilians once clearance has been completed is a standard problem.[26] For former military test sites (i.e., shooting ranges), clearance requires convincing evidence and verification that levels of residual contamination are at acceptable thresholds. The hyperspectral aerial survey and ground truth hyperspectral measurements provide a basis for success.

The hyperspectral survey of minefields was reported in 2010 (Yoresh), whereas the observer considers substantial limitation of the method due to vegetation's role in the method.[21,25,27]

Partial analyses of spectral features of plants fed by explosives appear quite often. A very simple goal was defined: "To determine if a technique called hyperspectral imaging can be used as an accurate tool for detecting buried explosives."[28] In 2014 (Smit et al), the analysis was serious: "Indigenous trees in

20 liter pots contaminated with different TNT concentrations, plants were kept in semi-natural conditions, concentrations used were from 30 mg/kg, to 5000 mg/kg.[29] Initial results show that there are impacts. Some trees showed more impact than others. The plants healthier than their neighbors could indicate the presence of a minefield : toxins from explosives leak into the surrounding environment, affecting plant health, especially herbaceous plants more than woody plants.[30,31] They are considering creating an 'Explosive Specific Index' that will record how explosives affect various vegetation types." In 2016, Manley reported: "Three species representing different functional types (Cyperus esculentus, a sedge; Ulmus alata, a tree; Vitis labrusca, a vine) exposed to RDX and TNT over a nine-week period.[32] Woody species, exhibited changes in pigment content, leaf area, specific leaf area, dry leaf biomass, and canopy reflectance."

The hyperspectral detection of illicit plants is a technology suitable for counter-drug survey in case of combined drug plants fields with mines and the improvised explosive devices (IED) in certain countries e.g., coca fields in Colombia.[33,34] The availability of a new generation of hyperspectral sensors (full frame cameras), which provide data in near real time, is key to the implementation of this technology.

In the last several years, UAVs were frequently considered for detection purposes, although the first fully operational project based on UAV platforms for mine action was done in 2014.[35] In future projects, the use of the full frame hyperspectral cameras will significantly advance results of the survey.

METHODS AND MATERIALS

Experience from several airborne-based NTS projects enabled a unique and holistic approach to the problem of large suspected hazardous areas (SHA), the minefields survey and the challenges and chances for hyperspectral technology.[35,36] SHA is an area where there is reasonable suspicion of mine and explosive remnants of war (ERW) contamination on the basis of indirect evidence of the presence of mines and ERW.

OBJECTIVES AND GOALS

Our current work in a hyperspectral domain was led by the following goals:

- **Goal 1:** Develop, test, evaluate, and operationally validate a system suitable for hyperspectral NTS based on the application of a multi-engine UAV and currently available hyperspectral sensors.
- **Goal 2:** Collect and prove that the pure spectral samples (endmembers) data for considered UXO enable their detection.
- **Goal 3:** Prove that the spectral vegetation indices enable discriminating grassy vegetation IN and OUT of the minefield.

OBJECTIVES:

- To develop, test, evaluate, and validate the system for hyperspectral data collection via UAV and helicopter that are suitable for applications in NTS.
- To assess SHAs and minefields, not the positions of mines, and consider the minefields with sub-surface mines.
- To develop a hyperspectral data library of unexploded ordnance (UXO) collected after the unplanned explosion of the ammunition depot. To derive functions that link probabilities of detection, classification, recognition, and identification with spatial resolution of very high resolution images in the visible wavelengths.
- To consider only the grassy vegetation as the potential carriers of information of buried mines. Avoid the analysis of particular vegetation types and take into account a mixture of grassy vegetation (IN and OUT) of the considered area instead. Differences in spectrum and vegetation indices values were expected and should be confirmed.

The considered SHA and minefield (IN) surrounding the vegetated area (OUT) were available with the same features (soil, moisture, vegetation). This area was not cultivated from the time the mines were buried until survey. The hyperspectral data acquisition of the SHA, minefield and surrounding area were conducted simultaneously in the same acquisition flight.

Since 2002, we have used the hyperspectral system for analyses in the ecology and forestry sectors.[5,11,12] The initial key influence on our goals was made in 2011 by Šestak, who supported the concept that the mixture of grassy vegetation should be the representative of the situation in the considered minefields and SHA instead of one preselected vegetation type.[37]

MINEFIELDS

Within the scope of the TIRAMISU project, two approaches were defined regarding the hyperspectral detection of minefields and SHA. The aim of the first approach was to develop, test, evaluate, and validate a system for hyperspectral data collection via UAV and helicopter that is suitable for application in NTS, to collect pure spectral samples (endmembers), to derive hyperspectral cubes for considered set of UXO, and to prove that the vegetation indices can discriminate between the grass IN and OUT of the minefield. The work on the first approach was continued, and hyperspectral survey flights have been made by UAVs and helicopters on SHAs and minefields for a total area of 514,000 sq m. Survey was done from lower altitudes, and valuable data with high spatial resolution were gained, Figure 3 (page 50) and Figure 4. The second approach was large-scale, aerial, hyperspectral acquisition of SHAs and minefields in different terrain, climate, vegetation, and mine contamination. It was planned to survey around 136 sq km of SHAs and minefields with a HySpex sensor (visible, near infrared,

shortwave infrared). Also, the ground truth mission for that area was planned and prepared. The main expected benefit should have been a significant set of hyperspectral data representing the above-mentioned areas of interest. Based on these data, it would be possible to differentiate land cover classes and derive reliable statistics of vegetation characteristics and features difference from IN and OUT of the contaminated areas. Unfortunately, these surveys were never conducted.

Figure 4a depicts the SHA and Murgići minefield near Lički Osik in Croatia. The image of Murgići is visualized by narrow wavelengths (8 nm) spectral images (central wavelengths: red = 650 nm, green = 550 nm, blue = 458 nm). Areas in the blue delineated polygons have been demined. This area, with a minefield near Benkovac, served as the research, development, testing, evaluation, and validation area. Figure 4b shows a small example area selected from the demined area that demonstrates the hyperspectral survey potentials for NTS. This area is hilly and has a continental climate.

