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In this issue: **Borehole Electromagnetics** and **The Effect of Water on Suppressing Explosions**

# THE JOURNAL

of Conventional Weapons Destruction

Issue 22.1 | April 2018

**EDITORIAL**  
**EVOLUTION**  
**OF PPE**  
**IN HMA**



**Spotlight on**

**EUROPE**

*Field Notes*

- Minefield Sketch Maps in HMA
- Mitigating Environmental Impact
- Clearance in Somaliland

CONTRIBUTING ORGANIZATIONS:



GICHD



Black Tusk  
GEOPHYSICS



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of Conventional Weapons Destruction

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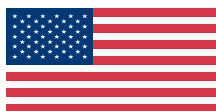
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**Cover Photo**

Members of Minekommando Dänemark holding warning signs from a cleared minefield, Jutland, Summer 1945. Image courtesy of Dan Mouritzsen - Silkeborg Bunkermuseum Denmark. See article page 19.



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JAMES MADISON UNIVERSITY



## FROM THE DIRECTOR

This April, I attended the 15th International Symposium “Mine Action 2018” in Slano, Croatia. Organized by the Office for Mine Action, Croatian Mine Action Centre, and HCR-CTRO, this four-day event was an exciting opportunity to learn about forthcoming detection technologies and current challenges in the field of humanitarian mine action. The conference gave me the chance to put forward HMA advancement throughout the years in a presentation entitled “Mining the Past for Future Mine Action Success.” It also provided me the occasion to speak with a wide number of highly-motivated and passionate researchers and program managers, all of whom I hope will continue to share their knowledge and experience with the rest of the HMA community.

Looking toward the future, others also reflect on the evolution of HMA throughout the years, both in various conferences around the world, including at the NDN-UN 2018 conference, when CISR hosted “Examining the Past to Promote Future Success,” that included panelists from the Afghanistan National Disaster Management Authority, GICHD, UNMAS and CISR. Similarly, our editorial for this issue is from Andy Smith, who considers the “Evolution of PPE.” He argues that although there has been few advances in the development of PPE in the past 20 years, improvements to procedures and equipment help mitigate hazards and reduces the risks to deminers. In addition, Smith argues that there are four needs that should be addressed: better blast-resistant hand tools, the invention of a lighter and stronger blast visor to encourage the correct use of visors, the development of flexible ceramic armor, and the ability to assess new products using low-cost tests that simulate typical demining accidents.

Our focus for this issue of *The Journal* is Europe. In their article, “Advanced Geophysical Classification of WWII-era Unexploded Bombs Using Borehole Electromagnetics,” Dr. Laurens Beran and Dr. Stephen Billings from Black Tusk Geophysics discuss the use of advanced geophysical classification (AGC) to reliably identify World War II-era unexploded bombs that continue to present public safety hazards in Germany. The article discusses survey design and the challenges of applying AGC to classify unexploded bombs in urban environments. In addition, Roly Evans from the Geneva International Centre for Humanitarian Demining shares his research on the vast clearance of minefields in Denmark following the end of World War II by between 750 and 2,600 German POWs or Surrendered Army Personnel.

From those working in the field, we have several exciting new articles. Ed Lajoie and Megan Dwyer from The HALO’s Trust (HALO) discuss operations in Somaliland, including manual and mechanical mine clearance, battle area clearance, mine risk education, and physical security and stockpile management. Also from HALO, Jesse Hamlin and Luan Jaupi explain how the Colotrac scanner digitize minefield sketch maps from the field for later use on desktop or laptop computers, archiving the maps as the historical records. From Janus Global Operations, Bradley Alford, Ed Curran, and Shawn Cole examine the use of unmanned aerial vehicles (UAV) to assist in search and clearance operations in Iraq. Additionally, Martin Jebens (DRM-Consultancy) and Gianluca Maspoli (GICHD) discusses the ways in which environmental concerns can successfully be mainstreamed into mine action operations. Lastly, Stephen Salter and John Parkes describe the physics behind why water can efficiently suppress the effects of explosions. Their article does an excellent job explaining the science at work and suggests how to create support structures that allow water to suppress explosions safely and effectively.

Looking toward the future, we are excited that CISR’s next Senior Managers’ Course will be regionally held in South and Central Asia, in Dushanbe, Tajikistan, from June 25 to July 13. CISR is honored to work with a great team from the Tajikistan National Mine Action Centre and other local partners. And in looking toward our next issue of *The Journal*, we have a variety of interesting topics to explore including a focus on Iraq and Syria, an editorial on the future of HMA, and the safe and secure management of ammunition.



Ken Rutherford  
CISR Director

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# PPE Development and Needs in HMA

by Andy Smith [ University of Genoa ]



Left to right, the image shows flechettes from a munition, pre-chopped fragments from a bounding fragmentation mine, and pre-scored diamond fragmentation from a submunition.

*Image courtesy of the author.*

As written in the International Mine Action Standards (IMAS) 10.30 on personal protective equipment (PPE), “the primary means of preventing explosive injury in the workplace is by the supervised use of demining tools and processes that reduce the likelihood of an unintended detonation.” The IMAS goes on to state that PPE “should be the final protective measure after all planning, training and procedural efforts to reduce risk have been taken.” To date the “final protective measure” has been to provide PPE that is **practical** but that does not provide full protection.

The threat posed by the blast wave(s) associated with the detonation of high or low explosive is highly dependent on the quantity of explosive involved. With small blast mines, the speed of the blast front (as the volume of gas expands) rapidly declines and many deminers wearing no protection on their bodies have suffered no body injury despite being very close during accidents. The evidence from the Database of Demining Accidents (DDAS) is that body armor serves little proven purpose when the accident involves a small blast mine unless the deminer’s hand-tool breaks up and becomes part of the hazard. In any close-quarter blast involving kilograms of explosive, the disruptive blast forces can pass through body armor and pulverize the cells of the wearer almost as effectively as if the armor were not there. Polycarbonate blast visors are also of no proven use in a large blast but are useful against small blasts. As long as the material is not deliberately

hardened, polycarbonate can flex in a way that has often prevented the blast front and associated tiny pieces of mine casing and unburned explosive from blinding the wearers.

It is fragmentation that causes most fatal injuries during demining. Fragmentation may come from the munition, from the soil and stones surrounding it, or tiny pieces of the explosive charge itself. Unsurprisingly, the most damaging kind of fragmentation is deliberately built into the munition either by designing a casing that fragments or by surrounding the explosive charge with fragments of metal, some of which may be shaped to be self-orientating and especially penetrating.

There are several reasons why the fragmentation threat to deminers has not been addressed despite the fact that even small fragmentation devices have regularly killed deminers wearing PPE.

1. To provide reliable protection against fragments by increasing the layers of flexible armor or by adding hard armor panels would increase weight dramatically. This would make the wearer uncomfortable and restrict mobility in a way that could increase the risk of an accident occurring. Experience indicates that it would also increase the risk of the PPE not being worn at all.
2. Effective fragmentation armor would have to be extended to protect the arms and legs because the spray of fragments is not confined to the torso. The improved armor would also have to cover the face and head, but





The images show combat body armor with a V50 of 450 m/s and a helmet after being struck by fragments from a PROM-1 bounding fragmentation mine. The deminer suffered multiple penetrations to torso, arms, and head and bled out rapidly. Images courtesy of the author.

effective transparent visor material that could match the protection of body armor is not available, so this is not possible.

3. The much increased costs would mean that demining organizations could not afford to do as much actual demining—and controlling the risks faced by deminers has to be balanced against the risks being faced by the population who are waiting for them to arrive.

Reasons one and two are based on the premise that any protection is only as good as its weakest point. To provide torso protection able to stop the fragments while leaving the wearer's arms or face unprotected is inconsistent and illogical. This is true, but it is not a good reason not to increase protection where we can because the PPE we provide is already inconsistent. The current IMAS requirement for body armor is a NATO STANAG V50 of 450 m/s while the face and eye protection is 5 mm polycarbonate, which has a NATO STANAG V50 of less than half of that.<sup>1,2</sup> The V50 is the speed at which half of the fragments (50 percent) compromise the protection. So how can we justify requiring torso protection that is far greater than for the face? The answer is that it is not logical, but it was the best we could do when this part of the IMAS was written.

There is always a balance to be drawn between what is practical and what is ideal. In humanitarian mine action (HMA), we have rarely pursued the ideal because whatever we do must be practical. This is seen as being realistic because many of the hazards we confront simply cannot be protected against with any PPE currently available.

For example, this KB1 submunition contains only 30 g of high explosive that produces an expanding blast front that is relatively easy to protect against at 30 cm. It also has a fragmentation body with steel ball bearings encased in a nylon body that most body armor used in HMA could stop at a distance of a meter, even if the visor could not. However, it

also has a shaped charge designed to penetrate armored steel, which nothing short of well-spaced layers of armored steel or reactive armor panels can stop close-up.

Whatever PPE is issued, the informed deminer knows that it cannot provide real protection against a worst case scenario, but that does not mean that we should not be trying to improve PPE so that it can provide effective protection more often.

The third reason for not improving PPE—increased cost—is unsound because failure to do “all that is reasonable” to protect the workers could end up costing the employer far more than the cost of better PPE. In the author's experience, most donors of HMA are open to requests for support to provide better PPE for those doing the work they fund.

#### Why Have There Been No Significant Improvements?

There have been improvements to demining PPE over the past twenty years, but most have been incremental. One example is



KB1 submission. Image courtesy of the author.



The images show the lighter blast visor and the ROFI face mask.<sup>5,6</sup>  
 Images courtesy of the author.

the availability of lighter body armor materials with a tighter weave that allows higher levels of protection to be achieved in a garment of the same weight, or more of the wearer to be covered without a weight increase. The design of a lighter visor and some improved hand tools have also been incremental improvements.<sup>3</sup> The ROFI demining face mask is the only truly novel advance because it makes use of a very lightweight laminate named PURE, but its design has been criticized and it is not widely used.<sup>4</sup>

Changes to demining PPE over the last twenty years have been largely minor for three reasons.

1. **Lack of demand.** There is a general absence of an expressed wish for better PPE from the end users or their managers.
2. **The current risk is thought tolerable.** A generally low level of accidents has led many involved in demining to consider the current level of risk to be tolerable.
3. **There are more immediate ways to manage risk.** Managing risk by making improvements to procedures is known to be effective at preventing injury, so efforts in that direction are more likely to yield immediate benefits.

#### Lack of Demand

Although deminers rarely ask for better PPE, that may be because they often believe that the PPE they have provides greater protection than it does or that nothing better is available.

The industry needs a PPE testing regime that provides a relevant means of comparing one PPE product with another. The only test we currently have is the NATO STANAG 2920 test, which was designed to provide a comparable measure of the protection offered against bullets and fragments in a combat scenario. To this end, the STANAG testing regime involves firing single, carefully shaped and weighed fragments of a very hard metal directly down a barrel toward the material at precisely measured speeds. The test is repeated at least six times with each strike well separated from the others. The result is calculated as a V50 in meters or feet per second.

Almost every part of the STANAG test is inappropriate to use when appraising demining PPE. When an explosive hazard detonates in front of a deminer, the PPE is struck by a blast front, which the test does nothing to replicate. It is also struck by fragments of the ground and parts of the munition's casing and/or deliberate fragments inside it. It may be struck by multiple fragments that are bunched closely together or following one after another. The fragments are not of a strictly controlled hardness, shape, and weight and have not been fired from a barrel. Even the pre-shaped fragments in fragmentation munitions tumble in the air, which usually makes them much easier to stop than a directed projectile moving at the same velocity. However, the explosions that launch these fragments can generate a brief heat of over 4,000 degrees Celsius (e.g., TNT) and some heat is transferred to the fragments, which can become hot enough to damage the material





There are large holes penetrating this body armor material, which has burned and shrunk away from hot fragments from a bounding mine. The material had a NATO STANAG 2920 V50 in excess of 450 m/s. Image courtesy of DDAS.

they strike by melting or burning it. It is true that much of the kinetic energy in any projectile is converted to heat when it is obliged to stop rapidly, but some fragments generated by mines and explosive ordnance start off hot, a fact that makes some PPE materials shrink away from them.

In 2007, a European Workshop Agreement resulted in the publication of a test protocol for demining PPE that was referenced in IMAS 10.30 in 2008 but was quickly found to be unfit for purpose and quietly removed in 2010.<sup>7,8</sup> An attempt to create a better European agreement was started by the Royal Military Academy (RMA) in Belgium as part of the TIRAMISU project in 2016 but was not completed.<sup>9</sup> One feature of the planned test was the use of a triple-barrel fragment launcher so that the effect of near simultaneous fragment strikes could be measured. There would still be no way of recording the heat of the fragment during flight, but this would be an advance because some armor materials cannot withstand multiple simultaneous impacts as well as others.

### The Current Risk is Thought Tolerable

The definition of **tolerable risk** in the IMAS is “risk which is accepted in a given context based on current values of society.”<sup>10</sup> This is taken directly from the definition used by the International Standards Organization (ISO) and was designed to apply across all industries, not specifically those dealing with explosive hazards in countries that lack the means to clear the hazards themselves. Every industry is intended to interpret that definition appropriately in their own working context.

The level of risk that people live with during conflict is usually higher than it would be during peacetime,

and this is a level of risk that is unavoidable and “accepted in a given context.”<sup>10</sup> When conflict is over, people often become accustomed to living with a higher level of risk than would be tolerated elsewhere. It is inappropriate for any humanitarian demining organization to adopt the high-risk mindset that may prevail in an insecure post-conflict context because it is the current humanitarian values in peaceful and secure societies that should apply. These are the values that those paying for humanitarian mine action want to promote as part of supporting a sustainable peace.

Throughout the history of HMA, the high level of risk that is tolerated where we work has been used to justify using lower levels of PPE than is acceptable during such activities as range clearance and explosive ordnance disposal (EOD) tasks in Europe and America. Early demining PPE was inadequate and ranged from industrial safety spectacles to combat armor and purpose-designed albeit minimal protection.

The requirements of the IMAS published in 2001 went some way to level that playing field but did not bring standards up to those used in civil EOD work in Europe and the United States, because those drafting the IMAS, including the author, deemed that impractical. However, if we could reduce the number of deminer injuries and/or the severity of their injuries, it is an obligation for any **humanitarian** organization to do so because we must do “everything reasonable” to manage and reduce risk of injury to our employees. So the current risk is only tolerable if we can show that we have done everything reasonable to manage and mitigate risk and show that we have done this in a way that would satisfy a court of law. Some international demining insurance



The image shows the RMA’s triple fragment launcher for testing PPE with near-simultaneous strikes. Image courtesy of Georgios Kechagiadakis and Marc Pirlot.



Left to right, the images show demining PPE used in Mozambique and Cambodia in 1997.<sup>11</sup>  
 Images courtesy of the author.

providers insist that the minimum level of PPE required in the IMAS is used, which implies that the IMAS level of PPE is broadly accepted as being **reasonable**, but PPE is only the final protective measure after all other reasonable means of managing risk have been taken.

The definition of tolerable risk in the current edition of the National Mine Action Standards in Lebanon includes examples that may be useful to others:<sup>13</sup>

*“...The ‘tolerable risk’ remaining after an area has been searched, cleared and released is the risk of explosive hazards being beneath the required search depth in that task area. The ‘tolerable risk’ to demining staff is the risk remaining after all reasonable efforts have been made to train, equip and supervise staff in the conduct of inherently safe demining procedures. All reasonable effort includes the production of a formal task risk assessment designed to ensure that appropriate measures to mitigate risk are taken. All formal risk assessments must be updated as work progresses and new*

*information becomes known. The Lebanon Mine Action Centre determines the level of risk that is tolerable at any task. In the event of disagreement, the final arbiters of what is ‘all reasonable effort’ shall be the Government and Courts of Justice in Lebanon.”<sup>14</sup>*

#### There Are More Immediate Ways to Manage Risk

Dramatic progress has been made in risk avoidance over the past twenty years. One breakthrough came because of advances in metal detector technology, which meant that many hazards with a minimum-metal content could be reliably located. Another was the use of small radio-controlled machines to process areas with fragmentation mines before the deminers deployed.<sup>15</sup> Then came the use of long-handled rakes for excavation that used distance to avoid injury when there was an anti-personnel blast mine detonation. Today, there is the increasing use of unmanned aerial vehicles (UAV) with high-resolution cameras that are able to hover and allow the remote inspection of potential hazards before anyone approaches.



The images show the PPE currently being used by a demining organization clearing improvised explosive devices (IED) in Syria. In the author’s opinion, they are doing everything reasonable to protect their workers both with PPE and with specialist IED training.  
 Images courtesy of MAT Kosovo.<sup>12</sup>



Images from a small unmanned aircraft (SUA) show the extent of structural damage, then close-up views of visible suspicious items.

Images courtesy of field operatives in Syria.

In the example above in Raqqah, Syria, in February 2018, a preliminary camera overview helped to identify access routes and make informed decisions about approaches that minimized risk to the workers. The skilled pilot then used the camera to look through doorways and windows and could identify a passive infrared (PIR) triggered IED (in the cardboard box with the sensor protruding) before anyone approached. The small unmanned aircraft (SUA) gave the organization an up-to-date overview of the extent of structural damage (a common cause of non-explosive injury), then a close-up view of visible suspicious items. They used this information to make an informed search plan that minimized risk to their staff.

Those conducting any kind of risk management must first have had appropriate training and/or experience so that they can identify and mitigate risks. Thereafter, managing risk effectively in HMA relies on having as much information about each unique task as possible so that an evidence-based risk assessment can be made. The use of SUA in Syria provides a good example of extending the knowledge available, improving identification and better mitigating risks in that context. Of course the process does not eliminate risk, but it does show an organization making “all reasonable effort” to identify risks as they plan to avoid casualties.

### Needs

The accident record in the DDAS shows that PPE has been worth wearing because it has often reduced the number or the severity of the wearer’s injuries. Although we have never had PPE that could reliably protect against all common fragmentation hazards in HMA, we still do not have a way to assess the relative effectiveness of existing or new PPE products, which might do better.

The hierarchy of common disabling injuries resulting from demining accidents over the past twenty years has only changed because stepping on a mine has become much less

frequent. As a result, catastrophic damage to hands and eyes are now by far the most common severe injuries. Meanwhile, fragmentation injuries still cause the most deaths.

Although there have been no significant advances in demining PPE over the past twenty years, there has been a reduction in the IMAS PPE requirement.<sup>16</sup> The original 2001 IMAS 10.30 PPE requirements included the provision of frontal throat protection and the wearing of a full-face visor. In 2008, these former requirements were downgraded to recommendations.<sup>17</sup> The author asked for one of these changes because the accident record showed that visors were not being worn (or worn correctly) when accidents occurred whereas goggles were already being used to good effect.<sup>18</sup> The requirement was reduced to allow the wearing of goggles but recommended the continued use of visors. The downgrading of the requirement for throat protection appears to have gone unnoticed because almost all demining body armor still has a collar that folds back in a blast and protects the wearer’s throat. Nonetheless, after the passage of ten years, it is perhaps time that the PPE requirements in IMAS 10.30 were revisited.

There are at least four other needs related to PPE that should be addressed:

1. To reduce the severity of blast injuries, further improvements in the design of blast resistant hand-tools would be beneficial, as would their adoption by organizations who have not yet done so (the IMAS recommend their use but do not require it).
2. To reduce eye loss, the invention of a lighter and stronger blast visor material could encourage the correct use of visors. This is rumored to have already happened; however, the material’s manufacture and use have yet to filter down to readily available and affordable demining PPE.
3. To increase body protection, the development of flexible ceramic armor (e.g., modified Dragon Skin armor) or the use of PURE (i.e., the light material used in the





Smith (front) wearing the most commonly used demining PPE in Tajikistan in 2016 - the deminers behind are wearing the ROFI mask. Images courtesy of Major Firuz Asadbekov, Humanitarian Demining unit, Army of Tajikistan.