Figure 3a (page 50) depicts the Benkovac minefield. The red polygon outlines mined area 50 x 200 m. The black line is the border of the region of interest (ROI). The hyperspectral data and
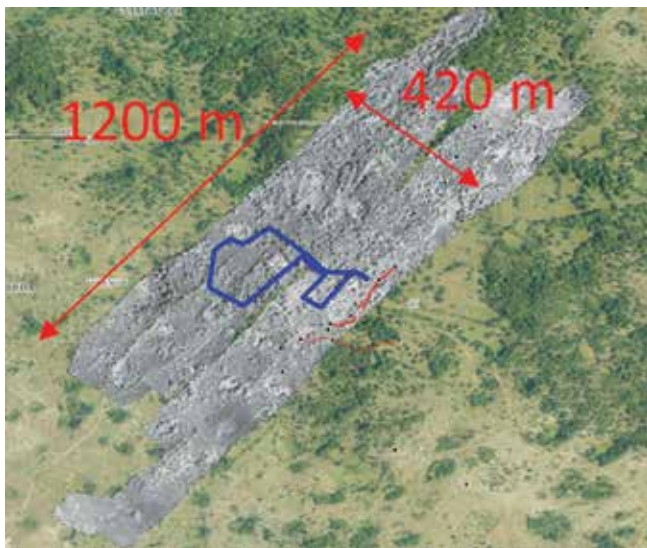

Figure 4a. The gray area of the Murgići minefield (> 504,000 sq m) near Lički Osik, Croatia, for which hyperspectral data were collected via helicopter. *Figure courtesy of the authors.*

Figure 4b. The small subarea selected from demined one (blue delineated polygon). *Figure courtesy of the authors.*

very high resolution color images were collected via helicopter and UAV. This area has a rocky terrain and a subcoastal climate. It contains 1,000 mines with very high density of 0.1 mine per sq m, and for that reason, served as the main area for our research. In the Benkovac minefield, hyperspectral acquisition was conducted via light helicopter, UAV, and ground vehicles in 2012, 2013, and 2015.

The Prototyping Model was applied in research and development of the hyperspectral acquisition system. The Prototyping Model is a systems development method in which an early approximation of a final system is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved. This model works best in scenarios where not all of the project requirements are known in detail ahead of time. It is an iterative, trial-and-error process that takes place between the developers and the users. The main difficulty is the need to understand the collected hyperspectral data from the minefields, and the ability to correct and calibrate the data, analyze the results, and decide on the next step in the system development.[10] This process is reflected later in the article.

UNEXPLODED ORDNANCE

Addressing the on-surface issue was done by examining the exploded ammunition depot of Pađene (near the town of Knin, Croatia), in which an explosion occurred in 2011 and large amounts of UXO were scattered in an approximately 5 km radius area. The area was under ground-based and airborne survey, during which hyperspectral UXO data was collected.[8,24] The main goal was to provide a reliable ground truth for discriminating UXO from its surrounding (soil, vegetation, etc.).

SENSORS, PLATFORMS, AND HYPERSPECTRAL DATA ACQUISITION

A helicopter-mounted, multi-sensor, aerial acquisition system with a hyperspectral line scanner was initially developed in the ARC project and later upgraded.[3–8] It was the first non-military system for airborne NTS. Several kinds of aerial platforms have been used in research and development of hyperspectral technology for minefield surveys. To achieve quality data, the following requirements for the platform have been defined:

- It needs to be able to operate at a low speed.
- It needs to be able to operate at low heights.
- Platform swinging and vibrations must be minimal.

These requirements are largely related to survey with the V9 hyperspectral line scanner, Figure 2a (page 50), and the complex procedure of pre-processing hyperspectral images by parametric geocoding.[6,7,10] Several data acquisition systems were developed for multiple platforms: light and heavy helicopters (Bell-206b, Gazela, Mi-8), a radio controlled blimp and different types of UAVs, Figure 6 (page 54). The acquisition systems

Cluster bomblets PTAB 2.5M - 1 12MK

Mortar round 60 P1

Artillery shells 130TF for M46

Round 100mm M69 P1

Mortar rounds 120mm TTF and 82 mm

Air to air missile 9M 114K-STURMt

Air bomb SAB 100 MP

Cluster bomb BL-755, container for bomblets

Air bomb BETAB 500

Warhead of air missile S-24B

Air cluster bomb RBK-250

Training missile VRS 57MM P1

Figure 5. The spectral features were measured for a number of UXO items.

Figure 6a. Mi-8.

Figure 6b. Radio-controlled blimp.

Figure 6c (left). Eight-engine unmanned aerial vehicle (UAV).
Figure 6d (right). Four-engine UAV with UHD-185 sensor.

Figure 6e (left). Bell-206 with V9 line scanner and UHD-185 frame sensor.
Figure 6f (right). Sensor pod on Bell-206.

are always assembled from several components: acquisition computer, communication unit, GPS receiver, and electric power supply. Moreover, the V9 hyperspectral line scanner requires inertial measuring unit (IMU) on board the aerial platform for measurement of its pitch, roll, and yaw. That much equipment encumbers the aerial platform significantly. For helicopters, the payload parameter was not a problem, while for the blimp (Figure 6b) and multi-engine UAVs (Figure 6c and Figure 6d), this is the most critical issue limiting flight performances and endurance. In 2015, we introduced a new hyperspectral sensor, a full-frame hyperspectral camera UHD-185 (generation 2012), with which we substituted the V9 line scanner used before (generation 2000). Application of the new camera enabled us to finalize successful development of the system and technology for aerial NTS survey via UAV and helicopter: Figure 6c-f. Technical stability and robustness of the system was confirmed during intensive data collection missions in Croatia, 2015. Developed acquisition systems on a light helicopter Bell-206B and multi-engine UAVs were approved and validated by the Croatian Mine Action Centre (CROMAC).[4]

The research of the basic behavior of hyperspectral features, potentially relevant for the goals and the objectives defined previously, was conducted on the Benkovac minefield, Figure 3a

Figure 6(a-f). Aerial platforms used in the research and development of the hyperspectral non-technical survey.
Figures courtesy of the authors.

RESEARCH AND DEVELOPMENT @ THE JOURNAL OF CONVENTIONAL WEAPONS DESTRUCTION

Figure 7a.

Figure 7b.

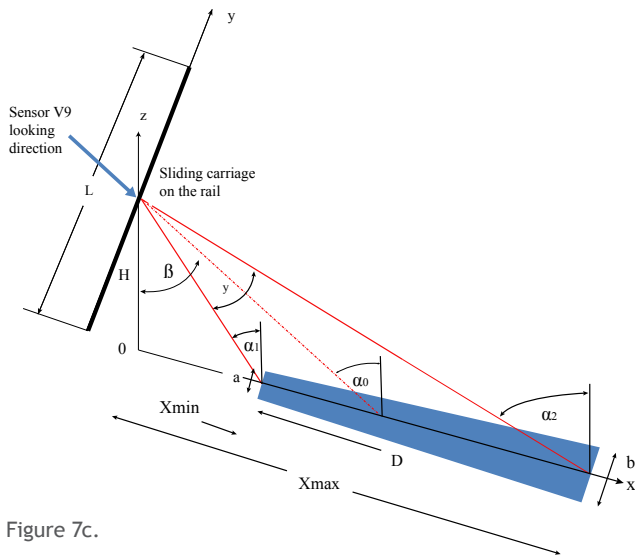Figure 8a.   Figure 8b.

Figure 7c.

Figure 7. Ground-based vehicle platforms for collecting hyperspectral data: a) for collecting nadir data, b) for collecting oblique data, and c) geometry for collecting oblique data.[9]
Figures courtesy of authors.

(page 50), using ground-based vehicle systems, Figure 7.[9] Through the ground-based systems' nadir mode, hyperspectral data and respective color video data were collected during 2012, Figure 16 (page 60). The ground-based hyperspectral survey systems show high sensitivity and very high spatial resolution of hyperspectral data of the minefield in flat terrain, but more processing is needed to overcome imaging geometry problems due to a rough terrain and to properly link the positions of buried mines with the hyperspectral data. A developed technique and technology of hyperspectral imaging from a UAV was operationally validated as a useful one, and it can completely substitute the ground-based hyperspectral survey.[4]

GEOMETRY OF ACQUISITION

Data collected by the V9 line scanner are spatially scattered due to pitch and roll of the aerial platform, see Figure 8a. After parametric geocoding, the lines are transformed to form a row of parallel lines, Figure 2a (page 50), and the result is the corresponding
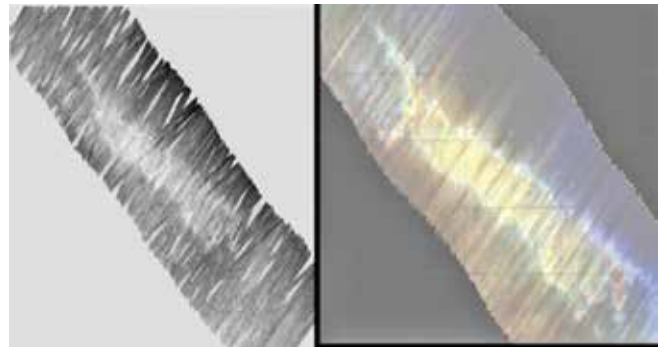

Figure 8c.

Figure 8 (a-c). Geometry of collecting airborne hyperspectral data a) with a line scanner, narrow rectangular areas (named - lines) are scattered due to pitch, roll, and yaw of the aerial platform. b) The parametric geocoding is needed to provide a hyperspectral images. c) The frame hyperspectral cameras produce a hyperspectral set of images for each frame (note white borders of the frames).
Figures courtesy of authors.

hyperspectral cube, Figure 8b. Data collected by hyperspectral frame sensor (model in Figure 2b) produce the hyperspectral cubes, their borders on images are white overlapping rectangles, Figure 8c.

The hyperspectral frame cameras that work in mode Figure 2c (page 50) have smaller number of wavelengths (channels), $K < W$, but their hyperspectral images enable mosaicking due to their full spatial resolution in comparison to cameras, which work in accordance to the model in Figure 2b (page 50).

CALIBRATION

Changes in the Sun's irradiance, see Figure 9, have strong negative impacts on the quality of the collected hyperspectral data and consequently on the airborne hyperspectral NTS operations.
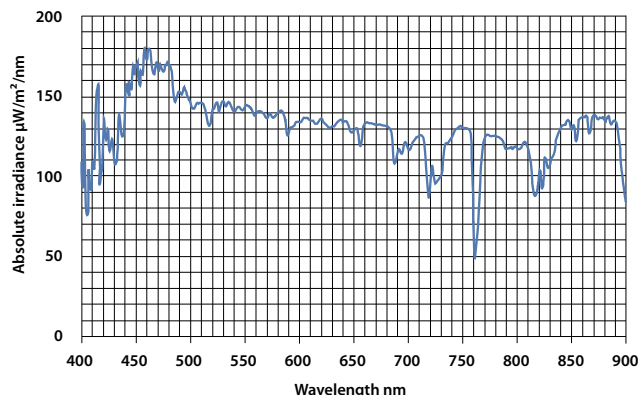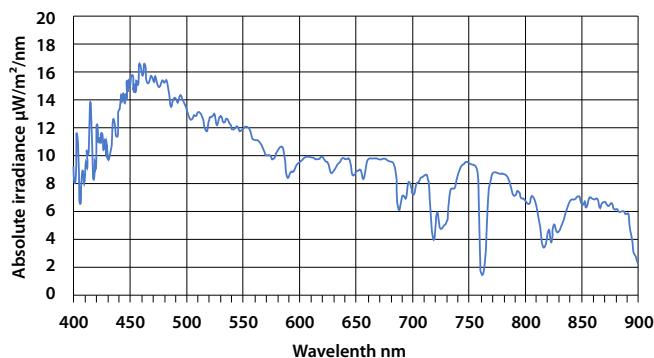
Figure 9a.

Figure 9b.

Figure 9 (a-b). Sun irradiance changes in the day. a) The absolute irradiance during working hours a) at 10:00 and b) at 19:32 local time.
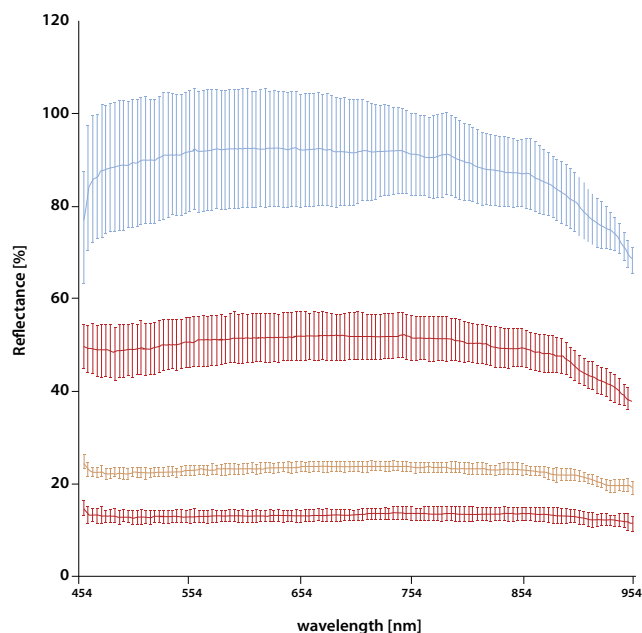*Figures courtesy of authors.*

Figure 10a.

Figure 10b.

Figure 10. Radiometry calibration of the hyperspectral data collected from UAV. a) Reflectance spectra of Spectralon at nominal levels 12%, 25%, 50% and 90% reflectance. b) Reflectance marker Spectralon.
Figures courtesy of authors.

The down-welling radiation sensors are necessary if the calibrated panels are not practical in the field.[20] The radiation sensor FODIS of the V9 line scanner can be the source of errors, whereas the frame sensor UHD-185 counts on a calibrated panel Spectralon for near range missions if done via UAV, Figure 10. If the frame sensor is used from the helicopter, larger calibrating objects should be used, while the measurements have to be done at the take-off and landing flight phases. The supervised vicarious calibration (Brook, Ben Dor 2011) is operationally the most suitable one.[38] The insolation variability limits hyperspectral survey by UAV at shorter time spans and at smaller ranges. Alternatively, helicopters are necessary platforms, as the speed is greater than the speed of the UAVs. Figure 9 shows an example of the changes of the absolute irradiance during working hours.