ROFI demining face mask) would be worthwhile. This armor need not be able to protect against rifle fire (often approaching 1,000 m/s), but any increase to comfort and affordability in deminer protection would be an improvement.

4. To allow end users to compare products, the ability to compare one PPE product's performance against another in a low-cost test that replicated an agreed, typical demining accident event would encourage manufacturers to make further incremental improvements.

Finally, while the PPE provision has remained fairly static, the refinement and development of procedures and equipment that keep people at a distance from the hazards has reduced risk to the deminers in many organizations over the past 20 years. Alongside the formal conduct of disciplined risk assessments, the author believes that the avoidance approach of responsible field operatives often demonstrates doing "all that is reasonable" to make risk tolerable in spite of the inadequacy of the available PPE.<sup>19</sup> ©

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A.V. Smith (AVS, Andy Smith) served as a PPE specialist on the International Mine Action Standards (IMAS) Review Board for 11 years and was the founder and keeper of the DDAS.<sup>20</sup> He has worked in humanitarian mine action (HMA) over more than 20 years at all levels from surveyor/deminer to Chief Technical Advisor to UNDP country programs. Having drafted the original IMAS Technical Note for Mine Action on Field Risk Assessment (TNMA), he was contracted by the Geneva International Centre for Humanitarian Demining (GICHD) to produce current field risk assessment training materials in 2016.<sup>21</sup>

FEATURE

# ADVANCED GEOPHYSICAL CLASSIFICATION OF WWII-ERA UNEXPLODED BOMBS USING BOREHOLE ELECTROMAGNETICS

by Laurens Beran, Ph.D., and Stephen Billings, Ph.D. [ Black Tusk Geophysics, Inc. ]

The legacy of World War II-era unexploded bombs (UXB) is an ongoing public safety hazard throughout Europe, and especially in Germany. Large, air-dropped bombs that are a legacy of Allied bombing campaigns are discovered on a weekly basis in Germany, requiring evacuations and disposal efforts costing hundreds of thousands of Euros in some instances.

This article presents recent work done by Black Tusk Geophysics using advanced geophysical classification (AGC) to reliably identify hazardous ordnance at urban sites in Germany. After briefly describing electromagnetic (EM) sensors and data processing required for AGC, this article will discuss survey and design considerations for characterization of large, deep UXBs in urban environments.

## Advanced Geophysical Classification

AGC combines geophysical sensors designed for detection and characterization of metallic targets with physical modeling of digital data to extract an intrinsic fingerprint for each target. This approach allows for reliable identification of intact ordnance and rejection of metallic clutter that would otherwise be excavated using conventional clearance methods (e.g., analog detection). Through U.S. Government-funded research and development programs, AGC technology has now matured to the point that it is mandated for munitions response work in the United States, and contractors must obtain International Organization for Standardization (ISO) accreditation to perform AGC work.<sup>1</sup>

AGC EM sensors rely on the same pulse-induction principles used in conventional metal detectors.<sup>2</sup> A time-varying primary magnetic field is transmitted into the earth and induces currents in electrically conductive targets. These induced currents in turn radiate a secondary magnetic field that is measured by receivers at the surface. In order to support

target classification, advanced EM sensors employ three or more transmitters to obtain multiple looks at a target, and multiple receivers measure all components (i.e., x, y, and z) of the secondary fields induced by each transmitter.

These digital data are subsequently processed to recover a location, orientation, and depth for each detected target. Additionally, intrinsic target parameters, or **polarizabilities**, estimated from the data provide a target fingerprint and can be matched against a library of polarizabilities for ordnance. Polarizabilities also provide an indication of a target's size, shape, and composition (i.e., magnetic or non-magnetic metal), and can be used to identify unexpected ordnance that may not be included in a library.

## Advanced Geophysical Classification for Large and Deep UXB

In the context of the German UXB problem, there are two main challenges to the application of AGC. First, ordnance can be significantly deeper than is typically encountered at North American military ranges. Whereas mortars and projectiles are usually restricted to the top 2 m below ground surface, larger, air-dropped bombs of 250 lbs or greater are regularly encountered at depths up to 10 m. This is well outside the detection range of typical AGC sensors. Second, most urban sites have nearby infrastructure with a significant amount of metal (e.g., rebar, piping, etc.) that produces a strong EM response and obscures the signal from targets of interest. Images 1 through 4 (next page) show examples of urban locations where we have carried out borehole AGC surveys in Germany.

To overcome these challenges to AGC in Germany, we use a high-current transmitter and large transmitter loops to illuminate targets at depth. This produces a stronger field at depth than is possible with typical AGC sensors, which have transmitter loop sizes on the order of 1 m. Loops are





Image 1



Image 2



Image 3



Image 4

Images 1-4 (left). Examples of borehole EM surveys carried out at urban sites in Germany (blue PVC tubes are borehole casings). The red cable, most evident in Image 2, shows the transmitter cable, and wooden stakes are used to position loop corners. The yellow table visible in Image 3 is used to orient and lock the grey vertical shaft, which has the fluxgate magnetometer at its downhole end.

*All graphics courtesy of Boskalis Hirdes GmbH.*

ideally arranged to obtain illumination of a deep target from multiple directions. This is achieved with a rectangular transmitter loop that generates a vertical field, and figure-eight loops that generate horizontal fields (Figure 1, next page).

The field team collects measurements of the secondary field induced in a buried target using a fluxgate magnetometer that is deployed down boreholes. Fluxgate receiver measurements collected at depth significantly increase the amplitude of the measured target response and attenuate the background response due to infrastructure. This allows classification of targets that cannot be detected by typical AGC sensors deployed at the surface.

Typically, a prospective target is initially detected with another geophysical sensor deployed at the surface (e.g., ground penetrating radar or magnetics). Boreholes are subsequently drilled and cased with PVC tubing at approximately 2 m distance from the target. Fluxgate measurements are made at 0.5 m intervals in each borehole, ideally at depths ranging down to 2 m below the expected target. The fluxgate magnetometer measures three components of the magnetic field induced in a target. This receiver also provides a much longer measurement window (about 50 ms) than the loop receivers usually used for AGC applications (typically extending out to about 25 ms). This longer window allows for improved target classification in the presence of the background infrastructure response, as well as rejection of fast-decaying clutter. The fluxgate magnetometer data does, however, require removal of the earth's ambient magnetic field as well as careful control of sensor orientation during data acquisition.



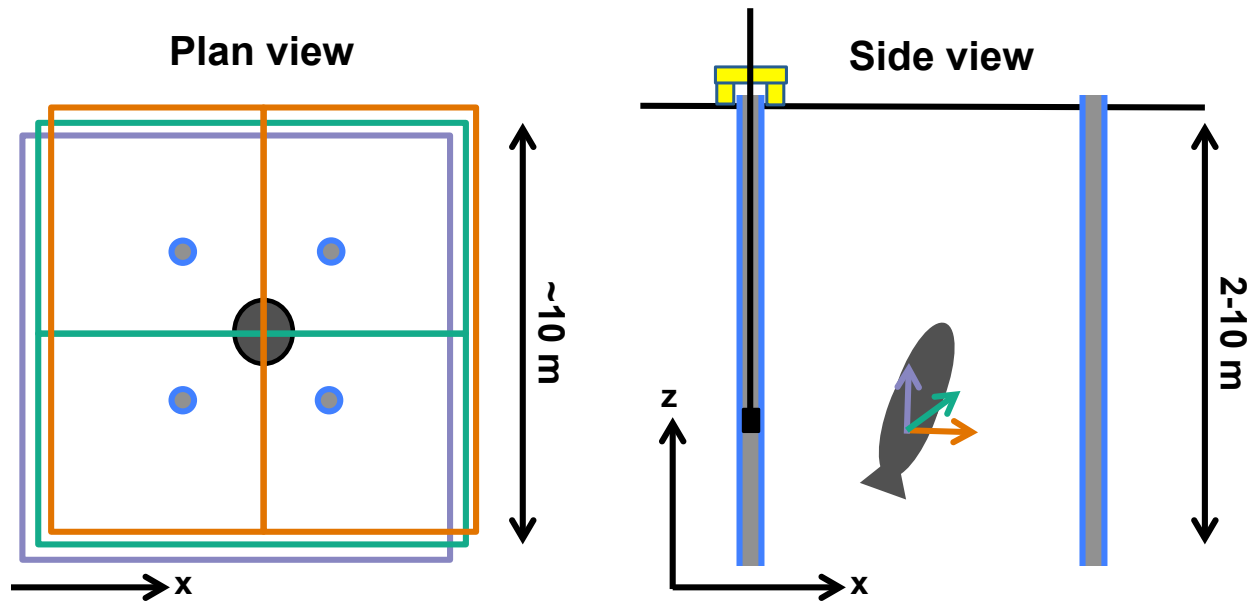


Figure 1 (above). Schematic of borehole EM survey. On the left, the plan view shows transmitter loops that generate primary magnetic fields directed in x, y, and z directions at the center of the survey (red, green, and blue lines, respectively). Loop offsets are for visualization; in practice loop corners coincide. Blue circles show typical borehole geometry with boreholes offset approximately 2 m from the center of the survey. On the right, the side view shows primary magnetic fields at the location of a buried target, boreholes, and receiver apparatus (yellow table and downhole magnetometer in left borehole).

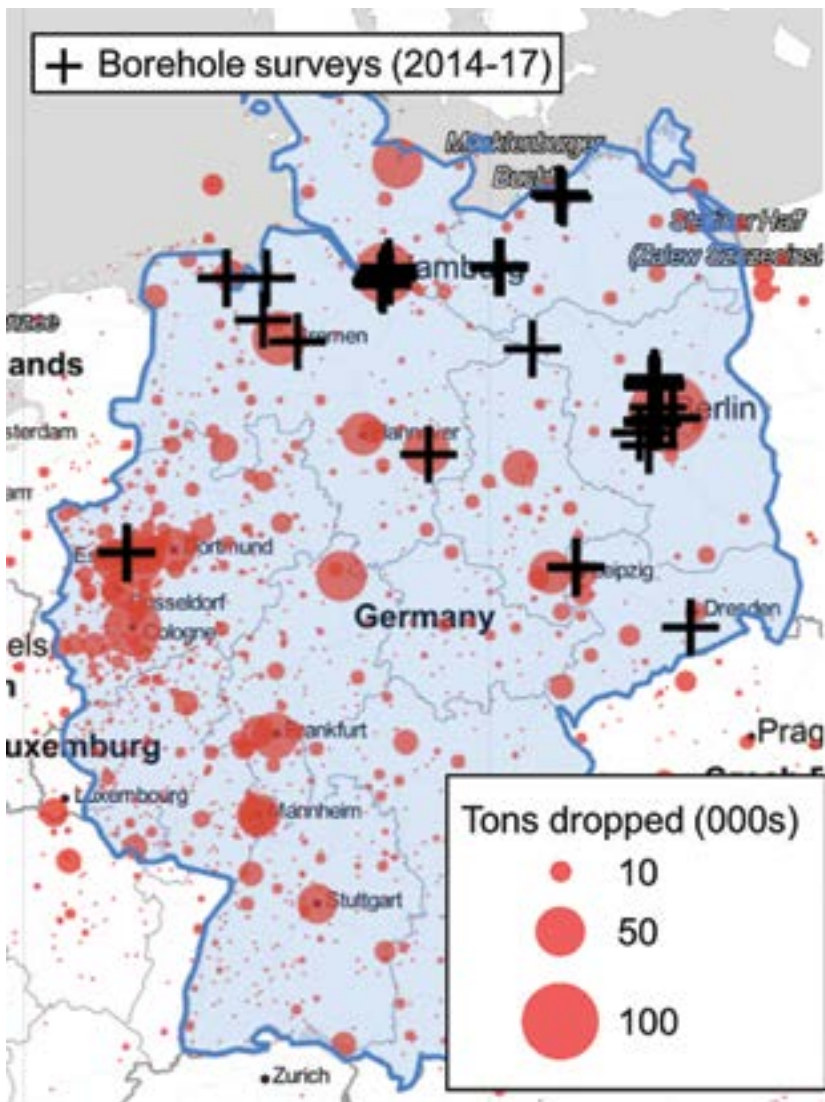


Figure 2 (right). Historical map of Allied bombing from 1939 to 1945, generated using Theater History of Operations data.<sup>3</sup> Approximately 150 locations in northern Germany surveyed using borehole electromagnetics are also shown, with a large concentration in Oranienburg, just north of Berlin.



Image 5

Borehole survey in Oranienburg, Germany.



Image 6



Image 7

A 500 lb U.S. General Purpose (GP) bomb subsequently excavated at this site. The target was reflected off of bedrock, resulting in a nose-up orientation that prevented triggering of the delayed-action fuse.

### UXB Classification in Oranienburg, Germany

Since 2014, Black Tusk Geophysics and partners have carried out more than 100 borehole surveys to characterize buried targets in Germany (Figure 2). The work has been concentrated in and around Berlin and in particular in the northern suburb of Oranienburg. This town underwent heavy aerial bombardment from 1944 to 1945. Oranienburg was targeted for its military and logistical importance, and because it was the site of

uranium processing for the German nuclear research program. On 15 March 1945, American B-17 bombers struck the town in order to prevent the advancing Soviets from seizing German nuclear facilities.

During multiple air raids on Oranienburg, Allied bombers dropped ordnance equipped with delayed action fuses designed to trigger detonation hours or days after impact. The fuses were designed to trigger if the bomb rested in a



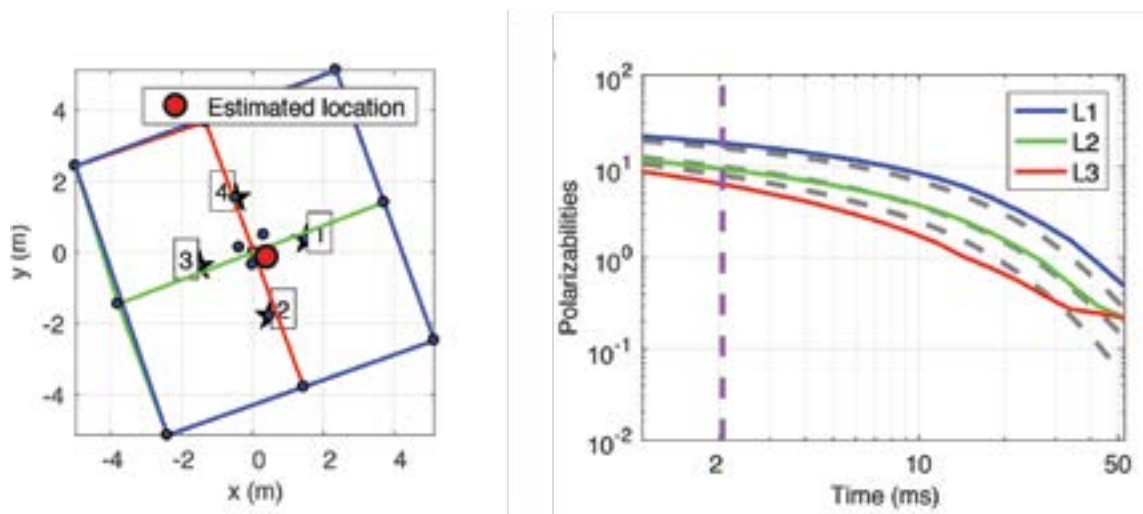


Figure 3. Borehole EM data and analysis for survey shown in Images 5, 6 and 7. Left: Borehole survey geometry with solid lines indicate transmitters, and numbered stars indicate measured boreholes. The red marker indicates estimated target location; the estimated depth is 3.9 m. Right: Estimated polarizabilities (solid lines) and reference polarizabilities for 500 lb U.S. GP bomb (dashed lines). The vertical dashed line indicates 2 ms time channel for data shown in Figure 4.

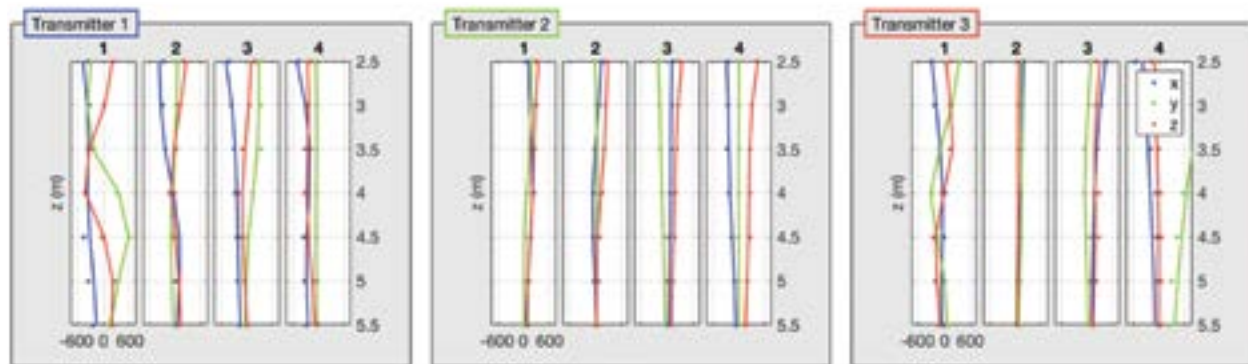


Figure 4. Data collected in the four boreholes for the survey in Figure 3. Axis titles indicate borehole numbers. Observed x, y, and z-component data (dots) were measured at 0.5 m intervals between 2.5 and 5.5 m below the ground surface. Data are in units of picoTesla/Ampere. A strong anomaly is apparent in the data, particularly in borehole 1. Predicted data obtained by fitting a model to the observed data are shown as solid lines. The model predicts a target at 4 m depth with location and polarizabilities shown in Figure 3.

nose-down orientation. However, many delayed action bombs in Oranienburg ended up in nose-up orientations after they encountered bedrock, and authorities estimate that there are hundreds of unexploded bombs still present in the town.<sup>4</sup> The delayed action fuses are highly unstable and can easily be triggered if a bomb is disturbed.

Images 5, 6 and 7 (previous page) show photos of a borehole EM survey and subsequent target excavation carried out in a pedestrian area in Oranienburg in 2017. Borehole data collected with this survey are shown in Figures 3 and 4. Our AGC analysis found that this anomaly was a good match to a 500 lb U.S. bomb, with slow-decaying polarizabilities that are indicative of intact ordnance.

While the previous example is a clear-cut case of an intact UXB, the majority of targets (about 80 percent) surveyed using borehole EM are eliminated as potential UXBs on the basis of

Black Tusk Geophysics' AGC analysis. Low amplitude and/or fast-decaying polarizabilities are diagnostic of smaller items and allow for unambiguous target classification and a reduction in unnecessary excavations. This is in contrast with other geophysical methods used to detect deep UXBs. In particular, while borehole magnetometry can reliably detect ferrous (e.g., steel) targets, characterization with magnetics data can be ambiguous because the parameters extracted from magnetics data are not uniquely related to target size.<sup>5</sup>

Finally, Images 8 and 9 (next page) highlight quality control (QC) of AGC using borehole EM. In the context of conventional AGC surveys using EM sensors deployed at the surface, blind seeding of standardized test items is used by regulators to verify that classification processing carried out by a contractor will identify all targets of interest. Given the size and depth of UXBs encountered in borehole surveys,





Images 8 and 9. Data collection at a borehole test pit. A 3 m deep test pit is used to collect measurements of ordnance that are then added to a reference library of target polarizabilities. The test pit is also used to collect QC measurements that verify classification processing.

blind seeding at field sites is impractical. We instead use data collected at a test site to verify that classification processing works for known items; groundtruth is withheld from the data analyst for these data sets. In addition, we have augmented our polarizability reference library by collecting high-quality measurements with inert ordnance in the test pit.