NEAR REAL TIME CONTROL OF COLLECTED HYPERSPECTRAL DATA

The near real-time frame hyperspectral sensors (frame sensor), which operate in accordance to Figure 2b (page 50), enable control of the data collecting from the helicopter, see Figure 11. This is the most important operational advantage for hyperspectral NTS of SHAs, as minefields in some areas are out of range for UAV platforms. The technology that is currently available does not enable near real-time control of data while flying UAVs, but it is possible after landing.
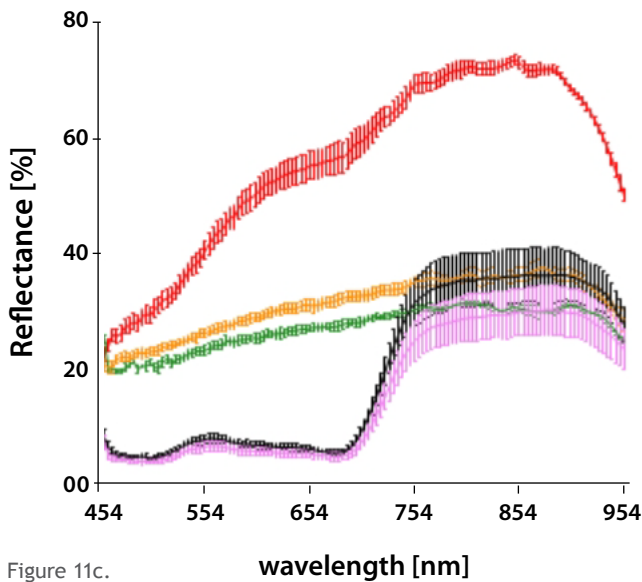
Figure 11a.

Figure 11b.

Figure 11c.

Figure 11d.

Figure 11. a) Sensor operator can check the reflectance spectra of objects and terrain below the helicopter. b) Example of objects below the helicopter during the acquisition flight, c) reflectance spectra of areas from d). Note that the same colors are used for selection of areas on c) and d) for presenting their reflectance.
Figures courtesy of authors.

DEMONSTRATING THE BENEFITS OF NTS AND UXO DETECTION BY SELECTED PROCESSING

The hyperspectral remote sensing, data processing, and application in many domains are very developed, and basic information is available in many sources.[14,15,17,18,37,39,40] While our goal is to enable aerial hyperspectral NTS of SHAs and minefields and the survey of UXO, we will select two simple examples that clearly demonstrate the convincing benefits that are operationally feasible. In these examples, we apply the following processing methods: (1) the Feature Mapping method, using the data of selected wavelengths and (2) the Spectral Angle Mapping (SAM) method of processing hyperspectral data.[29,39] In these examples, we avoided thorough quantitative analyses (e.g., by confusion matrix), while the visual comparison of images verifies effects.

THE FEATURE MAPPING METHOD OF PROCESSING OF HYPERSPECTRAL DATA

The Feature Mapping method enables the visual interpretation of a reference image to guide the automated classification procedures applied to any number of images at different wavelengths. Results are the set of spectral categories or feature classes. This method takes advantage of visual interpretation skills, and the classification can be simply programmed. Another advantage is the application

of the subset of any $K < W$ hyperspectral images, W is maximum number of images in used wavelength range from λ_{min} to λ_{max}. Therefore this method is suitable for hyperspectral sensors that operate in modes, Figure 2c (page 50), that provide full spatial resolution of hyperspectral data in K spectral wavelengths. The example in Figure 12 (page 58) demonstrates useful outcomes of Feature Mapping applied to eight wavelengths from 135 available wavelengths, Figure 12a, Figure 12d, Figure 12e, three wavelengths in Figure 12f, and only two wavelengths in Figure 12b and Figure 12c. The eight wavelengths were selected after reflectance spectra analysis in the considered hyperspectral scene from Figure 4b (page 53), the aim was to discriminate between the road, grassy meadow, and trees. The selected wavelengths were 450 nm, 502 nm, 550 nm, 602 nm, 650 nm, 702 nm, 750 nm, and 802 nm.

THE BENEFITS FOR NTS

1. The grassy vegetation in meadow Figure 12d are easily discriminated from trees Figure 12e, while in the TIRAMISU 2012 project, this was not solved.

2. The road is partially covered by grass but can be detected from eight wavelengths, Figure 12a.

3. The normalized difference vegetation index *NDVI* detects the road, Figure 12b. Here is *NDVI* = (*NIR-R*)/(*NIR+R*), where *NIR* is the image at wavelengths 750 nm, 702 nm, or
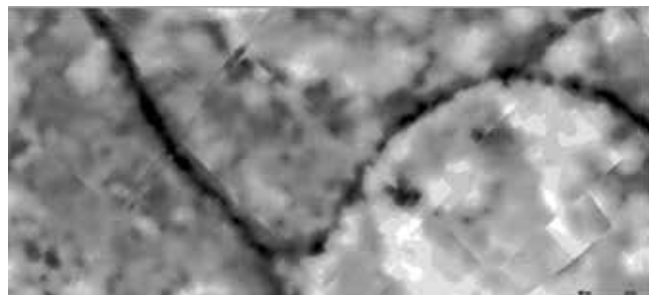
Figure 12a.

Figure 12b.
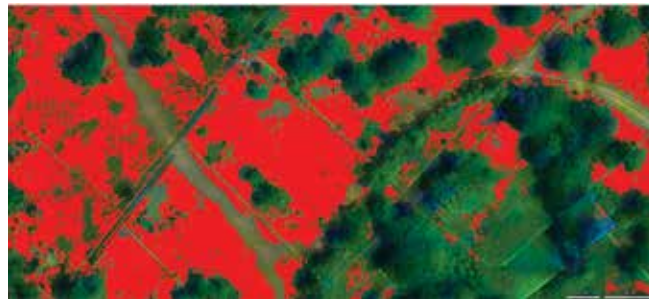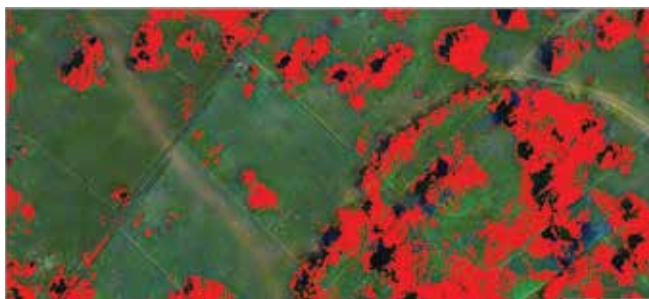

Figure 12c.

Figure 12d.

Figure 12e.

Figure 12f.

Figure 12 (a-f). Application of the feature mapping and computer-assisted photo interpretation (CAPI) on the hyperspectral images at selected wavelengths for discrimination of the field road and the meadow with grassy plants from trees.
Figures courtesy of authors.

802 nm, R is the image at wavelength 650 nm. Figure 12c shows negative of *NDVI* from Figure 12b.

4. If three images are selected that present red, green, and blue parts of visible spectra (650 nm, 550 nm, 450 nm), trees cannot be reliably classified, Figure 12f, whereas eight wavelengths, Figure 12e, are successful.