### Conclusion

Black Tusk Geophysics have extended AGC techniques developed for identification of small, near-surface munitions to the problem of large, deep UXBs in urban environments. Using large transmitter loops at the surface and receivers deployed down boreholes, this technology can minimize response from infrastructure and characterize targets that cannot be detected with EM sensors operating on the surface. AGC processing of borehole data provides improved identification of UXBs relative to other geophysical methods (magnetics or radar) and reduces unnecessary excavations of metallic clutter. Ongoing work is investigating the use of this technology for characterization of UXBs in the presence of magnetic soils in Southeast Asia.

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See endnotes page 61

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Dr. Laurens Beran is a senior geophysicist with Black Tusk Geophysics in Vancouver, Canada. He specializes in development and application of algorithms for classification of unexploded ordnance (UXO). Dr. Beran has served as the principal investigator of Strategic Environmental Research and Development Program (SERDP) projects MR-2226 and MR-1629. His current work focuses on detection and classification of deep UXO and underwater UXO. Dr. Beran completed his master's and doctoral degrees in geophysics at the University of British Columbia.

**Stephen Billings, Ph.D.**  
Adjunct Professor  
University of British Columbia



Dr. Stephen Billings has over 20 years' experience working with geophysical sensor data, including 17 years where he has concentrated on improving methods for detection and characterization of UXO. He is an adjunct professor in Earth and Ocean Sciences at the University of British Columbia. He has also been a principal investigator on 10 completed SERDP-ESTCP munitions response projects, ranging from developing and testing classification strategies for magnetic and electromagnetic sensors to developing and certifying new sensor systems. Dr. Billings is based in Brisbane, Australia.



*in the SPOTLIGHT*

**EUROPE**



# Lessons from the Past: The Rapid Clearance of Denmark's Minefields in 1945

by Roly Evans [ Geneva International Centre for Humanitarian Demining ]

The clearance of the vast majority of Denmark's minefields during 1945 was remarkable. In just under five months, a force ranging between 750 and 2,600 German prisoners of war (POW) under the supervision of 250–350 Danish officers and noncommissioned officers cleared 1,389,281 mines from an area of 1,103.2 sq km (425.9 sq mi).<sup>1</sup> Such speed of clearance stands in stark contrast with much of modern humanitarian mine action since the 1990s. This article will explain how such speed was possible and why it could not reasonably be repeated today. The article will also identify a number of important lessons that remain to be learned.

Between 1943 and 1945, German forces in Denmark emplaced approximately 1,401,946 anti-personnel and anti-tank mines, mostly on beaches suitable for amphibious landing, but also around key facilities such as radar stations.<sup>2</sup> On 4 May 1945 at Lüneburg Heath, east of Hamburg, the Allies accepted the unconditional surrender of the German forces in Denmark, along with those in the Netherlands and northwest Germany. Item 3 of the Instrument of Surrender stipulated that “the German command is to carry out at once, and without argument or comment, all further orders that will be issued by the Allied Powers on any subject.”<sup>3</sup> On this basis an initial force of 1,000 German

Image 1. Order of General R.H. Dewing confirming the establishment of Minekommando Dänemark.  
Image courtesy of Vardemuseerne.

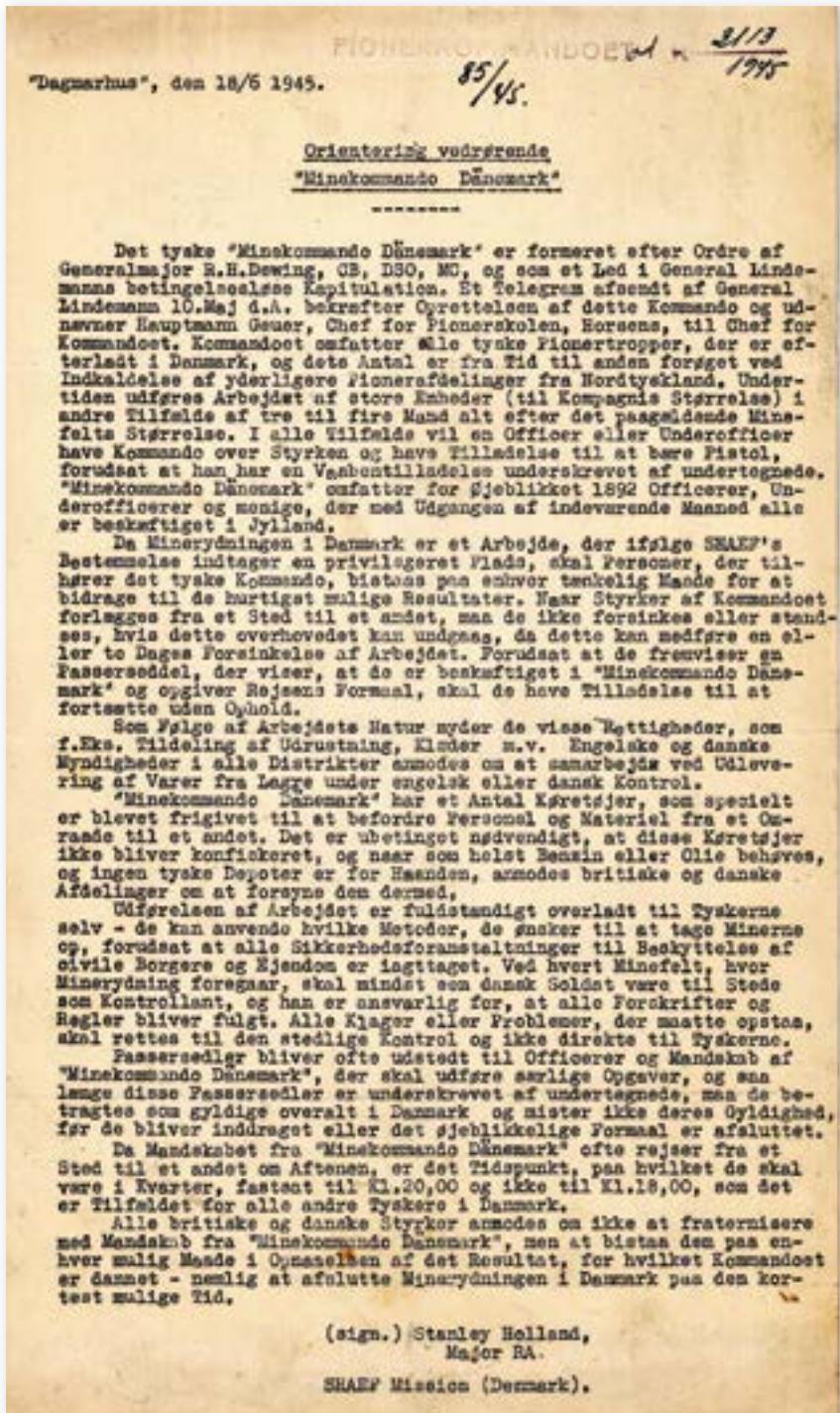






Image 2. A Sd.Kfz. 251 (Sonderkraftfahrzeug 251) halftrack alongside members of Minekommando Dänemark erecting a minefield fence, Jutland, Denmark, summer 1945. Excellent minefields records for the vast majority of minefields enabled accurate marking and fencing of dangerous areas and their rapid clearance in the summer of 1945. Image courtesy of the Danish Coastal Authority.



Image 3. Members of Minekommando Dänemark prodding for mines, Jutland Denmark, summer 1945. Prodding was often the main method of detection in Minekommando Dänemark, and this was probably linked to the high casualty rate. Today prodding is used as an aid excavation and is rarely deemed suitable as a primary means of detection. Note how close the deminers, without any PPE, are to each other. Today basic safety distances, site marking, and wearing of PPE would be enforced as a matter of routine. Mapham, James (Sergeant), No. 5 Army Film & Photographic Unit. Image courtesy of WAR OFFICE SECOND WORLD WAR OFFICIAL COLLECTION, IWM.

POWs, mostly Pioneer troops, were required to conduct clearance within Denmark. To better allow for the provisions of the 1929 Geneva Convention, the Germans were officially categorized as **Surrendered Enemy Personnel** rather than POWs. The other 200,000 odd German troops in Denmark returned to Germany in the weeks following the surrender.

Clearance started quickly and proceeded quickly. On 11 May 1945, within one week of the unconditional surrender, the first clearance tasks had begun.<sup>4</sup> This arrangement was formalized on 18 June 1945 with the founding of *Minekommando Dänemark* by order of General Dewing, commander of the British forces in Denmark. The initial contingent of 1,000 Pioneer soldiers had fallen to 750 in six weeks, most likely at least in part due to accidents; the June order increased the group to 1,892 officers and men.<sup>5</sup> By August 1945 the



Image 4. Still frame from the 1945 film *Livsfare Miner* showing members of Minekommando Dänemark prodding from a standing position for anti-tank mines, Jutland 1945. Image courtesy of the Danish Film Institute.<sup>13</sup>

number grew to 2,600.<sup>6</sup> Two-thirds of the personnel were directly employed in the field, while the remainder fulfilled staff functions. The organization of the clearance is worth noting. The British had overall command of the demining effort from the old German headquarters on Rådhuspladsen in Copenhagen. Major Stanley Holland, Royal Artillery, was the officer in charge. Supervision would be conducted by a cadre of about 250–350 Danish officers and men within an organization known as Dansk *Minekontrol*, headed by Kaptajn D.A.Wieth-Knudsen.<sup>7</sup> Working for both was the head of German Minekommando Dänemark, Hauptmann Geuer, formally Head of the Wehrmacht Pioneer School in Horsens.<sup>8,9</sup>

The Dewing order of 18 June 1945 was explicit on a number of points. First, “the execution of the work is completely left to the Germans themselves - they can use which methods they wish to take up the mines provided all security measures for the protection of civilians and property are observed. At each Minefield where mining takes place, at least one Danish soldier must be in control and he is responsible for compliance with all regulations and rules.”<sup>10</sup> Second, Minenkommando were to “complete the demining in Denmark at the shortest possible time.”<sup>11</sup>

The Germans used a number of methods to remove mines. Many of these would be deemed dangerous today. Safety distances between deminers were not observed in a way recognizable now. Prodding for mines in groups without any personal protective equipment was routine, whereas it now only tends to be used as a secondary aid to excavation rather than a primary detection technique. Prodding was also done using long prodders when searching for anti-tank mines.<sup>12</sup>

British Number 3 mine detectors were also available to search for metallic anti-tank mines, most commonly one of

four versions of the Tellermine. For anti-tank mines that were not easily detected, such as the Holzmine, only long prodders could be used. A breakdown of the 1,389,281 mines cleared between 11 May and 31 September 1945 can be found in Table 1.

Sometimes highly detailed clearance statistics were collected and recorded. Mines removed from a panel (i.e., a grouping or block of mine rows) would be marked as missing or booby-trapped. The same precision involved in creating the excellent minefield records was often repeated in the maintenance of clearance records.<sup>15</sup> At a national level the number of mines found per day was recorded (see Table 1). Even today, many countries could not give a similar breakdown of the mines and explosive remnants of war (ERW) cleared, despite the huge advances in information technology.

With pen, paper, and typewriters, better basic statistics were available over seventy years ago than is sometimes the case currently at national and even program level today.

Minekommando Dänemark also innovated in terms of the use of mechanical assets. A number of Panzer III tanks, StuG III assault guns, and Sd.Kfz. 251 halftracks, often in bad condition, were co-opted into service. Typically these would be used as some form of verification asset after clearance in a form of quality control known at the time as “test runs.” Two types of test runs were devised: an anti-tank minefield run and an anti-personnel and anti-tank minefield run. Unlike most modern mine verification vehicles, rollers were fitted to the rear of the tanks. Initially rollers were made of concrete,

Type of Mine	Model of Mine	Number Cleared - Type	Number Cleared - Model
<b>AT Mine</b>		452,819	
	Teller Mines		326,407
	Riegelmine		16,519
	Holzmine		85,435
	Pansermine Danemark		24,458
<b>AP Mine</b>		936,462	
	S-Mine		188,835
	Schützenmine		311,334
	Stockmine		213,338
	Schutzenmine Danemark og berger (locally made Schu Mines)		222,955
	<b>TOTAL</b>	<b>1,389,281</b>	<b>1,389,281</b>

Table 1. Table showing breakdown of mines cleared in Denmark 11 May-31 September 1945.<sup>14</sup> Table courtesy of author.





Image 5. Members of Minekommando Dänemark erecting a minefield fence, Jutland, Denmark, summer 1945. A bunker can just be made out on the sand dune behind the second figure from the right. As elsewhere on the Atlantic Wall, the minefields employed by the Germans were integrated into a wider defensive system and would often be covered by fire from a hardened shelter. *Image courtesy of the Danish Coastal Authority.*



Image 6. Members of Minekommando Dänemark pose on the front of a Sturmgeschütz III (StuG III) assault gun, Jutland, summer 1945. The StuG III was one of a number of armored vehicles used to tow rollers. *Image courtesy of the Danish Coastal Authority.*





Image 7. Members of Minekommando Dänemark pose with a number of Stockmine 43s and three Tellermine 42s cleared from a nearby minefield, Jutland, Denmark, summer 1945.  
*Image courtesy of Dan Mouritzsen - Silkeborg Bunkermuseum Denmark.*



Image 8. Members of Minekommando Dänemark walking the ground they have cleared in Jutland, Denmark, summer 1945. The practice of marching in close order over land to prove it was clear was widespread in the post-war years throughout Europe. Often the local population would be invited to observe in order to reassure them that their land was clear. While it appears callous, an equivalent does occur today—sometimes a clearance organization will play football on land cleared to reassure the local population. Mapham, James (Sergeant), No. 5 Army Film & Photographic Unit.  
*Image courtesy of WAR OFFICE SECOND WORLD WAR OFFICIAL COLLECTION, IWM.*





Image 9 (top). Still from the 2015 Danish-German film *Land of Mine*, showing cleared Tellermine 42s defused and awaiting transport to a demolition site. Often more mines were cleared daily in Denmark in 1945 than are cleared yearly in a number of countries today.

Image 10 (middle). Still from the 2015 Danish-German film *Land of Mine*, showing a character prodding for mines. Today if mines are hard to detect due to having minimum metal content or are in ground with heavy metal contamination, the deminer will usually employ full excavation within their lane rather than prodding.

Image 11 (bottom). Still from the 2015 Danish-German film *Land of Mine*, showing the terrain of the Junntland coast. All images this page courtesy of Camilla Hjelm.

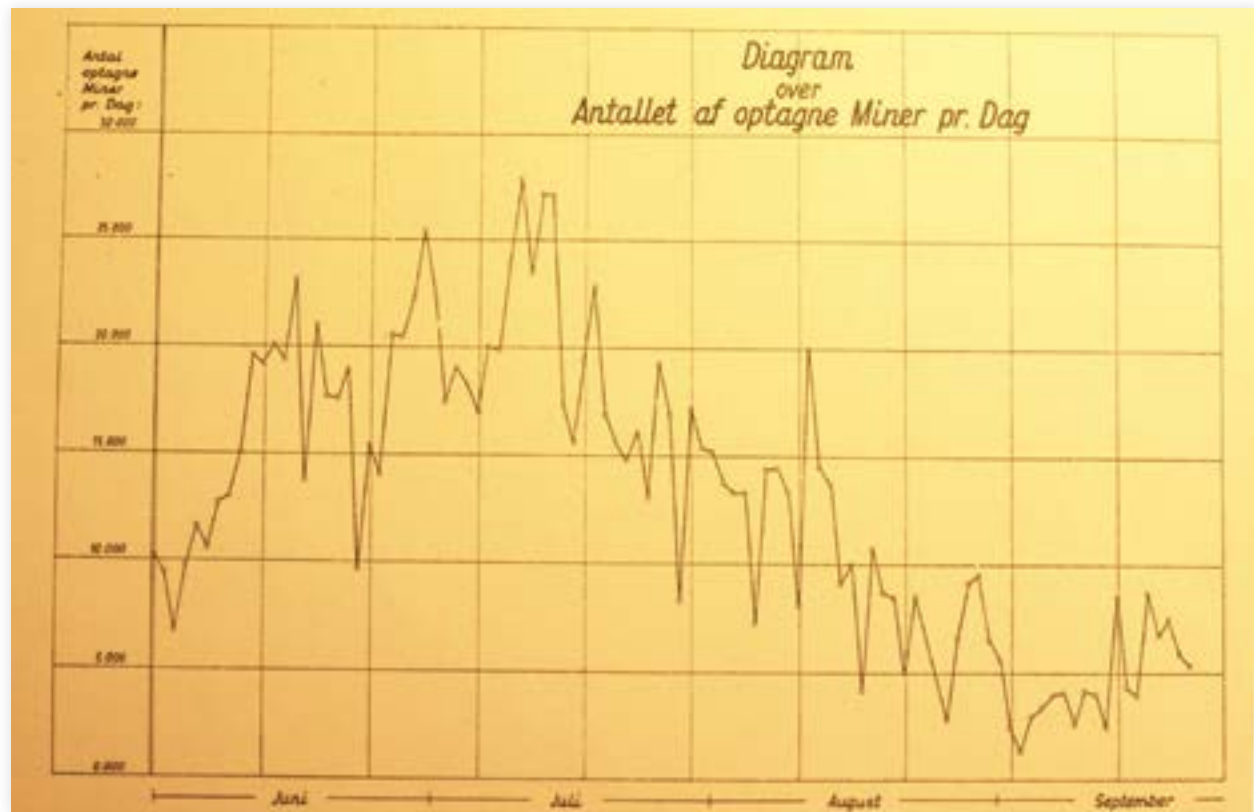


Image 12. Dansk Minekontrol graph showing the number of mines cleared daily in Denmark 11 May-31 September 1945. A conservative estimate of mines cleared versus working days gives an average of 9,715 mines cleared a day. Such daily clearance totals are remarkable and are rarely if ever repeated today.

Image courtesy of Dan Mouritzsen - Silkeborg Bunkermuseum Denmark.<sup>16</sup>

but these disintegrated too easily during repeated test runs. Concrete was replaced by steel and concrete rollers especially made at the Varde Steelworks. Fifteen vehicles are recorded as initiating mines with their tracks during test runs.<sup>18</sup> Panzer IIIs and StuG IIIs mainly only lost a track and a wheel. Unfortunate drivers typically experienced hearing damage. Examples of the patterns driven in test runs can be seen in Images 17 and 18.

The clearance of Denmark was costly, as was recognized at the time. In December 1945, Dansk Minekontrol listed 149 dead, 165 severely injured, and 167 lightly injured during the demining effort.<sup>20</sup> While the total workforce was not static, Dansk Minekontrol calculated that 20 percent of all deminers were either killed or injured. Dansk Minekontrol were keen to point out that the statistic of 100 deminers killed and 240 injured for every million mines removed in Denmark compared favorably to France, where it was claimed that 1,000 deminers were killed and 1,000 were injured for every million mines cleared.<sup>21</sup>

Demining was and is dangerous. In the 1940s, demining techniques were in their infancy. The casualties among allied military deminers were also very high.<sup>22</sup> In 1949, the

Geneva Conventions were updated. A revised Article 52 stated that “Unless he be a volunteer, no prisoner of war may be employed on labour which is of an unhealthy or dangerous nature. The removal of mines or similar devices shall be considered as dangerous labour.”<sup>23</sup>

The post-war clearance of Europe as a whole was undoubtedly quick, both by the standards of the day and historically. While hard to prove categorically, the 1945 Denmark clearance operation was probably amongst the fastest ever undertaken. On average in Denmark in the summer of 1945, 9,715 mines were cleared daily. By way of comparison to Denmark’s 1,389,281 mines cleared from an area of over 1,103.2 sq km (425.9 sq mi) by a force ranging between 750 and 2,600 German POWs, in the Netherlands between 20 May and 31 December 1945, the *Draeger Brigade* of up to 3,688 personnel cleared 1,079,857 landmines.<sup>24</sup> The scale and speed of both efforts in Denmark and Holland are perhaps dwarfed by those in France, where from 1945 to 1947, 48,000 German POWs and 3,000 French deminers cleared 13 million mines at a cost of 1,709 killed and 3,000 injured.<sup>25</sup>

In November 2004, during a speech in Nairobi, a senior mine action figure compared the European efforts in the



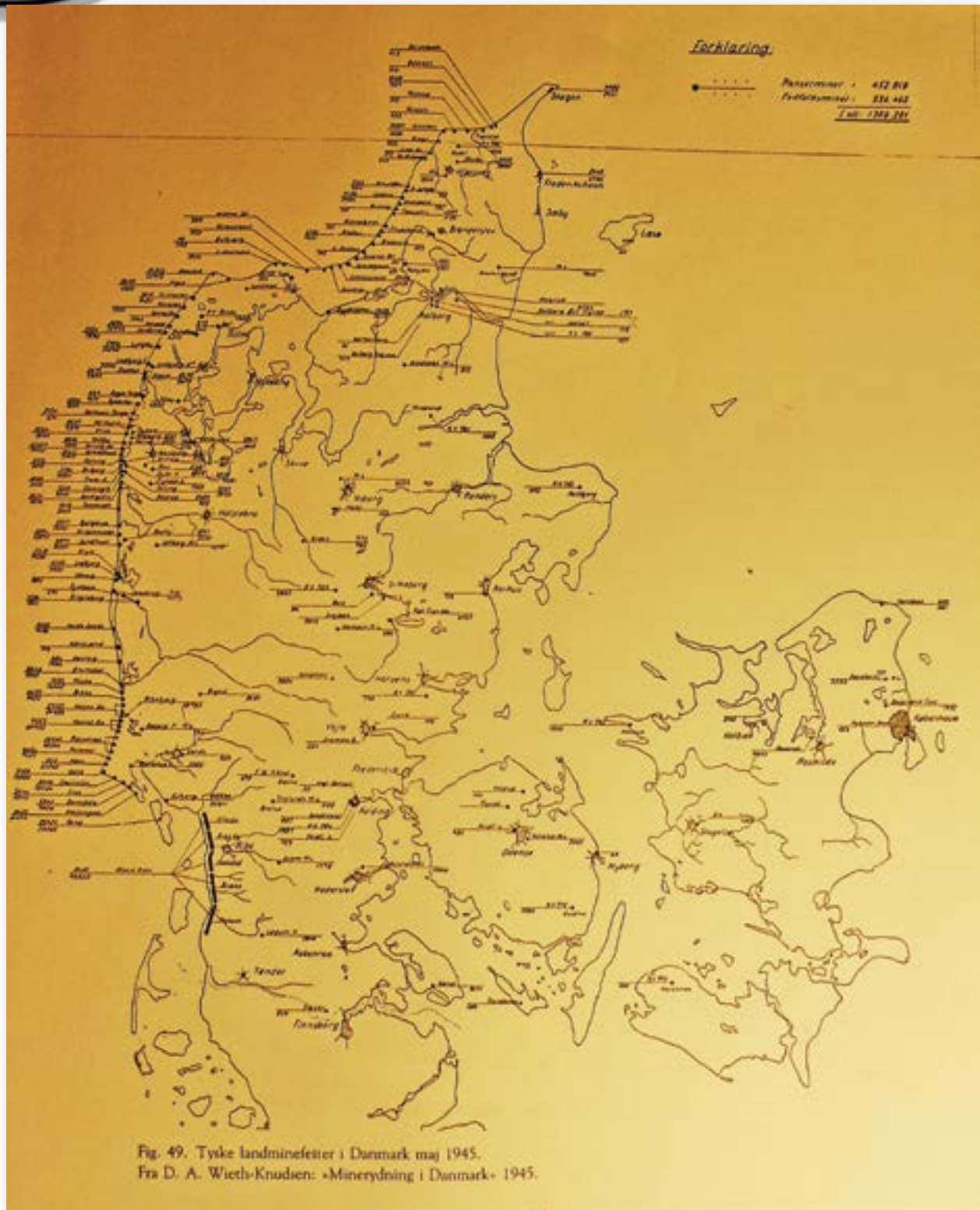


Fig. 49. Tykke landminesfelter i Danmark maj 1945.  
Fra D. A. Wieth-Knudsen: »Minerydning i Danmark» 1945.

Image 13. Dansk Minekontrol map showing the general locations of 1,389,281 mines cleared in Denmark 11 May-31 September 1945. On each line the figure above indicates anti-tank mines, the figure below indicates anti-personnel mines. Image courtesy of Dan Mouritzsen, Silkeborg Bunkermuseum Denmark.<sup>17</sup>







Image 15 and Image 16. Rollers attached to the back of Panzer IIIs and a StuG III assault gun used for quality control, Denmark 1945. Images courtesy of Dan Mouritzsen, Silkeborg Bunkermuseum Denmark.

1940s directly to the slowness of modern clearance operations.<sup>26</sup> Was this a fair comparison? The answer is yes and no. Yes in that modern clearance efforts are not as efficient as they could be. But no in that it is not practical to repeat much of the 1940s approach in the modern context. How much speed of clearance in Denmark contributed to high casualty figures remains debated to this day.<sup>27</sup> Acceptance of casualties can be argued to be a contributory factor in the rapid clearance but it was by no means the only factor or necessarily the key one.

The main reason why Denmark and other countries could be cleared so fast was simple: the operators knew where the mines were.<sup>28</sup> The Germans kept excellent records of the vast majority of their minefields. Wehrmacht draftsmen were highly

skilled and made very accurate minefield maps. This was nothing short of essential for rapid minefield clearance. A good example of such minefield records can be seen at Kirkehøje R.V.St. near Paarup in central Denmark. Between 26 July and 7 August 1944, a minefield of 5,983 Schützenminen was emplaced around the Luftwaffe Directional Radio Relay finding station. Obergefreiter Busse produced the minefield record, reproduced in Image 14, and the panel record reproduced in Image 22. The high level of detail and precision was common in German minefield records across Europe. This level of detail included the location of each panel and the number of Schützenminen it contained as well as the panel plan showing which mines were booby-trapped and which mines were left out of the pattern. Such detail would be envied by many modern clearance operators, even those clearing pattern minefields with reasonable minefield records in locations such as Turkey and the Falkland Islands/Malvinas. The principle problem of modern mine clearance, “where are the mines?” did not really exist in Denmark in 1945.

In many mine-affected countries in Europe, much of life today carries on as if there had never been minefields. The town of Esbjerg on the east coast of Jutland, very near to the Skallingen pen-

insula, illustrates this point. The town was heavily fortified by the Germans from 1943 onwards on both the seaward and landward side since any allied landing in the area would have needed to capture such a large port as soon as possible. Images 19 and 20 show the overall minefield plan for Esbjerg. Anti-tank and anti-personnel minefields were integrated to cover landward approaches along with various prepared demolitions in the port area.

Esbjerg was cleared during the summer of 1945. Records detail 63,888 mines of all types being removed.<sup>29</sup> Image 23 shows Esbjerg as it is today, much expanded, with the former minefields superimposed onto housing estates, industrial sites, etc. As with other countries in Europe at the time, it was shown that the recovery from landmines could be rapid



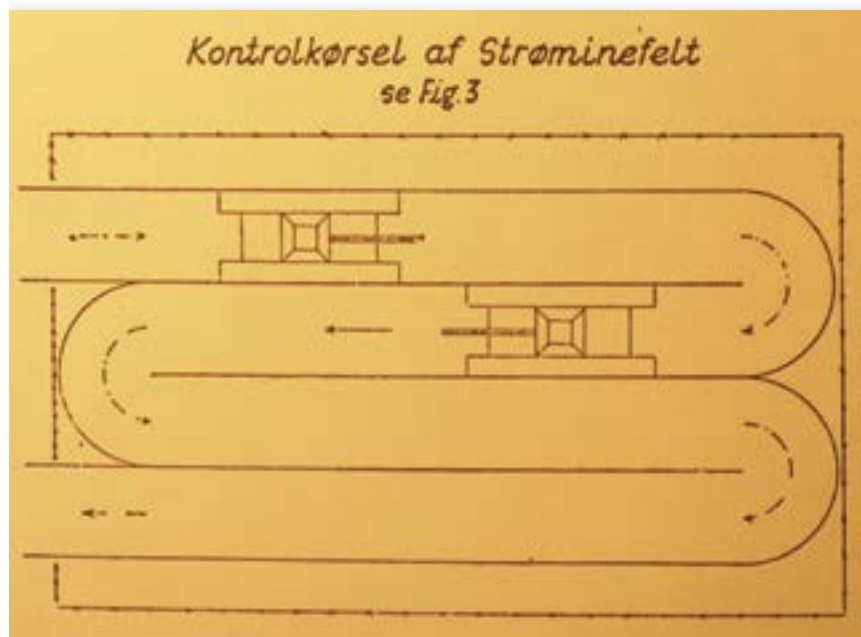
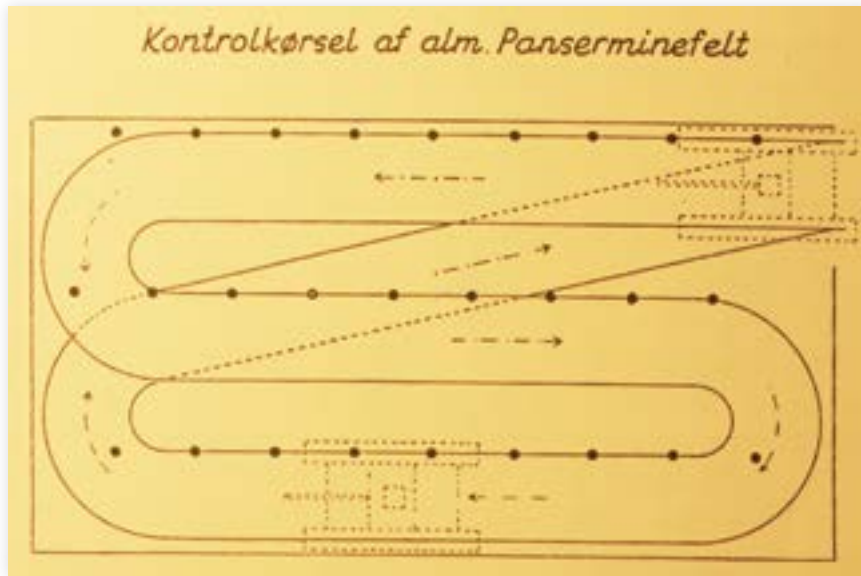


Image 17 and Image 18. Test runs patterns for quality control of cleared anti-tank minefields and anti-personnel minefields.

Images courtesy of Dan Mouritzsen - Silkeborg Bunkermuseum Denmark.<sup>19</sup>

to a point where the legacy is barely remembered by the general population decades later.

In December 1945, the Danes declared that 99 percent of the minefields in the country had been cleared—a remarkable achievement by any standard and one that deserves recognition despite the high human cost involved.<sup>30</sup> Most mine clearance by German POWs appears to have finished in February 1946.<sup>31</sup> The only areas remaining to be cleared were in Skallingen. These minefields presented a particularly difficult challenge. “The remaining mines were laid in a random distribution and consisted of several types, including both anti-tank and

anti-personnel mines.”<sup>32</sup> The movement of the sand presented further problems. Even in 1945, mines that had been in the ground for one or two years could be found under 1.5 m (1.6 yd) of sand.<sup>33</sup> Movement of mines by the sea was also an issue, just as it had been in the United Kingdom from 1940 onward.<sup>34</sup> The records suggested around 72,000 mines were laid at Skallingen of which 61,000 were cleared up to 1947.<sup>35</sup> Skallingen appears to be the one place where German minefield record keeping fell below the normal standard. It is also the one area that was not cleared in 1945. Since 1947, a further 3,500 were cleared, and an estimated 2,500 were swept away, having been in an area eroded by the sea over time. From 2005 to 2012, Denmark conducted the difficult and costly clearance of the last minefields believed to be in an area of 187,200 sq m (223,889.3 sq yd). A further 3,357 mines and 552 other items were destroyed.<sup>36</sup>

### Summary

Debate will continue about the decision of the Allies to co-opt Surrendered Enemy Personnel to conduct mine clearance in the 1940s, especially given a recent film on the subject called *Under sandet* or *Land of Mine* in English. The demining techniques used then were far higher risk than those that would be acceptable now. The inability to fully repeat this approach to some degree undermines direct comparisons with modern mine action. However, the key factor that allowed such rapid clearance, regardless of casualties, was the excellent minefield records kept by those who emplaced the minefields in the first place. In many parts of the world we unfortunately do not have the equivalent records that allow rapid identification of the actual contaminated ground and quick clearance.

It is clear that modern-day mine action still has much to learn from those who went before us, not least the importance







Image 19 (left) and Image 20 (above). Original overall German minefield plan for the defence of Esbjerg. Any Allied landing on the west coast of Denmark was unlikely due to difficulties in providing air cover. If such a landing had been attempted it would have required the capture of a port. Esbjerg was the second largest port in Denmark and the only viable option on the west coast of the country. For this reason the islands and spits on the seaward side, including Skallingen, were heavily mined. On the landward side of Esbjerg and around the port itself, 63,888 mines of all types were removed in 1945. Images courtesy of the Danish Engineer Regiment.



Image 21. Damage caused by an anti-tank mine on the track of a Panzer III during a “Test Run” of a minefield, Jutland, Denmark, summer 1945.

Image courtesy of Dan Mouritzsen - Silkeborg Bunkermuseum Denmark.

of field staff collecting sufficient and accurate data in order to better allow effective conduct of their operations and to better address the Mine Ban Treaty Article 7 obligations.<sup>37</sup> The Germans and Danes collected better data with pen, paper, and typewriter in 1945 than many programs and national authorities manage today with computers. We should aim to not only match them, but routinely surpass them. The introduction of IMSMA Core in coming years will hopefully aid improvements in relevant data collection and analysis. What is also needed is a change in working culture amongst more field staff so that they see accurate data collection and reporting as fundamental to their role.

What is indisputable is the bravery and sacrifice of those German deminers who, often very young, gave so much in the summer of 1945 in order to assist Denmark and other countries in Europe to begin the recovery from such a destructive conflict. I know of no memorial to these and the other POWs who died or were injured, in Denmark or in any other European country. Perhaps those who gave so much so that

Image 22 (right). One of the panel layouts for Fink section of the Kirkehøje minefield. Most mines emplaced by the Germans would be recorded individually in a panel plan such as this. Red crosses indicated booby trapped Schutzenmines, blue crosses where mines were deliberately not laid. Note that in this panel of 143 mines, 19 Schutzenmines (13%) were booby trapped with anti-lift devices.

Image courtesy of the Danish Engineer Regiment.

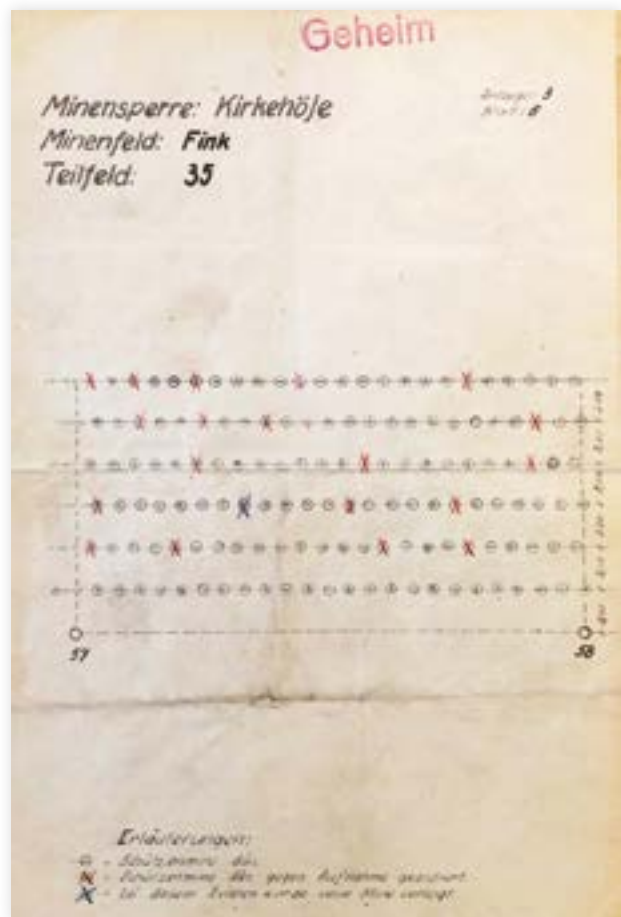






Image 23. Previous minefields cleared in 1945 superimposed on an expanded Esbjerg today. Red lines indicate anti tanks minefields containing either Tellermines or Holzmines. Green lines indicate anti-personnel minefields containing either Schützminen, Stockmines or S-Mines. S-Mines were known to cause most casualties to both attacking troops and deminers.  
 Image courtesy of the Danish Engineer Regiment.

these minefields would no longer endanger civilians should be recognized, regardless of the regime they once served? ©

*The author wishes to sincerely thank the following without whom this article would not have been possible. Major Peter Jegsen, Lance Corporal Preben Erichs, Dan Mouritzsen, Martin Jebens, John Jensen, and Antoon Meijers.*

*See endnotes page 61*

**Roly Evans**  
 Geneva International Centre for Humanitarian Demining



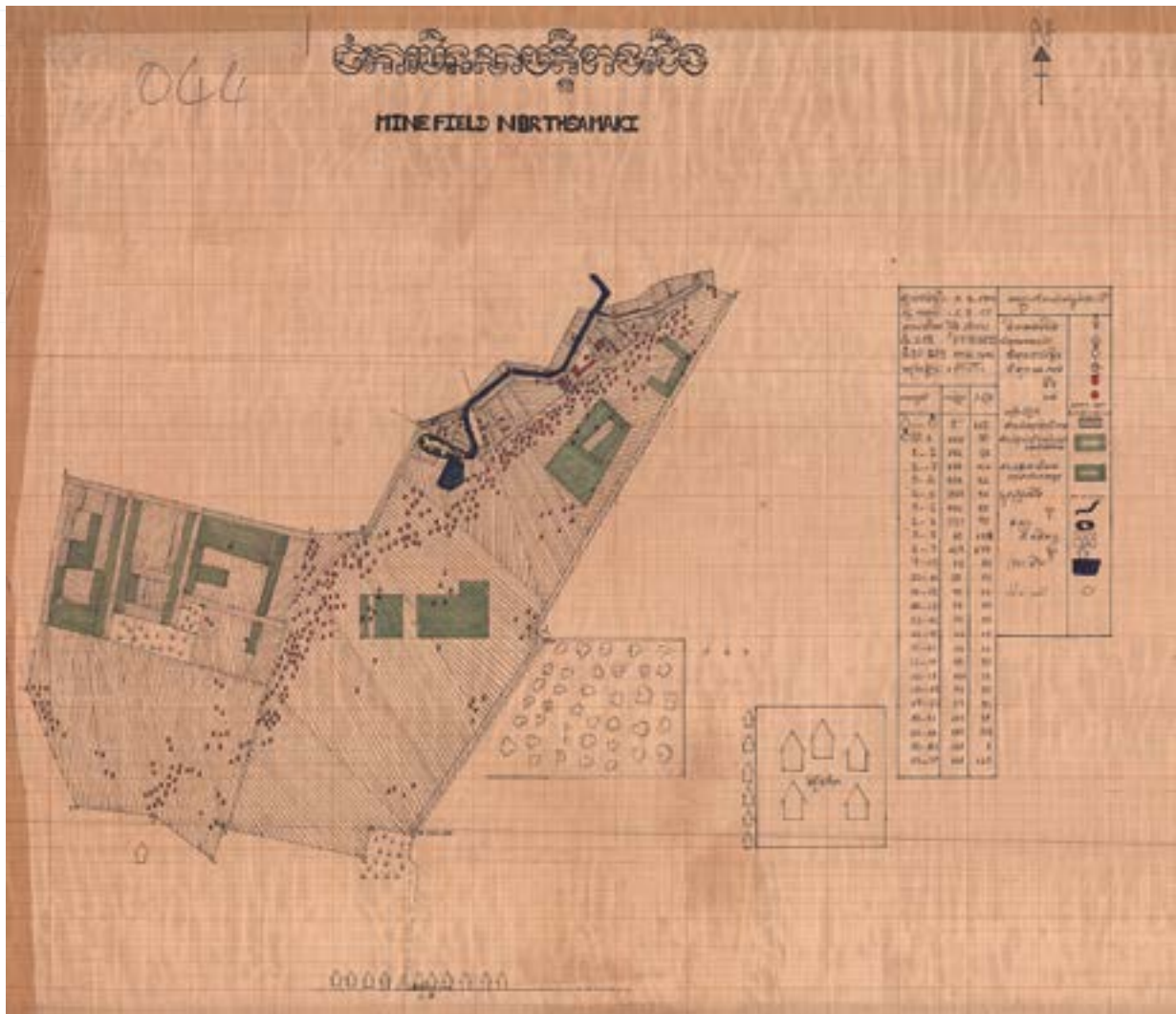
Roly Evans is an Advisor in Land Release and Operational Efficiency in the Risk Management Division at the Geneva International Centre for Humanitarian Demining (GICHD). He also covers training issues and conventional explosive ordnance disposal (EOD) including the Collaborative ORDnance data repository (CORD) and the GICHD Cluster Munitions Identification Tool (CMID). He has worked in the fields of survey, clearance, EOD, and physical security and stockpile management in Africa, Europe, the Middle East, South Asia, and Southeast Asia.