Note that for the Feature Mapping method to be successful, a selection of wavelengths is needed. While in the worst case, one can select more of them and gain the experience after several trials at a current scene.

HYPERSPECTRAL DETECTION OF UXO BY SAM METHOD

SAM is a method that uses the angle between any two spectral vectors originating from a common origin, where the magnitude of the angle indicates the similarity or dissimilarity of the materials—a smaller angle correlates with a more similar spectral signature.[39] The SAM method of processing was applied to a hyperspectral

cube of UXO described on page 53 and can be seen in Figure 13. Hyperspectral cube is the name for a hyperspectral images format in which consecutive images follow each other in accordance to increasing wavelengths. The spectral samples are measured from the hyperspectral cube in Figure 13a and stored. Via the SAM method, the shape of the mortar mine M60 in real environment (grass, red soil, and rocks) can be reconstructed, Figure 13b.

The diagram in Figure 14a shows measured radiance spectra of mortar mine M60 and environment, while the Figure 14b shows a radiometry marker Spectralon. Note that for SAM, the radiance data have been calibrated and transformed into reflectance.

THE BENEFITS FOR UXO DETECTION

- The provided spectral radiance data of UXO samples from Figure 5 (page 54), after transformation into reflectance, enables assessment of spectral endmembers and detection of target by the SAM method.

Figure 13a. Hyperspectral image of a target (the mortar mine M60) visualized by narrow band (10 nm) images (central wavelengths red – 650 nm, green 550 nm, blue 450 nm).
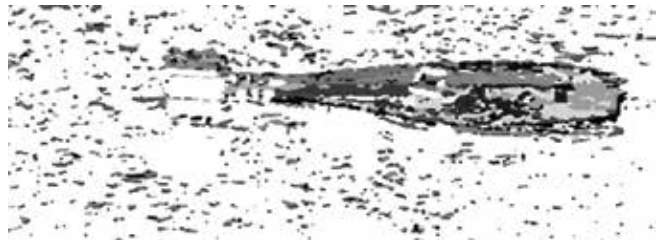*Figures courtesy of authors.*

Figure 13b. Spectral Angle Mapping (SAM) for angle 3, 7 degrees reconstructs the shape of the target.
Figures courtesy of authors.

- The initial spectral library of UXO samples, which were collected after the unplanned explosion of the ammunition depot, seems to be the first one published so far. In any case, this practice should be continued.
- Based on the gained experience with UXO, similar although more ambitious practice should be applied for improvised explosive devices (IED).

IMPLEMENTING THE MODIFIED JOHNSON'S CRITERIA FOR UXO SURVEY

The probability of successfully conducting aerial survey functions—detection, classification, recognition, and identification—of UXO can be estimated by comparing the spatial resolution of the electro-optical sensor (e.g., its ground resolving distance d) and the UXO dimensions. In the advanced Johnson's model, the two orthogonal dimensions of UXO (e.g., its length Lx, and width Ly) are combined in their geometrical mean: $Lc = (LxLy)^{1/2}$.[40] Describing the situation by the available number of resolution elements, $N = Lc/d$, the probably of the successful survey (P) is determined by:

$$P = (N/N50)^E / [1+(N/N50)^E], \quad E = 2.7+0.7(N/N50)$$

where the parameter $N50$ equals N needed for $P = 0.5$. Table 1 (page 60) indicates the value for $N50$ for each of four survey functions.

The above model relates the UXO dimensions, sensor resolution and probability of the success of the survey for a given item of UXO. Typical results are illustrated in Figure 15 (page 60), using the mortar mine M60 from Figure 5 (page 54).
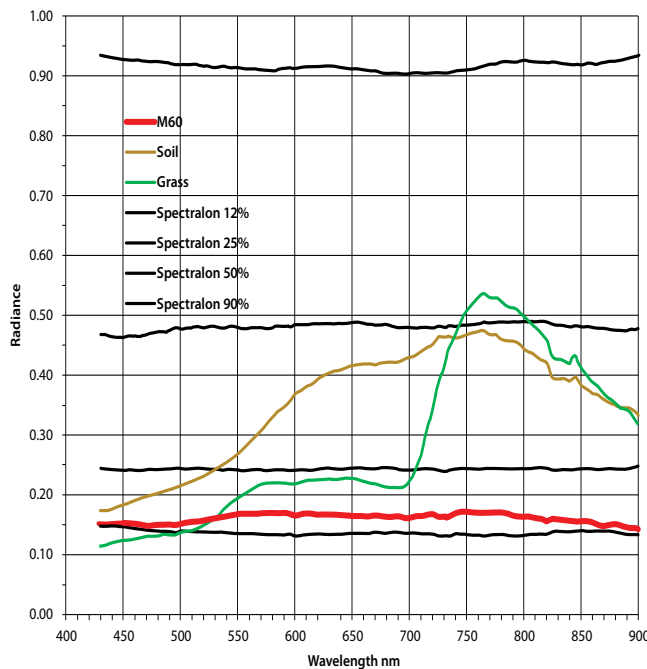

Figure 14a. Radiance spectra of the target M60, soil, grass, and calibration lines of 12%, 25%, 50%, and 90% radiance.
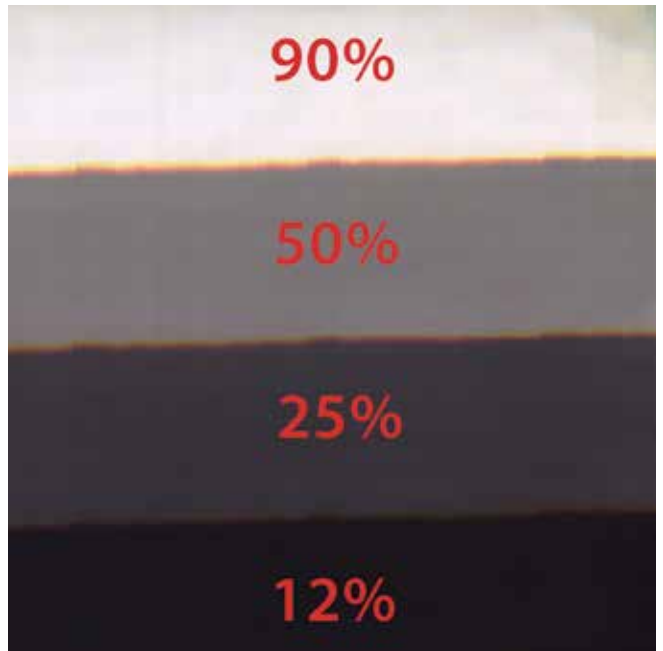*Figures courtesy of authors.*

Figure 14b. Hyperspectral image of the Spectralon marker for radiometry calibration.
Figures courtesy of authors.

Survey Function	N50
Detection	1.5
Classification	3.0
Recognition	6.0
Identification	12.0

Table 1. N50 values for 50% survey.
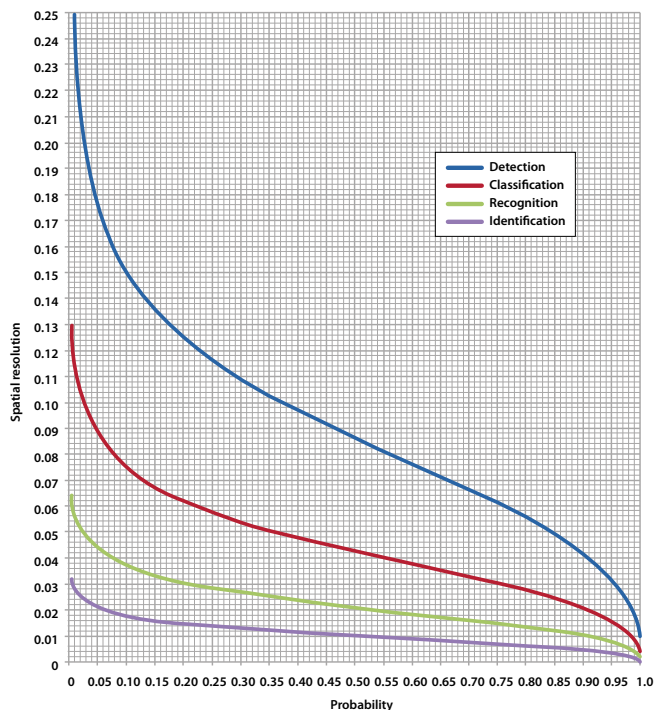*Table courtesy of M. Bajić.*

Figure 15. Required spatial resolution (m) for the required probability of the four survey functions in the case of the mortar mine M60.
Figure courtesy of M. Bajić.

Figure 16a.

Figure 16b.

⬛	Not used		
🟥	recorded (11-14.06.13)		
🟧	planed but not recorded		
●	I triage		
G	II triage (green)		

Figure 16c.

Figure 16d.   Figure 16e.   Figure 16f.

Figure 16 (a-f). Scheme of nadir measurements in the Benkovac minefield 2013. a) Scheme of collecting hyperspectral data. b) Aerial color image of the minefield. c) Legend of ground based nadir survey. d), e), and f) Types of the objects buried in the public part, landmines PMA-2, PMA-3, parts of a rifle grenade.
Figures courtesy of HCR-CTRO.

DETECTING THE DIFFERENCES OF GRASSY VEGETATION IN AND OUT OF THE MINEFIELD

The first hyperspectral data of grass inside the Benkovac minefield were collected by the V9 line scanner with a ground based nadir looking system, Figure 7a (page 55), Figure 16. Around 1,000 mines are buried in the Benkovac minefield. Locations for 150 mines are available for the public part of Figure 3a (page 50), while the mines in the blind test area are aimed at blind statistical tests and their distribution is not available. The mines are randomly distributed in 45 rows, each is 45 m long and 1 m wide. Between rows there are 3 m wide paths, and mines are buried in 1 x 1 m squares.

An interesting fact was that the reflectance spectra of grass IN and OUT of the minefield are different. The reflectance spectra IN the minefield show healthy grass in its full developmental phase, with a local maximum near 550 nm (chlorophyll), a deep minimum near 690 nm, and a step of reflectance after the red edge.
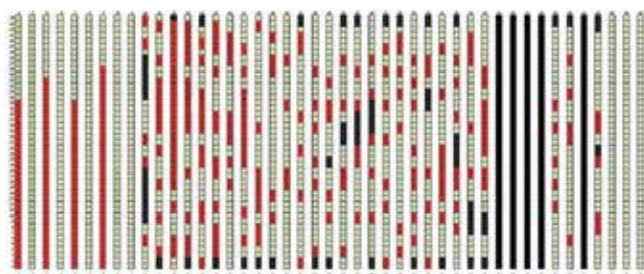
The spectra of the grass OUT of the minefield had distorted form, very different from the form of grass in the minefield. In the following phase, many different vegetation indices (from ENVI software list) were tested regarding their potential to quantify results of the mentioned spectral difference. In this analysis, we used the hyperspectral data collected by the V9 line scanner from a helicopter flying at altitudes of 210 m and 400 m. The provided spatial resolution was 0.4 m, data were parametrically geocoded and the radiometric/atmospheric calibrating were applied. Among the considered vegetation indices, six were stable in discriminating grass IN and OUT of the minefield, Table 2. The best results were obtained via carotenoid, whereas the chlorophyll total and CRI indices were obtained from Gitelson 2002, therefore further

Benkovac	Simple ratio index		Red edge NDVI		Vogelman 1		Carotenoid		Chlorophyll total		CRI	
Areas Fig. 3	min	max	min	max	min	max	min	max	min	max	min	max
OUT	0	7.21	0	0.47	0	1.98	-1.7	18.9	0	.64	0	11.8
IN	0	13.8	0	0.58	0	2.32	-0.8	26.3	0	1.1	0	15.9
Part of IN for blind tests	0	13.8	0	0.58	0	2.32	-0.8	26.3	0	1.1	0	15.9

Table 2. Range of values for Benkovac's vegetation indices.
Table courtesy of the authors.

analysis was done via carotenoid.[42] Note that data used for these three indices were collected by near real-time frame sensor UHD-185 from a helicopter, Figure 17. Data for bushes and trees are manually excluded from analysis (white blobs). The red polygon is the border of the whole Benkovac minefield.

The spatial distribution of the carotenoid of the grassy vegetation decreases if the threshold of the carotenoid is increasing, Figure 18 (page 62). These changes are presented in Figure 19 (page 62). The probability density function (PDF) proves that vegetation IN and OUT of the minefield can be discriminated.