## Field Notes

# Minefield Sketch Maps in Humanitarian Mine Action

by Jesse Hamlin and Luan Jaupi [ The HALO Trust ]



An example of a minefield sketch map in Cambodia from 1997. Each red dot represents the location of an anti-personnel mine that was destroyed by The HALO Trust.

*All graphics courtesy of The HALO Trust.*

Digital technology has the ability to bring minefield artifacts from the field to life. The HALO Trust (HALO) has been using Colortrac large format scanners in several programs around the world, to scan minefield sketch maps from the field, allowing these historical records to be viewed on desktop and laptop computers. Once the maps are scanned, they are georeferenced in geographic information systems (GIS) to display alongside other

layers, and used to allow HALO to build its database of activities through digitization of paper records alongside data that is recorded directly onto tablets.

### Preserving Historical Records

A minefield sketch map is a large, A0-sized, hand-drawn minefield map that is drawn to scale on grid paper. HALO has been drawing these maps for surveyed and cleared minefields



A minefield briefing in Cambodia is aided by the use of a minefield sketch map.



A data clerk scans a minefield sketch map from the field using a Colortac SmartLF Ci 40 large-format scanner and georeferenced it on top of minefield polygons in GIS.

since the mid-1990's, which included the period when modern GPS signals were not available to the general public. In 2000, selective availability from the intentional degradation of public GPS signals for national security reasons, was abolished by the U.S. Government under the direction of President Clinton.<sup>1</sup> All survey and clearance team leaders are trained on how to draw a minefield sketch map to scale in the field, based on the specific coordinate system (e.g., Universal Transverse Mercator or latitude/longitude) and units (e.g., meters or decimal degrees) used in country. Many of HALO's operations supervisors take great pride in producing high-quality sketch maps, and some are truly works of art.

Prior to clearance, a minefield supervisor hand-draws a sketch map for the minefield and constantly updates it during demining operations. The maps are also used for minefield briefing visits. As areas are cleared and mines or unexploded ordnance (UXO) are discovered, the supervisor marks these milestones on the map. After the minefield is cleared, which can take several months, a final sketch map is drawn showing the areas cleared, devices destroyed, and any accidents that took place prior to clearance as reported by the local residents. The final minefield completion sketch map is symbolic of the completion of the mined area and is used during handovers with the local population to explain what areas were cleared.





Boundaries of sketch maps georeferenced in GIS creating a nationwide mosaic and displayed in a web map. The sketches display once zoomed in on the web map.



The town of Anlong Veng in the north of Cambodia was one of the most heavily mined villages HALO encountered. Red dots show anti-personnel mines destroyed, blue areas indicate the areas HALO cleared, and green areas show the boundaries of the sketch maps of the minefields that were scanned and georeferenced.

After the completion of demining operations on a particular minefield, each map is finalized and sent to the program headquarters in each country for storage, digitizing in a PDF format, and archiving. Each map scan is then stored on a standard Windows file server for access by staff members. HALO

has used large format scanners in Afghanistan, Angola, Cambodia, Laos, Mozambique, Somaliland, and Sri Lanka.

Once the maps are in electronic format, it opens up several new ways to access the information. When stored on a central file server, the maps can be accessed by multiple computers in



A sketch map georeferenced and displayed in a web map. Red dots are mines destroyed by HALO, skulls represent accident locations.

the office. Electronic format is also a safeguard against map degradation or catastrophic destruction (e.g., flood or fire), and all maps are backed up on external hard drives or the cloud. Lastly, maps can be imported into GIS and georeferenced on top of minefield polygon data for an added level of detail. Once several maps are georeferenced, they can be combined into a single layer and published as a map service available to program staff via desktop or web GIS. This process will be described in detail later.

### *Bringing GIS To Life*

In today's age, HALO uses advanced web GIS, high-resolution satellite imagery, and mobile devices to collect data from the field. However, there is still huge value in drawing the paper sketch maps to scale in the field, as the accuracy of data collected in the field on tablets can be subpar (plus or minus 30–50 meters accuracy depending on signal and strength of the receiver). Moreover, the sketch maps provide an added level of detail typically not captured in GIS or most mine action databases. Verified details such as nearby villages, trails, rivers, other operators' clearance, and technical survey breaching lanes can be displayed on the maps along with the polygon boundary. The maps also record important information about the approximate locations of mines destroyed or previous accidents the local community (or their animals) may have had on the minefield.

Desktop GIS has the ability to georeference (that is, to align geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data) minefield sketch maps on top of other layers.<sup>2</sup> HALO uses the geo-referencing toolbar in ArcGIS to geo-reference sketch maps in line with minefield polygon areas. When overlaid with the minefield polygon boundary in GIS, a more detailed picture can be represented. This assists operations in planning future operations and understanding the nature of the threat on legacy minefields.

Taking this a step further, once multiple sketch maps are scanned and georeferenced, they can be combined into one layer, which displays all sketch maps (on top of the minefield polygons) in a country. In order to prevent the issue of multiple maps overlapping each other and obstructing the details of a particular minefield, each rectangular map is clipped to its polygon boundary in ArcGIS. After this process is completed, the maps can be viewed by data managers, operations officers, and program managers in desktop or web GIS, or as paper printouts or wall maps. HALO uses ArcGIS Server to publish layers like these in Cambodia for consumption on a program web map, which is accessible to anyone with access to its internal network.

The last step is to digitize mine locations and mine accidents directly into HALO's database. Most mine action operators record the boundary (i.e., polygon area) of a mined area





The same map with the mines and accidents digitized into HALO's PostgreSQL database and overlaid. All of this information is accessible via an ArcGIS Server web service on an interactive web map to operations staff.

in a database but rarely record the actual locations of the destroyed mines, which can often be a laborious process as GPS coordinates need to be recorded for each device in the field. By using the approximate locations on the sketch maps, HALO's data clerks can digitize the point locations directly into its enterprise database platforms (e.g., SQL Server, PostgreSQL). These data are then published as layers using ArcGIS Server to a web map (Leaflet API or ArcGIS Online), which allows non-GIS personnel to access the layers as they are updated in real time in HALO's database. This enables the organization to better demonstrate and understand the threat on the ground.

### *Case Study: HALO's Use of Sketch Map Digitization in Cambodia*

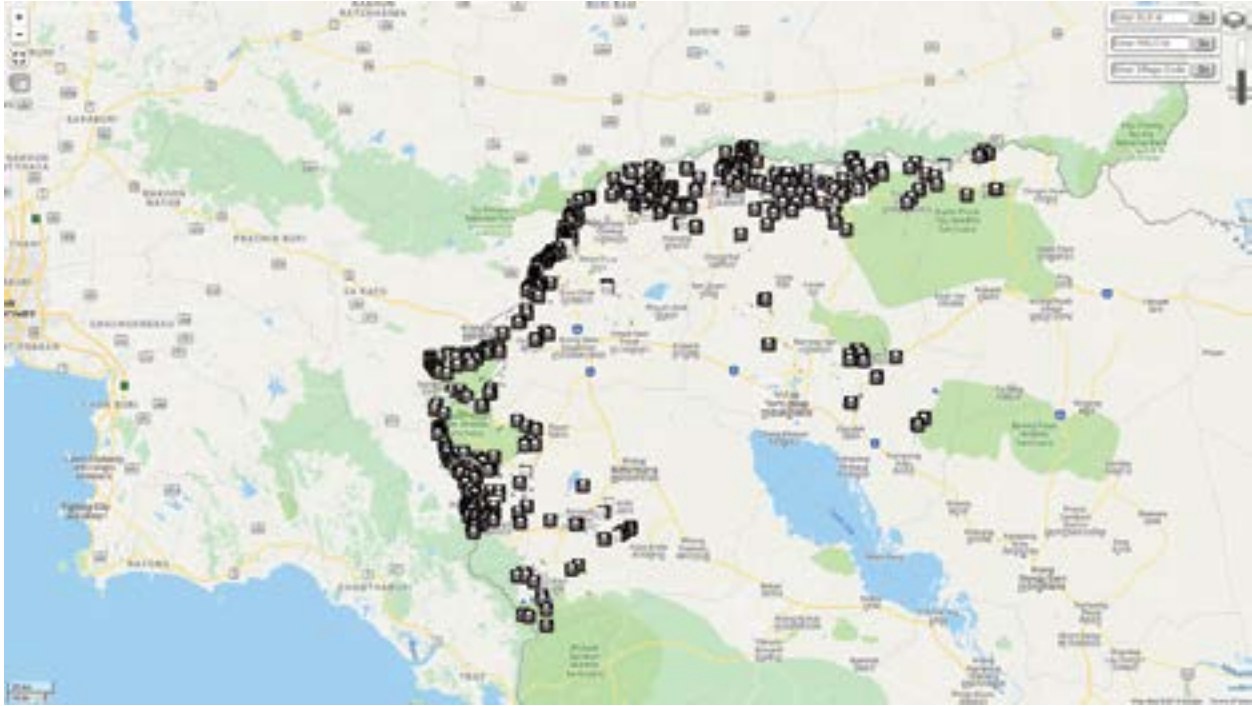
Landmines were laid in Cambodia during the ousting of the Khmer Rouge in 1979 and continued until its demise in 1998. Through a series of dry season offensives from 1984 to 1985, the Vietnamese military drove the Khmer Rouge (and 230,000 civilians) across the border into Thailand. To impede the return of the Khmer Rouge, tens of thousands of local people were forcibly conscripted into constructing a barrier minefield along the entire 750 kilometer (466 mile) length of the Cambodia-Thai border, a defensive plan known as the K5 Belt. Further landmines were laid by State of Cambodia forces to defend towns, villages, and supply routes from attack by opposition forces. In addition, Khmer Rouge and

monarchist opposition forces used landmines to protect newly won ground or to contaminate the interior of abandoned Vietnamese defensive positions.

Although 50 percent of Cambodia's minefields have now been cleared, Cambodia is still one of the most landmine impacted countries in the world with over 64,000 casualties recorded since 1979 and over 25,000 amputees—the highest ratio per capita in the world.<sup>3</sup> More than 80 percent of the total population live in rural areas, in communities dependent on agriculture. Northwest Cambodia has seen a 35 percent population increase since hostilities ceased and this rapid population growth has meant these areas represent a very high relative percentage of the national total of mine accidents.

Despite a reduction in casualty numbers over recent years, Cambodia's mine and explosive problem is still a major impediment to the social and economic development of the country. The landmine threat is now largely concentrated in just 21 border districts in the rural northwest of Cambodia. It prevents development by hindering access to land, water sources, roads, and health services, and it imposes financial and emotional hardship on families needing to care for a landmine survivor.

The amount of data generated and minefields recorded in Cambodia is staggering. A final minefield sketch map is hand drawn for each completed minefield once it has been cleared of all known mines and ordnance. Some of the sketch maps have



A mosaic that displays all anti-personnel mines, anti-tank mines, and items of UXO destroyed by HALO, as well as any human or animal accidents recorded on the program web maps, accessible to all program staff.

huge numbers of mines, a direct reflection of the level of contamination in the country and how dense the mines laid on the K5 mine belt really are.

The Cambodia program has now georeferenced all of its minefield sketch maps (11,762 as of August 2017). From this, an astonishing 164,000 records were digitized off of these maps by the program staff in order to create the mosaics for the web maps in GIS. A summary of the digitized records is below (numbers from August 2017):

1. 147,852 anti-personnel mines
2. 1,150 anti-tank mines
3. 12,927 UXO
4. 1,858 human accidents on minefields prior to clearance
5. 272 animal accidents

HALO is working to scan sketch maps in all of its countries in order to preserve and digitize this important work. As the technology for large-format scanners continues to improve and with reduced costs to acquire the technology, this goal should be achieved very soon.

*See endnotes page 62*

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Global GIS & Database Officer  
The HALO Trust



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**Luan Jaupi**  
Head of ICT  
The HALO Trust



Luan Jaupi joined The HALO Trust in 2005. He is responsible for all information management and GIS in headquarters and all HALO programs. He has a master's degree in computer science from the University of Tirana, Albania, and a master's degree in business informatics from the European University of Viadrina, Germany.



## Field Notes

# Mitigating Adverse Environmental Impacts in Mine Action

by Martin Jebens [ DRM-Consultancy ] and  
Gianluca Maspoli, Ph.D., [ Geneva International Centre for Humanitarian Demining ]

In order to help mitigate adverse environmental impacts, this article supports the mainstreaming of environmental concerns into mine action. This is achievable by strengthening existing standards, and is motivated by two main factors.

Firstly, an increased consideration of environmental issues is based on growing concerns about climate change and is reflected in international treaties and agreements. Additionally, the *2030 Agenda for Sustainable Development* (2030 Agenda) and the *Sendai Framework for Disaster Risk Reduction* (SFDRR) are significantly important to the protection of the environment and are relevant frameworks for mine action.

Secondly, International Mine Action Standards (IMAS) are an essential tool for mainstreaming environmental concerns,

and in particular IMAS 10.70 “Safety & occupational health - Protection of the environment.”<sup>1</sup> This guidance can be improved, and this article proposes changes to IMAS 10.70 in order to better reflect current needs and practices.

### Why The Environment Matters

The environment is the foundation for sustainable development and significantly influences people’s livelihoods at local, regional, and global levels. Over the past decades, the environment has become a major concern. On one hand, climate change endangers all societies but especially those in developing countries. On the other hand, human development and armed conflicts have impacted the environment via increased pollution and exploitation of resources.<sup>2</sup>



Figure 1. Commitment to environment protection and risk reduction.  
Figure courtesy of Gravitazz, the United Nations, and IHG.

National legislation and various international treaties target environmental protection, including the Geneva Conventions, which prohibit all means and methods of warfare that cause severe, widespread, or long-term damage to the environment.<sup>3</sup> The *Anti-Personnel Mine Ban Convention* (APMBC) and the *Convention on Cluster Munitions* (CCM) account for the environment in relation to extension requests and transparency reports.<sup>4</sup> Other international agreements and treaties like the *Paris Agreement*, the *Convention on Biological Diversity*, and the *Convention to Combat Desertification* pay specific attention to the environment. Their aim is to lower the risk of loss of life and poverty and improve people's daily lives by advocating for sustainable and holistic solutions. Moreover, important international frameworks like the 2030 Agenda and the SFDRR have brought additional focus to the environment.

### *Sustainable Development and Risk Reduction*

The 2030 Agenda is intended “to end all forms of poverty, fight inequalities and tackle climate change” and the environment is featured prominently as one of the three fundamental dimensions, in addition to economic and social issues.<sup>5</sup> The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda address these three dimensions and aim to shape global development, peacebuilding, and humanitarian agendas.

The Geneva International Centre for Humanitarian Demining (GICHD) has looked into how mine action can contribute to the implementation of the SDGs and how they can be mainstreamed within mine action.<sup>6</sup> The GICHD's study shows that 12 of 17 SDGs are directly relevant for mine action and points out that SDGs can bring a new emphasis on environmental mitigation measures for impacts like “deforestation, land degradation, climate change vulnerability and loss of biodiversity.”<sup>6</sup> The study also identifies that mine-affected countries, operators, and donors intend to review their mine action strategies with the purpose of aligning with the SDGs.<sup>6</sup> Ultimately, the 2030 Agenda brings new momentum to protecting the environment and calls for an enhancement of the existing instruments in mine action.

The SFDRR was adopted by U.N. Member States on 18 March 2015 at the Third U.N. World Conference on Disaster Risk Reduction. The SFDRR aims to reduce the risks from both natural hazards and man-made disasters. Disaster

risk reduction is not a stand-alone process, it needs to be coordinated with sustainable development; therefore, SFDRR is linked to the SDGs. The SFDRR states that activities like natural resources management, land use, and urban planning are central to disaster risk reduction. It introduces “a wide scope that includes risk of small-scale and slow-onset disasters as well as man-made, technological, environmental, and biological hazards.”<sup>7</sup> As such, the SFDRR also applies to mine action.

The SFDRR does not determine how to manage specific disaster risks but outlines how disaster risk reduction needs to be holistic. It calls for coherence between disaster risk management policies and practices across sectors related to the environment, technological hazards, and biological hazards respectively.<sup>7</sup> Therefore, a key element in the SFDRR is to ensure that stakeholders coordinate across sectors and on all levels: locally, nationally, and internationally.

The SFDRR and the 2030 Agenda are highly-developed frameworks, forming a platform for environmental protection that should be integrated in the mine action sector. The driver in these frameworks is to decrease the risk to human life by developing capacity and to increase resilience, thereby creating a better future.<sup>8</sup> In order to do so, an improved collaboration among mine action organizations and other stakeholders is needed, not only through policies and planning, but also through monitoring and evaluation.<sup>9</sup> These requirements are addressed by the International Organization for Standardization (ISO) in their current version of standards on environmental management (e.g., ISO 14001:2015) and should be included in IMAS 10.70.

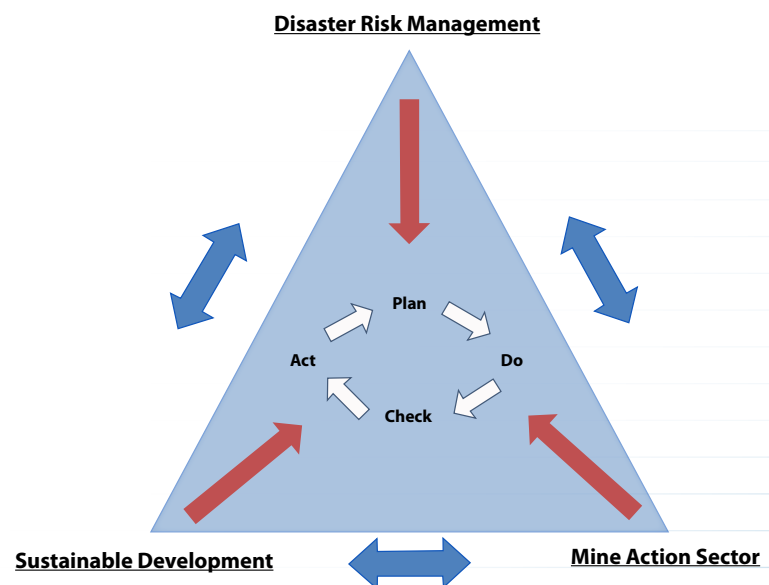


Figure 2. Integrating mine action, SDGs and SFDRR.  
Figure courtesy of Martin Jebens and Carlo Sorensen.