DISCUSSION

The large and costly airborne hyperspectral systems were available for more than two decades yet without any impact on humanitarian mine action.[2] Alternatively, the application of hyperspectral technology in many civilian domains is widely used and well developed and has good results and significant impacts. The availability of hyperspectral sensors, which are suitable for use via multi-engine UAVs, enables the development of systems that can be implemented in humanitarian mine action. In the scope of the 2012 TIRAMISU project, two approaches were defined with regard to hyperspectral detection of minefields and SHAs.[4] The first approach was realized by three tasks. The first task was aimed at researching and developing the hyperspectral system for data collecting via multi-engine UAV and helicopter, which are suitable for hyperspectral NTS. The second task was to collect hyperspectral data of UXO inside areas where ammunition depots have exploded, including pure spectral samples (endmembers) of the area and the object of interest. The third task was to analyze and verify the vegetation indices that show the difference between grassy vegetation IN and OUT of the minefield. All three tasks were accomplished. The results, the conditions, and the limitations are presented in the current paper and elsewhere.[13] The system for collecting hyperspectral data via multi-engine UAV and helicopter was operationally validated and the hyperspectral NTS functionality is included in the operational TIRAMISU Advanced Intelligence Decision Support System (T-AIDSS), which is the advanced version of AIDSS.[4,36]
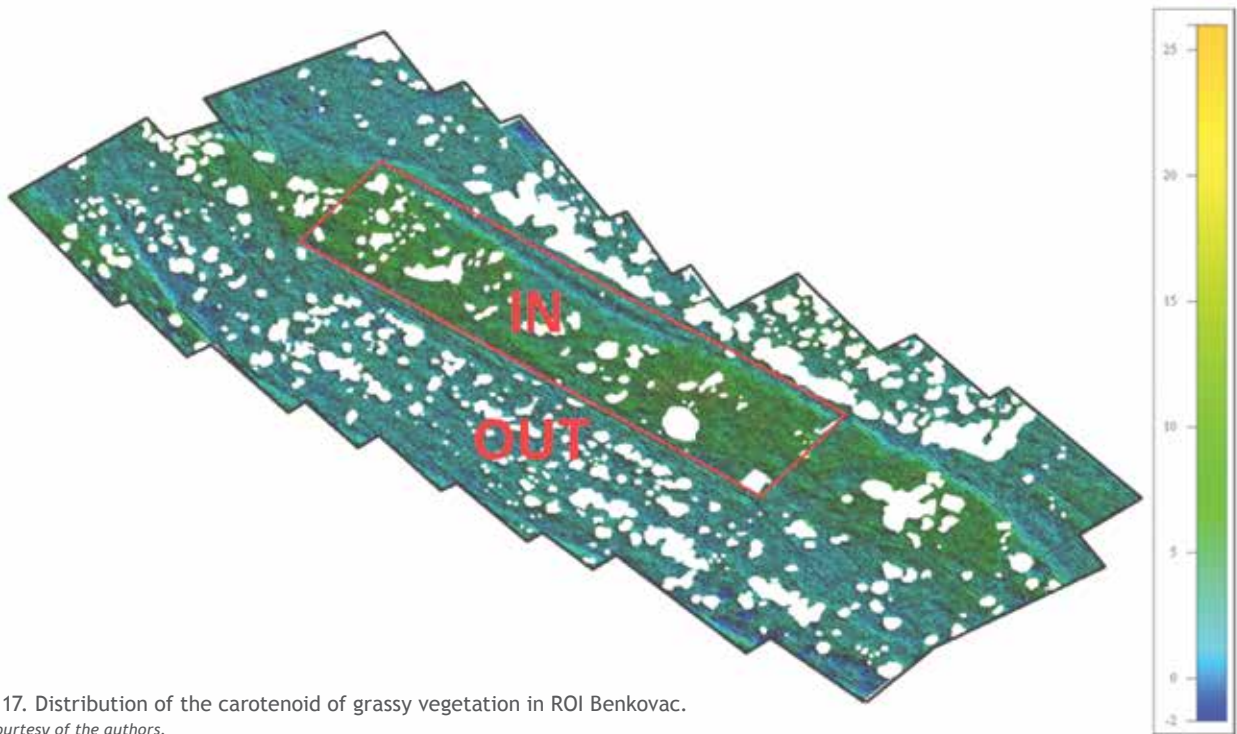

Figure 17. Distribution of the carotenoid of grassy vegetation in ROI Benkovac.
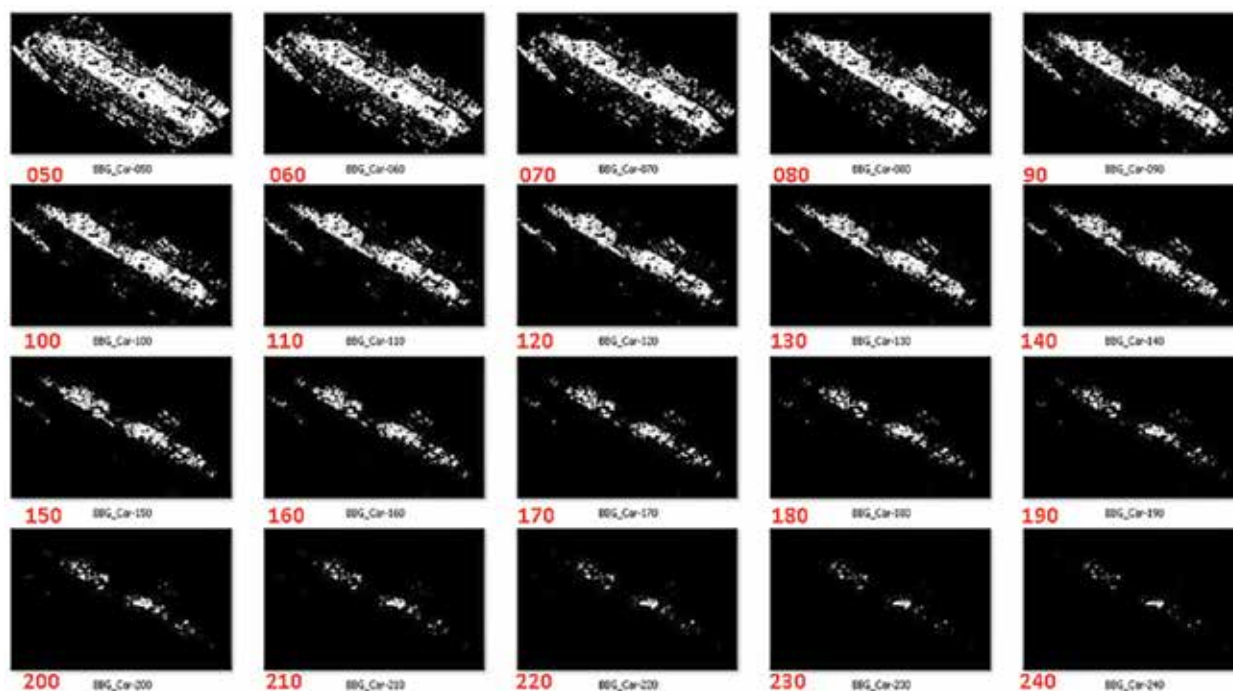*Figure courtesy of the authors.*

Figure 18. Increasing the carotenoid threshold decreases the outside (OUT) area quicker than the area inside (IN). Red font indicates the threshold level, which is changed from minimum (-2) to maximum (44) and scaled in the range from 0 to 255 (8 bits).
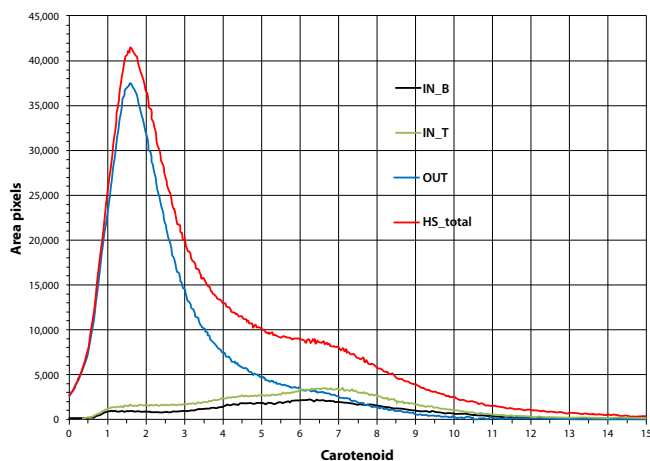*Figure courtesy of the authors.*

Figure 19. Decrease of the areas with the carotenoid outside (OUT and inside (IN, IN_B) the minefield near Benkovac.
Figure courtesy of the authors.