Figure 2 (previous page) illustrates the need to integrate disaster risk reduction, SDGs, and the mine action sector to foster the protection of the environment.<sup>10</sup> It underlines the requirement for introducing the plan-do-check-act (PDCA) principle, which is a fundamental condition in the ISO system to reduce environmental risks by adopting ISO standards or adapting other standards (e.g., IMAS) to address specific challenges. The ISO should serve as a basis for the adjustment of IMAS 10.70, as well as taking into account regional differences and the need to avoid transferring risks. This has to be done by assessing environmental and societal needs. In addition, it is important to keep in mind that planning itself is not enough to decrease risks for the environment and must go hand-in-hand with awareness rising.

### *Environment, Mine Action, and International Mine Action Standards*

Mine action can impact the environment positively but also negatively by degrading land or giving rise to pollution, therein changing the ecosystem and affecting civilians' livelihoods. Appropriate assessments and management can help in incorporating environmental mitigation measures. These include sound applications of the land release approach to limit heavily-invasive clearance methods and appropriate remediation activities.

In 2005, Ian McLean pointed out that environmental issues were "treated as peripheral" and argued in favor of a higher consideration, especially in the context of "mainstreaming demining with development." According to McLean, there was a need to "explore the issue, raise awareness, create incentives and educate the practitioners."<sup>11</sup>

Since then, awareness has increased, impacts of contamination and clearance operations are better understood, and methods to reduce such impacts have been developed. The relevance of adapting mine action operations to fragile ecosystems is documented, and experiences show that mitigation of negative impacts is important to ensure livelihoods, avoid additional environmental degradation, and take advantage of opportunities for sustainable development.

For instance, conflicts put natural environments under stress and contamination from mines contributes to this, especially in contexts where the balance between the ecosystem and human activities can be easily disrupted. This is illustrated by the case of Kuwait, which suffered contamination during the Gulf War in 1990–1991 and went through clearance operations in the aftermath. The laying of landmines and clearance operations produced immediate and

long-term environmental damages that consisted of "soil disturbance, soil compaction and loss of biodiversity and deterioration of vegetation cover."<sup>12</sup>

Another example is Yemen, where the rural population depends on a very sensitive environment, and traditional laws forbid the cutting of trees. Studies show that poverty is higher in contaminated areas.<sup>13</sup> In such contexts, mine action helps to fight poverty by granting access to grazing and farming lands, and to sources of water and firewood. However, these positive impacts demand trade-offs between operational requirements, local practices, and environmental features in order to avoid unintended consequences.

The mitigation of possible negative environmental impacts is also relevant in contexts that are not immediate post-conflict but where there are legal international obligations. For example, the Skallingen peninsula in Denmark was contaminated by landmines from World War II, and clearance was needed to fulfill obligations under the APMBC, but the country had to preserve the ecology of Skallingen, which is a protected area. A study of the environment was thus conducted, and clearance included methods that reduce the impact on wildlife and erosion.<sup>14</sup>

The GICHD has worked to improve the mitigation of adverse environmental impacts in mine action as well. Particular attention was given to mechanical clearance, which is a cost-effective method but can create adverse impacts like erosion, deforestation, ground pollution, and soil structure damage.<sup>15</sup> However, environmental considerations are not restricted to mechanical clearance, as other activities can produce negative consequences: disposal of ordnance, disposal of debris and hazardous waste, burning of vegetation, establishment and dismantlement of temporary facilities, and transportation of hazardous material.<sup>16</sup> Mine action, as well as other humanitarian operations, has a potential impact on the environment due to the presence of staff, equipment, and facilities, which may create stress on local resources and environmental degradation if improperly managed.<sup>17</sup>

The increased awareness and knowledge of environmental issues is reflected in the IMAS 10.70, which sets general requirements and responsibilities for the protection of the environment. It states that operations "should be carried out without damaging property or infrastructure, in a manner that minimizes the impact on the environment" and planning "shall take into account the effects of those operations, and any supporting activities, on the environment."<sup>18</sup> Ultimately, mine action organizations should ensure that the land "is left in a state whereby it is suitable for its intended use once demining operations cease."<sup>18</sup>



Image 1. The need for remediation after clearance is evident from the Skallingen project.  
Image courtesy of Martin Jebens and the Danish Coastal Authority.

IMAS are a key instrument to mainstream the protection of the environment, and there is room for a review of IMAS 10.70 in order to better reflect international treaties, agreements, frameworks, and the current increased relevance of environmental concerns. Two examples—Cambodia and Croatia—substantiate the importance of the environment in mine action and illustrate concrete attempts that have been made by mine action national authorities.

### *Cambodia*

Cambodia has experienced a rapid rate of deforestation with tree cover loss accelerating faster than in any other country in the world.<sup>19</sup> The deforestation has socio-economic consequences and increases national climate change vulnerabilities. Cambodia is also home of many protected areas and endangered species. While mine action often occurs in environmentally sensitive areas, it is important to take steps to avoid contributing to deforestation and the loss of biodiversity.

Cambodia's National Mine Action Strategy 2018–2025 includes the goal of ensuring that mine action is “environment protection sensitive.”<sup>20</sup> The objective is to mainstream environmental protection in mine action. The process of developing

the strategy was supported by the United Nations Development Programme (UNDP) in Cambodia and has relied on a comprehensive Environmental and Social Impact Assessment.<sup>21</sup>

This attention to the environment also reflects international obligations. Cambodia ratified several international treaties that all have links to national level planning, including the National Environmental Action Plan, the National Protected Area Strategic Management Plan, the National Biodiversity Strategy and Action Plan, and the Cambodia Climate Change Plan. These treaties implement the United Nations Framework Convention on Climate Change as well as Cambodia's National Program to Combat Land Degradation.<sup>19</sup> In order to mitigate the potential environmental impacts, cooperation is needed between UNDP, the Cambodian Mine Action and Victim Assistance Authority (CMAA), operators, and other stakeholders to lower direct and indirect negative environmental consequences and threats to cultural resources.

### *Croatia*

Inclusion of environmental protection in Croatian mine action was the result of top-down and bottom-up processes. There is a growing awareness of the importance of environmental protection and sustainable development by civil



society. An institutional framework is now in place to advocate for a higher degree of environmental protection and to gather stakeholders for the management of protected areas at the county level.

At an early stage, this multi-stakeholder approach—including the Croatian Mine Action Centre (CROMAC), the Office for Mine Action, the Ministry of Economy, the Ministry of Environment and Nature Protection, the State Institute for Nature Protection, the Croatian Forests Company, operators, counties, and park authorities—has created a common understanding of the complexity and interconnectedness among all organizations involved.

Croatia does not have a specific national mine action standard on environment. Instead, CROMAC has developed its own regulations for demining operations building on the ISO system, particularly ISO 14001. This is in line with the national demining organizations that follow the ISO 14001 or are ISO-certified. In fact, ISO 14001 has become a common reference standard for Croatian companies.

When tendering for projects where demining takes place inside protected nature areas in Croatia, where monitoring is conducted by specialized organizations, operators must provide documentation on environmental protection in order to be selected and obtain permission for operation. An additional tool to implement mitigation measures is the legal basis of the National Environmental Protection Act.

### *Enhancing The Protection of The Environment*

The enhancement of the protection of the environment needs to be closely related to operational requirements. On this point, mine action can count on IMAS as an instrument to strengthen the sector in mitigating adverse environmental impacts. The following sections outline a number of points to be considered in a review of IMAS 10.70 in order to strengthen guidance on environment protection and to ensure that the international frameworks described earlier are better integrated into mine action.

### *Environmental Impact Assessments*

Operational safety is a must in mine action. The protection of the environment at times will be at odds with safety measures, and balancing these two needs will require coordination and planning among stakeholders. A thorough environmental impact assessment together with technical and non-technical survey can define and establish mitigation measures, which lower adverse impacts on the environment without compromising the safety of operators and cost-effectiveness of operations. Moreover, an impact assessment

can help make cost-effective choices. IMAS 10.70 should better capture the need of environmental impact assessments. This would also be in line with ISO 14001. Among other countries, both Croatia and Cambodia are currently successfully implementing environmental assessments to find optimal solutions to protect the environment.

### *Raising Awareness*

In both Cambodia and Croatia, increased awareness was identified as a fundamental condition for the successful implementation of environmental protection. Ideally, raising awareness of environmental protection should take place at all organizational levels, including both national and international stakeholders, and create a feeling of ownership for the population.<sup>22</sup> Awareness raising should also identify new partners who could possibly contribute to the mitigation of adverse environmental impacts with capacities or funding.

### *Improved Management*

Improved management can be achieved by establishing environmental policies and strengthening the importance of the environment in the tender process (statement of works), standard operating procedures, monitoring, and training. A revised IMAS 10.70, which reflects the ISO 14001 system, would be a key tool to improve management. The ISO 14001 points to strong environmental management by implementing environmentally sensitive policies and strategies. Environmental management systems result in a more systematic and cost-effective approach to protect the environment than an ad hoc approach.<sup>23</sup>

### *Increased Coordination*

Clearance of landmines and explosive remnants of war (ERW) relates to the environment, is multi-sectoral, and requires effective coordination and knowledge sharing. Therefore, increased coordination between stakeholders is essential and improves awareness so that appropriate mitigation measures can be established.

Increased coordination among environmental stakeholders also secures the use of existing capacities, frameworks, and legal acts. Stakeholders would include international, regional, and national environmental organizations, governmental bodies, NGOs, and academia. Coordination is identified as one of the major problems in the humanitarian sector to improve relief work and avoid gaps as well as duplicating efforts. Coordination is thus a fundamental need to make the protection of the environment cost effective.

## Conclusion

Improved environmental protection is needed to create a sustainable future. The 2030 Agenda and the Sendai Framework embody this need. To integrate both these frameworks, mine action could benefit by improving its approaches to mitigation of adverse environmental impacts. Both the Croatia and Cambodia cases illustrate that sustainable development is a concern and a reason for the protection of the environment.

Due to the diversity of environments in which mine action takes place, environmental assessment should become an important and integrated part of the work. Environmental protection is cross-sectoral, and stakeholders' coordination is crucial to address threats to the environment. Different actors can contribute with their specific expertise to find solutions that do not compromise the security of staff and cost-effectiveness of operations while improving mitigation measures. This is best done by introducing a systematic approach as is already taking place for other aspects in mine action: quality assurance, quality control, and land release. A management system targeting the environment can therefore be integrated into already existing approaches in mine action.

In addition, the importance of promoting awareness toward environmental protection and mitigating adverse impacts among all stakeholders cannot be underestimated. Environmental mitigation is likely to increase expenses and should be reflected in the funding due to new demands and criteria introduced in the mine action sector.

A revised IMAS 10.70 on environment, which builds on ISO 14001, must address these issues to a higher degree. The revision should aim to release land so that wildlife and the

population are not exposed to short- or long-term adverse environmental impacts while ensuring cost-effectiveness and the security of those involved in clearance activities. Ultimately, a revised IMAS 10.70 should ensure that mine action programs return the land back as it was before mines were laid, therein improving livelihoods and a sustainable use of land. ©

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# Field Notes

## Clearing Safe Spaces for Drought Affected Communities in Somaliland

by Ed Lajoie and Megan Dwyer [ The HALO Trust ]

Governments and nongovernmental organizations (NGO) working in the Horn of Africa consistently identify conflict and climate change as two primary drivers of insecurity in the region. The HALO Trust's landmine and explosive remnants of war (ERW) clearance in the Republic of Somaliland over the last 19 years has been at the intersection of these two issues.

### History of Conflict in Modern Somaliland

Somaliland is a self-declared independent republic but is not recognized by the United Nations and its member states. Located in the northwest region of Somalia, Somaliland borders the semi-autonomous region of Puntland to the east, Ethiopia to the south and southwest, Djibouti to the northwest, and the Gulf of Aden to the north. The region that now comprises Somaliland was home to various sultanates until becoming a British protectorate from 1884 until independence on 26 June 1960. On 1 July 1960, Somaliland reunited with the successor state of Italy's protectorate in the south to form the Somali Republic. On 18 May 1991 with the Somali Republic crumbling, the Republic of Somaliland unilaterally declared its independence and maintains a de facto state to this day.

The majority of the landmine and ERW contamination in Somaliland is the result of three periods of major conflict. In 1977, Somali President Siad Barre launched the Ogaden War against regional rival Ethiopia, ostensibly to regain the Ogaden territory of eastern Ethiopia regarded by the Somali government as rightfully part of a "greater Somalia." In order

to secure the border and establish forward logistics bases for resupplying troops in Ethiopia, the Somali National Army (SNA) established a series of military installations ringed by anti-personnel and anti-tank mines on the border between Somaliland and Ethiopia. During this time, large amounts of weapons, ammunition, and military equipment were brought into the country. Both Somalia and Ethiopia had been Soviet client states and received large amounts of military assistance; however, with the start of the Ogaden War, the Soviets were forced to choose sides and decided to back Ethiopia. Eager to seize the opportunity to win an ally in the region, the United States stepped in and began supplying war material to Somalia. This infusion of armaments helped fuel the next stage of conflict in the country.

By the 1980s, Somaliland was growing disillusioned with the Somali Democratic Republic as it was called after Siad Barre's 1969 takeover. Power and resources were held disproportionately by those in the south, while the north was bearing the burden of the aftereffects of the Ogaden War including an influx of Somali refugees from the disputed region. The Somali National Movement (SNM) was founded in 1981 as an organization advocating political redress of northern grievances but morphed into an all-out revolutionary independence movement by the mid-'80s as the Somali government sought to eliminate all resistance with increasingly harsh methods.

During this time, which is generally considered part of the Somali Civil War, the SNA continued laying mines to protect its bases and infrastructure from SNM attacks, while the SNM used landmines to ambush SNA patrols and logistics

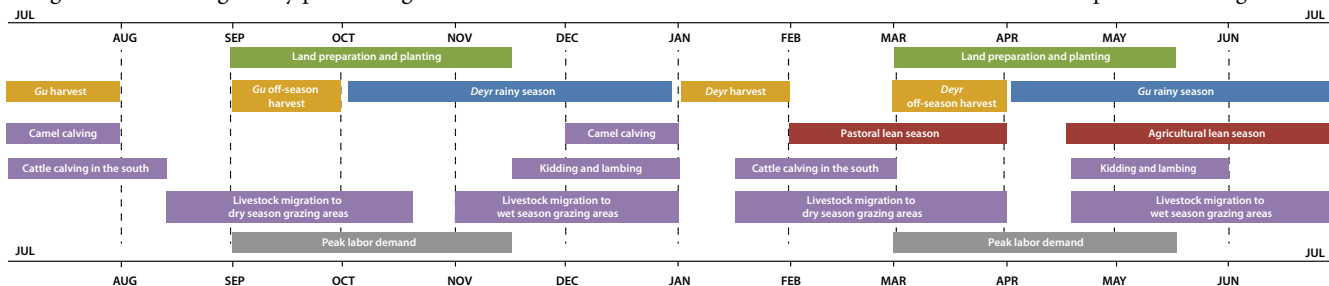


Figure 1. Somaliland seasonal calendar showing the two rainy seasons. Figure courtesy of Famine Early Warning Systems.

convoys. Massive amounts of ordnance were deployed by the SNA on the civilian population of Somaliland, most notably during the aerial bombing and artillery bombardments of the cities of Hargeisa and Burao, both of which were almost completely destroyed. When the regime of Siad Barre collapsed in 1991, SNM fighters were able to gain the upper hand as SNA forces pulled back.

Subsequent to independence, large scale interfactional clashes occurred in Somaliland as different groups vied for political power. These clashes included small-scale mine laying, as armed groups sought to establish control of land by denying other groups' access. The large amounts of weapons and ammunition remaining from the civil war added to the volatility of an already unstable region.

### *HALO's Work in Somaliland*

The HALO Trust began operations in Somaliland in 1999, conducting manual and mechanical mine clearance, battle area clearance (BAC), explosive ordnance disposal (EOD), physical security and stockpile management (PSSM), and mine risk education (MRE). HALO is active in all regions of Somaliland and, from 1999 to January 2018, has cleared 2,340 hectares of land, removing 3,560 anti-personnel mines, 1,348 anti-tank mines, 101,413 items of unexploded ordnance (UXO) and stray ammunition, and 150,372 rounds of small arms ammunition. After almost twenty years of clearance in Somaliland, HALO is now focusing on finishing the final large high-priority tasks in the country, mainly former SNA positions on the border with Ethiopia. If funding levels remain constant and the severity of the drought does not return to its pre-2018 levels, the clearance of these tasks should be completed by mid-to-late 2019. During the next year, HALO will also focus on raising the capacity of the national authorities to deal with the remaining small, low, and medium priority tasks, which mainly consist of isolated roads as well as the continuing threat posed by UXO and stray ammunition.

HALO's work in Somaliland is currently funded by generous support from the United Kingdom (DFID), the Office of Weapons Removal and Abatement in the U.S. State Department's Bureau of Political-Military Affairs (PM/WRA), Germany (German Federal Foreign Office), Ireland (Irish Aid), Finland (Ministry of Foreign Affairs), and the Netherlands (Ministry of Foreign Affairs). Previous donors include the Norwegian government (Royal Ministry of Foreign Affairs), Switzerland (Federal Department of Foreign Affairs/Agency for Development and Cooperation (SDC)), Belgium (Federal Government of Belgium), and Canada (Canada International Development Agency).

### *Climate Change and Drought*

HALO's clearance work in Somaliland and the overall development of the country have been heavily impacted by one of the worst droughts to hit the region in recent history. Somaliland usually experiences rainfall in two seasons every year: the Gu rainy season from April to July and the Deyr rainy season from October to January.<sup>1</sup> Beginning in 2016 and continuing into 2017, Somaliland experienced a drought caused by lower than average rainfalls for four consecutive seasons. Throughout October 2017, when seasonal rains are usually heaviest, rainfall was 50 percent below average.<sup>1</sup> Extremely poor harvests caused by this lack of rainfall along with the death of up to 80 percent of the country's livestock has plunged the region into crisis conditions as families across the Horn of Africa struggled to survive.<sup>2</sup> The loss of livelihoods and lack of food security displaced many rural families, pushing them toward populated areas in search of a support system. In 2017, using data from the United Nations Refugee Agency (UNHCR), the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) reported over 242,000 internally displaced persons (IDP) within Somaliland.<sup>3</sup> However, the International Organization for Migration (IOM) estimates that the true number of IDPs in Somaliland may be as high as 1,004,400.<sup>4</sup> Although the Famine Early Warning System reports that the situation has slightly improved in 2018, much of Somaliland is predicted to have crisis or emergency levels of food insecurity between February and May 2018.<sup>5</sup>

### *Demining and ERW Clearance Opens Humanitarian Space*

In the first half of 2017, HALO's operations were heavily affected by the drought as teams could not obtain enough water to supply remote camps without harming already struggling communities. Minefields in the worst affected areas were suspended as the teams had to relocate to other tasks closer to areas with consistent water sources. In the second half of the year, HALO was able to return to tasks on the border with Ethiopia and prioritized tasks to include assistance to persons displaced by the drought. As has been observed in many other countries, as IDPs move into new and unfamiliar areas that have mine and ERW risks, they are often at a greater risk of being injured or killed, especially if they come from an area without such threats.