Figure 20. Probability density function of carotenoid inside of the Benkovac minefield (PDF_IN_B, PDF_IN_T) and outside (PDF_OUT), the dependence on values of threshold level values.
Figure courtesy of the authors.

Although the 2012 TIRAMISU project was planned to combine the top-down and bottom-up approaches to the research, we were limited to two minefields (10,000 sq m and 504,000 sq m) instead on the large area (136 sq km = 136,000,000 sq m). Regardless, a simple analysis of the reflectance spectra of the grassy vegetation in the considered minefield and its neighboring areas showed an increase of greenness and vegetation stress, visible in the deteriorated shape of the reflectance response in comparison to the shape of healthy vegetation.[30,31,32,43] In the analysis of the data collected by the V9 line scanner, we excluded ground (soil) contribution by using the normalized difference vegetation index, while the bushes and trees data were manually excluded for both sensors.

Six of many considered vegetation indices that are verified to be suitable for the discrimination of grassy vegetation IN and OUT of the minefield have been analyzed, whereas only the results for the carotenoid are shown. Future research should apply the fusion methods of available indices where improvement is expected.[17]

CONCLUSION

- The first goal was achieved: we developed a system suitable for hyperspectral NTS based on the application of currently available hyperspectral sensors for multi-engine UAVs. The use of full frame hyperspectral camera mounted via UAV was proved an innovation for the framework of mine action.

- The second goal was achieved: the hyperspectral cubes and pure spectral samples (endmembers) data were collected for a number of the UXO scattered after the ammunition depot explosion, and their use has been demonstrated for the mortar mine M60. The diagrams that link the needed probability of the survey (from the detection to the identification) were derived for all considered UXO.
- The third goal was achieved: proving that the spectral vegetation indices enable discrimination of the grassy vegetation IN and OUT of the minefield. This was thoroughly analyzed on several vegetation indices, whereas the example of the carotenoid was presented for the Benkovac minefield (spatial mines density 0.1 min/sq m).
- The appearance and the advancement of the operational characteristics of the hyperspectral sensors that are suitable for application from UAV is the challenge for deployment in humanitarian mine action as well as in counter-IED domains.
- A variety of interests and approaches came together, e.g., hyperspectral technology, vegetation, explosives. We invite cooperation in future joint efforts in this domain. ©

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Milan Bajić, Ph.D., Ret. Lt. Col., former professor of remote sensing at the Faculty of Geodesy, University of Zagreb. He is a member of the Scientific Council of HCR-CTRO, Zagreb, Croatia, and was involved in a number of projects and various emergency response, technology developments, capacity building, and advanced intelligence decision support avtivities in Croatia and Bosnia and Herzegovina. He led Croatian teams in the European Commission's research and development projects on airborne remote sensing for mine action (SMART, ARC, TIRAMISU), and has written more than 50 scientific papers about remote sensing and humanitarian mine action.

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Anna Brook, Ph.D., is a senior lecturer and head of the Remote Sensing Laboratory at the University of Haifa, Israel. She received her Ph.D. in environmental sciences with a thesis on "Reflectance Spectroscopy as a Tool to Assess the Quality of Concrete in situ" from the Porter School of Environmental Studies at Tel-Aviv University in 2010. Her current research interests include image and signal processing, automation target recognition, sub-pixel detection, spatial and temporal models and pattern recognition.

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The Early Years of Demining in Bosnia and Herzegovina: Transfer to National Ownership by Mansfield [from page 20]
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Bosnia and Herzegovina: ITF Perspective 20 Years After the Conflict by Sančanin [from page 24]
1. Based in Slovenia, *ITF Enhancing Human Security* was originally established as *International Trust Fund for Demining and Mine Victims Assistance (ITF)* in March 1998 and began operating under their new name in January 2012.
2. The state of Bosnia and Herzegovina (BiH) is composed of two largely autonomous constitutional and legal entities—the Federation of Bosnia and Herzegovina (mostly populated by Bosniaks and Croats) and Republic of Srpska (mostly populated by Serbs)—and a third micro entity, the Brčko District. The Federation of Bosnia and Herzegovina is a highly complex entity further consisting of 10 federal units—cantons—while the Republic of Srpska is a centralized republic. Bosnia and Herzegovina has a bicameral legislature and a three-member Presidency composed of a member from each major ethnic group. However, the state government power is highly limited as the BiH is largely decentralized, with the major political and administrative power contained within the two largely autonomous entities (Federation of BiH and Republic of Srpska).
3. Without consent and boycotted by the majority of BiH Serbian ethnic population.
4. By regular military formations as well as numerous para-military groups.
5. External state border established according to the former SFRY internal administrative republic borders.
6. From 20 December 1995 to 20 December 1996, a NATO-led international peacekeeping force (IFOR) of 60,000 troops deployed in Bosnia and Herzegovina to implement and monitor the military aspects of the Dayton Peace Accords, replacing the U.N. peacekeeping force UNPROFOR, which originally arrived in 1992. IFOR was succeeded by a smaller, NATO-led Stabilization Force (SFOR) whose mission was to deter any potential renewed hostilities. The European Union Force Althea (EUFOR Althea) replaced SFOR on 2 December 2004, and today consists of less than one thousand personnel.
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As the number one cause of military casualties, IEDs are one of the greatest threats to civilians in Afghanistan, Iraq, Libya, and Syria, and becoming an increasing threat in Europe, the United Kingdom and the United States. How are traditional humanitarian CWD programs dealing with the increasing prevalence of IEDs and pressure plate IEDs?

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SPOTLIGHT

Southeast Asia

How are international NGOs and national mine action operators in Southeast Asia addressing threats? What has changed in the way data is collected and analyzed? What lessons learned can be shared with the broader CWD community?

Of particular interest are Burma, Cambodia, Laos, Nepal, Thailand, and Vietnam.

FEATURE

Evolving Nature of Survey and Mobile Technologies

How has the prevalence of **mobile technology** changed the survey documentation process? What are some of the successes and challenges faced by CWD organizations when conducting surveys? How is the scope of a country's contamination measured? How is quality assurance measured prior to land release?

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SPOTLIGHT

Western Hemisphere

How have negotiations between governments and nonstate armed groups affected the demining process in Central and South America? What lessons learned can be taken from the ongoing demining operations conducted by military forces and their collaboration with newly accredited civilian deminers?

FEATURE

Physical Security and Stockpile Management (PSSM)

What are the most common challenges faced by organizations attempting to curb the spread of illicit small arms and light weapons? What lessons learned can be shared with the broader community? Potential topics relating to PSSM include ammunition disposal, stockpile management, surplus reduction, improved marking and tracing capabilities, and the destruction of illicit and obsolete SA/LW.

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