In July 2017, an eight-year-old girl in an IDP camp near the town of Adhi-Adeeye in Sool region found a stray hand grenade in an area adjacent to the camp, which was the scene of fighting between Puntland and Somaliland forces between



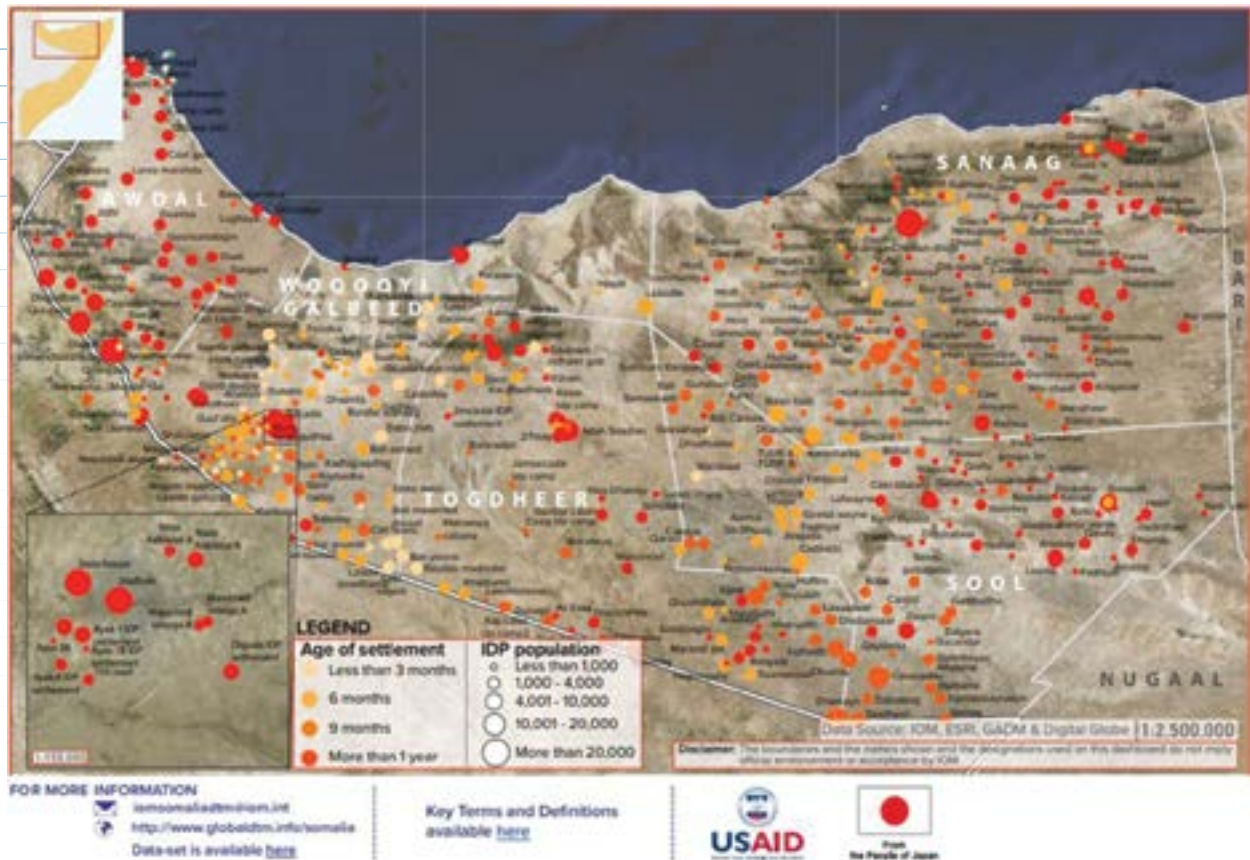


Figure 2. A map of IDP camp locations in Somaliland as of November 2017 produced by IOM.  
 Figure courtesy of IOM.

2004 and 2008. The girl brought the grenade into her family's cooking area in front of their house and pulled the pin unaware of the danger of the item. The resulting explosion killed the girl and wounded 17 others as they were preparing food. HALO immediately sent a team to the area to conduct BAC and EOD activities, as well as the MRE team to conduct education seminars with the civilians. HALO found and destroyed 23 items of UXO and stray ammunition, while six additional UXO items were handed over by the surrounding community.

As refugees move toward populated areas, land previously cleared by HALO has been repurposed to serve IDPs as a safe area to set up camp, as was the case near the village of Khaatumo. Khaatumo village is located on the border with Ethiopia and was heavily mined during both the Ogaden War (1977–1978) and Somali Civil War (1988–1991) to protect military camps and prevent road access. HALO cleared over 750,000 sq m (896,992.5 sq yd) of ground around a former military camp between 2014 and 2015, finding and destroying 57 anti-personnel and four anti-tank mines. The area now houses two IDP camps for people displaced by drought.

The arrival of IDPs in Khaatumo has increased the pressure on local water sources. The villagers in Khaatumo rely on limited water supplies from local wells, while the IDPs must

travel to the nearby village of Jeenyo Laaye to use wells there. However, these wells are swiftly running dry and causing water prices to increase from US\$2 a barrel in late December to \$2.50 a barrel in January 2018, an enormous sum in a country where the average income per person is less than \$1 per day.

HALO's current task in Khaatumo is to clear the road between Khaatumo and Jeenyo Laaye, freeing up access for IDPs and villagers alike. Clearing the 18 km (11.2 mi) route will save beneficiaries a significant amount of time and effort in accessing the water source at Jeenyo Laaye, as they are currently forced to travel 38 km (23.6 mi) through detours and side roads.

HALO's work to open roads is also important to the safety of economic migrants as was recently demonstrated by an accident in the Lughaya area. On 21 January 2018, a dual-wheel flatbed truck carrying approximately 30 people detonated an anti-tank mine on a track 12 km (7.5 mi) south of Lughaya, a town of 14,000 inhabitants in Northwest Somaliland. The passengers in the vehicle were economic migrants trying to reach a boat in Lughaya town in order to travel abroad in search of work. Fortunately, due to the mine's depth and standoff provided by boxes that the passengers were standing on, only two people were slightly injured. With ever-growing numbers of displaced persons passing through Somaliland from Ethiopia

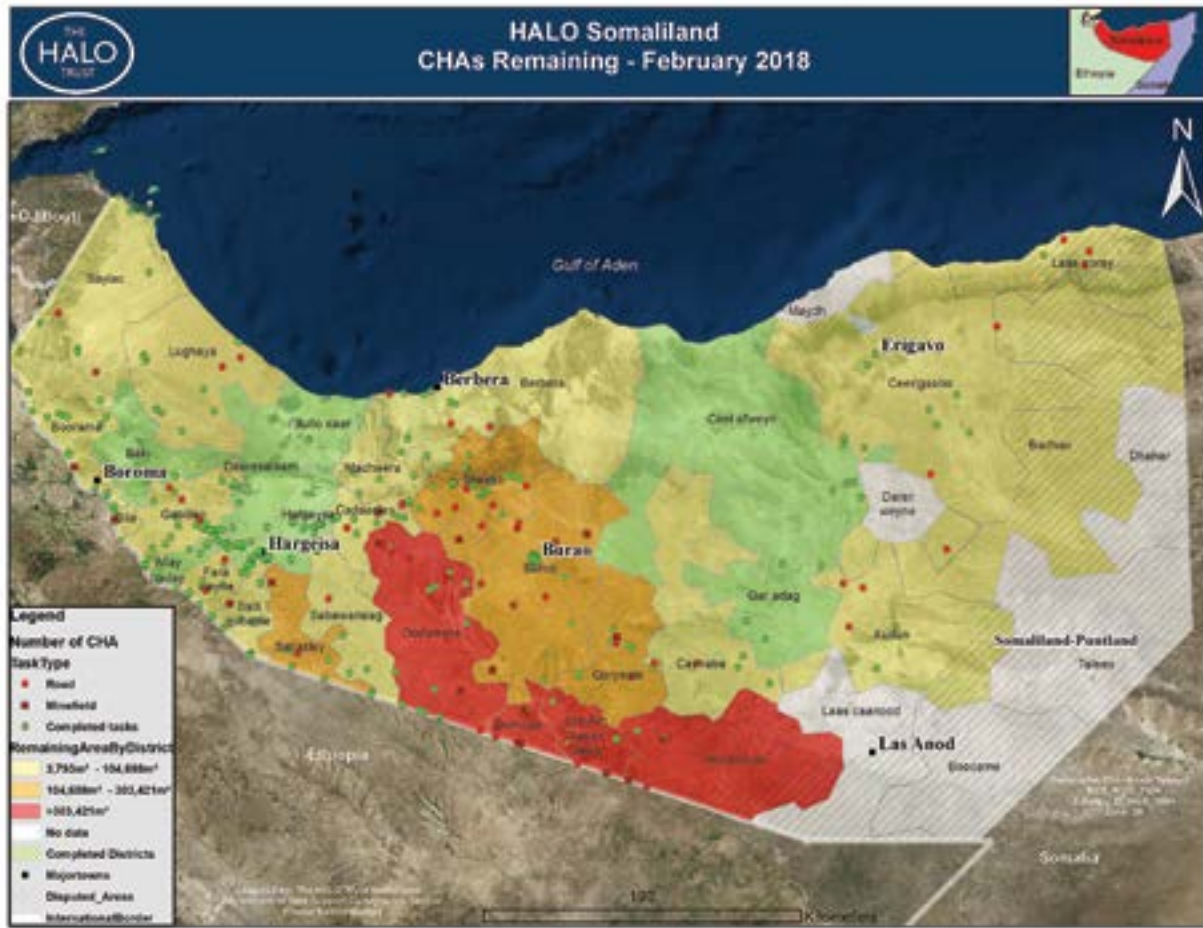


Figure 3. The green circles on the map indicate minefields cleared by The HALO Trust. The red circles depict remaining road tasks, while the squares represent former military camp positions. Note the significant overlap with the IDP camp map. Figure courtesy of The HALO Trust.

to access the coast for the purpose of economic migration, the threat of landmines is a daily hazard and one that carries significant impacts.

### Conclusion

Since the beginning of the drought in 2016, HALO’s clearance teams have released 134,000 sq m (160,262.7 sq yd) of land for agricultural use such as growing fruit, vegetables, and cereal as well as grazing land for livestock. In addition, 156,000 sq m (186,574.4 sq yd) of land has been cleared for community development, and 986,000 sq m (1,179,256.2 sq yd) of land has been cleared to allow access for water collection, health facilities, schools, markets, and other aspects of livelihood previously cut off by the threat of landmines.

The activities conducted by HALO provide support to urban and rural communities that have a history of conflict or that have been severely impacted by the drought. Clan disputes in Somaliland are often centered on agricultural land and access to resources such as water. By clearing mined land, HALO improves access to these resources, reducing the likelihood of disputes arising, which in turn has a stabilizing effect on the region and the country.

Nearly 60 percent of deprived households in Somaliland rely on livestock to sustain their livelihoods.<sup>6</sup> Somalis are famously adept pastoralists and rely heavily on livestock not only for their milk and meat, but also as an investment. In an environment where banking and savings facilities are limited, livestock, particularly camels, represent a key alternative. The loss of camels, when one steps on an anti-tank mine and kills several in a herd, can destroy the wealth of not only



Locals returning from a watering point pass by the Jeenyo Laaye minefield in Somaliland. Photo courtesy of The HALO Trust.



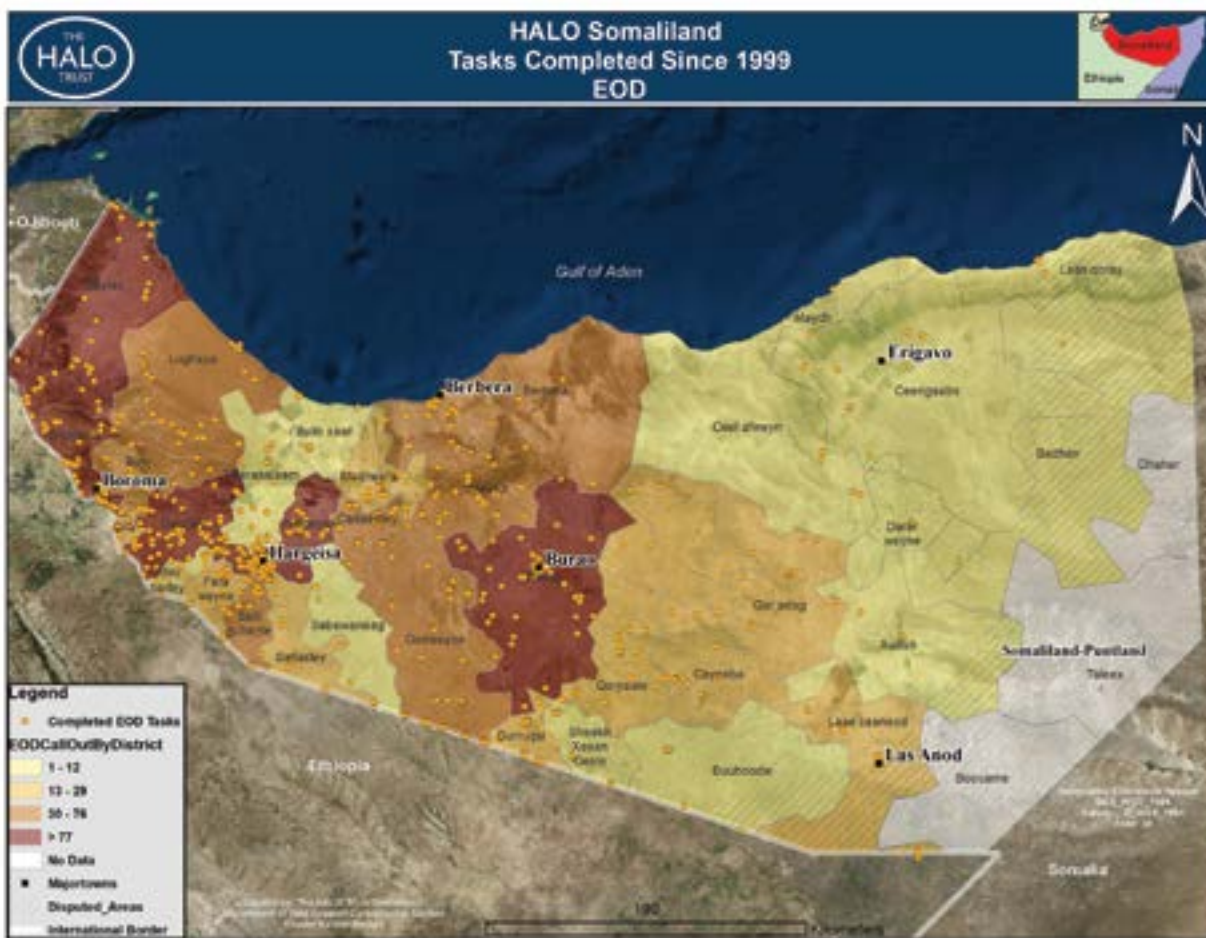


Figure 4. HALO completed EOD tasks in Somaliland.  
Figure courtesy of The HALO Trust.

single families but often the wider community. In addition to the prevention of accidents to people, the prevention of accidents to livestock is also an important outcome.

HALO also recruits staff from local communities, and with over 500 local nationals employed in Somaliland, the injection of money into local economies through salaries is significant. In areas where there are few other income alternatives, this approach has a proven stabilization effect on the entire country.

The humanitarian situation in Somaliland significantly deteriorated in 2017, as several seasons of poor and below-average rainfall impacted food security and livelihoods, and the situation is expected to deteriorate further in 2018. The Food and Agriculture Organization (FAO) stated that rural livelihoods are people’s best defence against famine, and HALO intends to continue supporting these livelihoods through opening access to resources and protecting lives and property.<sup>7</sup>

See endnotes page 63

**Ed Lajoie**  
Somaliland Deputy Program Manager  
The HALO Trust



Ed Lajoie is Somaliland Deputy Program Manager at The HALO Trust. Ed joined HALO in November 2013 as a projects officer working in Mozambique until 2015. He received operations training in Cambodia and Afghanistan before running operations in Zimbabwe in April 2016 and his current position in July 2017. Prior to HALO, Ed worked with the Center for International Stabilization and Recovery. Ed is IMAS Level 3 EOD qualified, and holds a Bachelor of Arts in international affairs with a concentration in Middle East studies from James Madison University.

**Megan Dwyer**  
Somaliland Program Support Officer  
The HALO Trust



Megan Dwyer is Somaliland Program Support Officer at The HALO Trust. Megan joined HALO in 2017 as the Program Support Officer for Somaliland after previously living and working in Somaliland for a year. She brings with her eight years of research experience and a bachelor’s degree in biology and a master’s degree in international relations. Megan has worked for various humanitarian NGOs, most recently with a research consulting firm focused on Africa.



## Field Notes

# DETERMINING THE VALUE OF UAVS IN IRAQ

by Bradley Alford, Ed Curran, and Shawn Cole [ Janus Global Operations ]

As areas of Iraq and Syria controlled by ISIS are liberated, internally displaced persons (IDP) are returning to their homes to face widespread destruction and contamination from deadly improvised explosive devices (IED) implanted by ISIS to maim, kill, and terrorize. Janus Global Operations (Janus) currently operates throughout Iraq, clearing IEDs with a focus on bringing critical infrastructure online to allow IDPs to return safely and resume their lives.

Operating in urban environments has proven challenging due to the high volume of destroyed buildings and associated rubble. In urban environments, operators are exposed to uncertain situations when traditional detection methods can be dangerous. Among the primary goals of industry best practices is to protect operators by limiting their exposure to explosive remnants of war, including IEDs. In a destroyed factory, small copper crush wires, which ISIS has used extensively for victim-activated IEDs, can be difficult to detect, and exposing operators to this threat is unacceptable. Situations like this drive new innovations in search and clearance operational technology to protect operators by more safely finding and disrupting IEDs.

Operator safety and operational quality are Janus' two primary goals. To augment the successful outcomes of our operations and to further mitigate the risk to our operators, Janus has been testing the validity of adopting unmanned aerial vehicles (UAV), or drones, to assist in search and clearance operations. This article discusses the results from our extensive field testing.

### What is a UAV?

A UAV, commonly referred to as a drone, is an aircraft without a human pilot onboard. Small UAVs are components of small unmanned aircraft systems (SUAS), which includes a UAV, a ground-based operator, and a system of communication between the two. The communication is achieved via a radio control unit that incorporates a transmitter (Tx) for commanding the UAV and a receiver for receiving data from

the UAV (e.g., a video feed, battery data, and flight telemetry). Regulations and definitions vary around the world, but a small UAV is generally considered to weigh 20 kg (44 lbs) or less.

### Utilizing UAV Technology in Iraq

A UAV that supports search, improvised explosive device disposal (IEDD), and explosive ordnance disposal (EOD) operations in Iraq is a force multiplier. It is a defining tool for deploying limited resources, such as equipment and manpower, directly to a hazardous area with minimal risk and maximum target intelligence. The surveillance data can be appraised and the correct assets employed, enabling operations to commence in a timely manner.

### Equipment Used for UAV Operations

UAV prices have fallen dramatically, and are now accessible to most audiences. Current prices range from small children's toys that can be purchased for under US\$100 to larger hobbyist machines designed to provide high-quality visual data that can cost thousands. Janus chose the DJI Phantom 4 Pro (P4P) for use in Iraq due to its local availability as well as the rigorous environmental field testing that has already been conducted by the manufacturer and independent technology evaluators to validate the system's ruggedness. The P4P is a small quadcopter aircraft that carries a high-definition (HD) camera, stabilized on a three-axis (roll, pitch, and yaw) gimbal, and is capable of recording video and still images. The P4P weighs approximately 1.4 kg (3.0 lbs) and has a maximum quoted flight time of approximately 30 minutes per battery, with a transmission range of 5–7 km (3.1–4.3 mi). The UAV has a maximum range of 500 m (546.8 yd) horizontally and 121.9 m (133.3 yards) vertically, or the operator's visual range. The UAV can fly intelligently, and has anti-collision sensors (front, rear, below, and on the port and starboard planes), which the pilot may use or turn off as necessary. The UAV streams a live video feed to the Tx, which is either viewed





DJI Phantom 4 Pro (P4P) Quadcopter.  
Courtesy of Shawn Cole, Task Order Leader, Janus Global Operations LLC.

by an attached phone or tablet, or in the case of the P4P Plus model, a dedicated first-person view (FPV) screen on the Tx.

The camera has the capability to record up to Ultrahigh Definition (4K) at 60 frames per second, but video is typically streamed at 1080p full HD or 720p HD if the feed is weakened. It is possible to take photographs while video is being recorded by pressing specific buttons on the Tx or by touching specific icons on the FPV touchscreen.

The P4P's sale is strictly limited to international agencies and is available for \$1,400–1,900. Replacement parts are available through a specific retailer in Erbil, and can be expected within 10–20 days of request. The ease of purchasing and using UAVs has, however, also been recognized by terror groups as well as government security forces in Iraq. Thus, the sale of drones and the areas where they can fly are now regulated in Iraq. To use UAV technology in Iraq, each site requires a general letter of authority to fly from the local mayor or police/army commander, and it is advisable to notify Iraqi security force commanders and civilian authorities in the vicinity of operational sites of planned UAV flights.

### *Evaluation Parameters and Testing*

Janus conducted a trial and evaluation (T&E) in Iraq to assess the effectiveness of UAV support to operations, utilizing a P4P Plus. The T&E took place in four typical environments: area search, buildings, warehouses, and routes. Trip wires, crush wires, pressure plates, and concealed IEDs were prepared and emplaced in these environments to prove the concept and to test the feasibility and capabilities of the onboard camera and FPV screen. The optimal operating distance of the P4P was gathered as a result of the testing.

### *Testing Results and Best Practices*

The results from observing the pressure plate and crush wire IEDs suggest that an initial flight plan should have a significant UAV height in order to search for associated ground signs first (with buried main charges likely providing the most easily-recognized indicator of potential contamination). Ground signs can include indicators such as disturbed earth, sight line markers, and tamping. After a potential target is located, a closer and detailed look can be taken for potential switches. Whereas ground signs may indicate the presence of a buried pressure plate, the absence of ground sign coming from a located main charge may indicate the presence of a crush wire as the initiator. Finally, a detailed slow and low sweep of the area should be made in Tripod Mode, which is a setting that significantly slows down the P4P but allows for more precise control and smoother video footage to increase the quality of imagery. This is best done from four differing cardinal points across the area of concern. The height and angle of the sun may help or hinder UAV optics and, to achieve the highest visibility, multiple approaches from differing angles should be made.

The UAV performed well in large, open-plan storage units, but anti-collision algorithms prevented it from entering conventional doorways without disabling this safety mechanism. DJI has produced a smaller UAV product, the Spark, which retails for approximately \$750 and is a quarter of the P4P's size: 20 cm (7.8 in) in length. The Spark appears to excel in tight and confined conditions and still has a stabilized HD camera onboard. The only limiting factor is a flight time of 16 minutes. The associated amount of hovering involved with flying in a confined area will reduce the flight time. Currently, the P4P is still a preferable option due to its durability and skilled pilots can compensate for disabled safety mechanisms.

We found that a profound parallax effect occurs when attempting to fly a UAV over a target more than 200 m (218 yd) away.<sup>1</sup> In order to negate this, missions should be supported by a range finder and at least one pair of binoculars. UAV pilots should have at least five-to-eight hours of flight training before supporting live operations. This allows the operator to develop muscle memory, dexterity, familiarity with the aircraft, and patience in order to become sufficiently proficient with the SUAS to ensure a successful outcome.

All video footage should be recorded in 4K/2.7K resolution.<sup>2</sup> At this level of resolution the quality of the video imagery is sufficiently high to pause and capture high resolution screenshots directly from the video playback. During operations, a detail can be spotted on a laptop monitor (not previously seen by the UAV operator), and the possibility exists



Tests of the UAV were conducted inside a small and confined building.  
 Courtesy of Shawn Cole, Task Order Leader, Janus Global Operations LLC.

to capture it, export it, add digital filters, and zoom. With 1080p/720p resolution, the results are less defined and crucial detail could be missed.

Further tests were conducted using the UAV inside a small and confined building. The camera on the P4P is central on the vertical plane running through the middle of the UAV. However, it is offset on the central horizontal plane and sits below the central line. This made the assessment of the drone location when flying through entrances with limited clearance while utilizing the FPV screen awkward. After flying into a building, the GPS signal that the UAV uses to maintain position can be blocked. The UAV then reverts to utilizing the visual sensors on the bottom of the UAV body to hold position while hovering. Unfortunately, this only works with ample light available. Tripod Mode had to be used to delay the UAV movements and maintain maximum control inside the building. Any future attempts should incorporate the use of propeller guards. In a confined space, if flying low or moving through a window gap, turbulence is created from the rotors that results in the UAV drifting, making it difficult to control. If a propeller hits an obstacle, such as a door frame, then the UAV will likely crash, possibly be damaged and need recovering, which defeats the point of using the UAV.

### *Benefits To Using UAV Technology*

From our testing, Janus believes that there would be many benefits to adding UAVs to the inventory of IEDD/EOD teams. Their use would enhance capability, safety, and speed and are summarized as but not limited to being capable of:

- Area reduction.
- Confirmation of explosive hazard (EH) contamination.
- Establishing target patterns and direction.
- Investigating ground signs on operational sites.
- Non-technical and technical survey support.
- Observation in restricted access areas.
- Protective security detail surveillance (e.g., vehicle breakdowns in hostile areas).
- Reconnaissance prior to entering previous work sites after a security incident.
- Remote reconnaissance of viable IEDs.
- Render Safe Procedure (RSP) confirmation.
- Route checks.
- Support for mechanical assets.
- Target confirmation.
- Up-to-date imagery of operational task sites for:
  - Briefings
  - Reporting

### *Limitations to Using UAV Technology*

While UAVs have proven to be invaluable tools for both



humanitarian and military operations, our tests indicate that they do have the following limitations/complications in application of IEDD search:

- Battery endurance (average 20 minutes flight time).
- Flying ability of the UAV operator.
- Flying over busy highways and roads.
- Flying over densely populated areas.
- Flying through small gaps and inside buildings.
- Authority to fly locally (government/police/military).
- Nighttime flying.
- Public perception – these camera platforms can be confused with weapons.
- Proximity to airports and air traffic.
- Visibility
- Weather conditions (rain and electrical storms).
- Wind speeds in excess of 17 km/hr.

### Technology Limitation Mitigations

A UAV operation can be time consuming, and sufficient battery power must be included for each mission. Each P4P battery has a maximum listed life span of 30 minutes; however, during testing, it was found to be closer to 20–25 minutes. The automatic low-battery level is signaled to the UAV operator once the battery level descends below 30 percent. If the warning is not heeded, an autonomous function takes control of the UAV and flies it back to its original take-off position. Each mission should have at least three fully-charged batteries on-site in addition to a main charger or a vehicle charger.

Thermal imaging cameras are now available for the DJI P4P UAV platform. These retail at approximately \$2,500 and would significantly increase the effectiveness of the UAV. When flown in Tripod Mode over large areas, fresh anomalies are easily spotted, subtle differences in temperatures are easily distinguishable, landmines, IEDs, VS-500 IED mines, and items of ERW will all hold temperature values that differ from the mean ground temperature and, as such, are easily spotted from height despite being concealed.

### Conclusion

The use of UAV technology to support IEDD/EOD operations in Iraq has increased Janus' overall effectiveness in Iraq. The relatively small cost of implementing UAVs into the respective areas of operations and integrating them into daily operations has the potential to render large benefits. By training more UAV operators and integrating thermal imaging cameras into the UAV platform, Janus plans to further develop the capability of this technology for IEDD/EOD operations.

During the trial, an entry-level UAV—the P4P Plus—was used, primarily utilized by hobbyists. DJI (and many other UAV manufacturers) have systems that are capable of even more applications. These UAVs can carry small payloads and have greater flight endurance, better cameras, and thermal imaging as standard. While the trial UAV was robust and performed well, the fixed FPV screen prevented third-party software from being used.

As UAV costs continue to decline, getting these inexpensive tools into the hands of trained operators across the world will evolve procedures and standards, and help mitigate operator risk. As UAVs are used more broadly for IEDD/EOD operations, more innovative UAV solutions will be crafted that address the current limitations, leading to greater efficiency, economy, and operator safety. ©

See endnotes page 63

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High Threat Integrated Tracking Specialist



Bradley Alford works for Janus Global Operations in support of Diplomatic Security operations abroad. He previously worked for Janus on the U.S. Department of State conventional weapons destruction programs in Afghanistan, Bosnia and Herzegovina, Iraq, and Laos. He has lived in Morocco, where he studied Arabic through the U.S. Department of Defense's Project Global Officer Program. He also worked as a research intern for the NATO Defense College in Rome. Alford holds a Bachelor of Arts in International Affairs with a concentration in the Middle East.

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Edward J. Curran III graduated from James Madison University in December 2017 with a B.S. in Public Policy and Administration and a concentration in Management. Prior to attending James Madison, Curran served in the United States Marine Corps as an all-source intelligence analyst. He deployed to Musa Qalah with Kilo Company, 3d Battalion 2d Marines in 2011 and gained experience in counter IED operations. He deployed again aboard the USS Kearsarge with the 26 Marine Expeditionary Unit in 2013. Curran later worked after his graduation from James Madison as the Project Intel Support Officer in support of Janus' Conventional Weapons Destruction (CWD) Program in Iraq.

**Shawn Cole**  
Janus Global Operations, LLC  
Task Order Leader

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# R&D

Research and Development

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Unexploded Ordnance Center of Excellence (UXOCOE)**





# WHY IS WATER SO EFFICIENT AT SUPPRESSING THE EFFECTS OF EXPLOSIONS?

by Stephen Salter [ University of Edinburgh ] and John Parkes

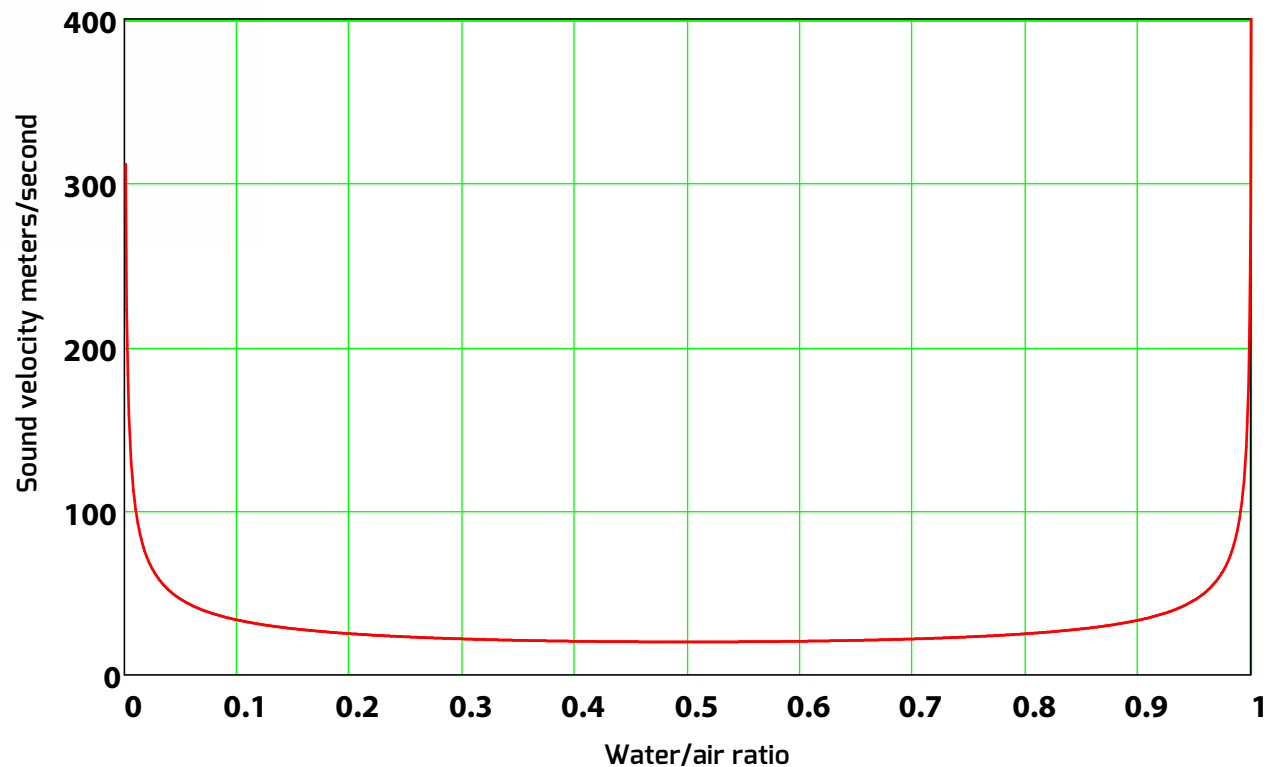


Figure 1. The speed of sound in mixtures of water and air as a function of the water/air ratio. All graphics courtesy of the authors.

When most experienced explosives engineers first observe an explosion suppressed by bags of water, they are convinced that there has been a misfire. Depending on the amount of water and the way it is contained, the overpressure can be reduced by a factor of ten, sometimes more than twenty.<sup>1</sup> The number of fragments from shell cases can be one hundred times less. Their velocities can be seven times. Slugs from focal point charges are stopped. Safety distances around magazines can be cut. The number of people evacuated from a bomb disposal site can be reduced. In June 1999, engineers from 33 Regiment (Explosive Ordnance Disposal) saved an entire village in Kosovo from the detonation of a 2,000-pound NATO bomb by using water bags.

This article outlines some of the physics behind the effects. Latent heat, fast external pressure rise, drag of fragments, momentum transfer, the speed of sound in gas-liquid mixtures, and interference with the combustion of carbon are all involved, but perhaps other mysteries still remain. Some practical details of the technique are also discussed.

## HEAT

The latent heat needed to evaporate a kilogram of water is 2.25 megajoules. The explosive energy from 1 kilogram of TNT is 4.45 megajoules.

Water is cheap and can be affordably placed weighing much more than twice its weight in explosives. An explosion breaks water into a fine spray. The surface area of spray is six times the water volume divided by drop diameter and can be very large. For example, a cubic meter of water broken into 30 micron drops has a surface area of 200,000 square meters. This large area provides a splendid chance for evaporation. The exact rate of heat transfer cannot be known without knowledge of the distribution of drop diameters and their velocities relative to the surrounding hot gases. However, by making reasonable guesses, one can show that all the heat can be transferred to water drops in times of the order of a few milliseconds. Cooling the products of an explosion by ten times on the absolute temperature scale will give correspondingly large reductions in the pressure and volume of gases.

## SOUND SPEED

The speed of sound in any medium is given by dividing the bulk modulus by the density and taking the square root. (The bulk modulus of a substance indicates how hard it is to reduce its volume by increasing pressure and is the ratio of an applied pressure to the resulting fractional change in volume.) Water at 15 degrees Celsius has a rather high bulk modulus of  $2.05 \times 10^9$  newton per square meter and a density of

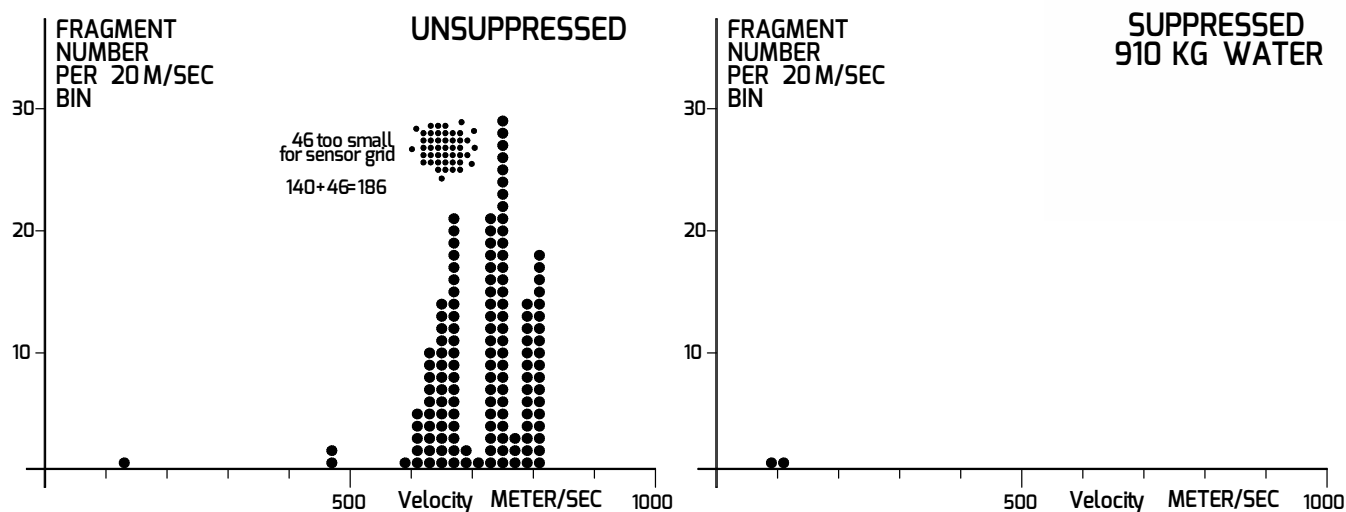


Figure 2. Fragment number and velocity from pairs of 155 mm M107 howitzer shells.

999 kilogram per cubic meter, giving it a speed of sound of 1,432 meters per second. At the frequencies of sound and explosive waves, the bulk modulus of a gas is given by its pressure times the ratio of its specific heat at constant pressure and constant volume. This ratio is often given the symbol  $\gamma$  with the value 1.4 for diatomic gasses like air. The density of ambient air is about 1.22 kilogram per cubic meter giving it a speed of sound of 341 meters per second.

The speed of sound in a mixture of water and air is very interesting. A fifty-fifty mixture by volume would have double the bulk modulus of air (i.e., 283,640 newton per squared meter) and half the density of water (i.e., 499.5 kilogram per cubic meter).<sup>2</sup> This mixture would have a speed of sound of only 23.8 meters per second, a factor of 17 down on normal speed in waterless air. Figure 1 shows a graph of the speed of sound in water/air mixtures as a function of water-to-air fraction. The effect is very strong for ratios between 0.03 and 0.97.

A video sequence of a water-suppressed explosion shows that the rate of advance of the spray front is very close to the velocities shown in Figure 1.

#### MOMENTUM TRANSFER

The conical geometry of a focal point charge can produce a slug of metal moving with a velocity that is considerably above the detonation velocity of the best explosives. The velocity is so high that a very thick armor plate can be penetrated. However, when such a projectile hits two bags of water, about the dimensions of a pillow, hanging on an easel made of domestic, hollow-core doors, the entire mass of water is blown out from the far side of the furthest pillow. Suppose that a slug weighing 0.1 kilogram is approaching the target at 10,000 meters per second. The momentum is 1,000 kilogram meters per second. This has to be conserved. When the slug hits the front wall of a water bag, a positive pressure wave with a spherical front propagates through the water. When this reaches the far side of the bag, there is an impedance mismatch because the mechanical properties of air and water are so different. This results in the reflection of the positive pressure wave as a negative front, but a liquid cannot sustain large negative pressures. The result is that water sprays out from the entire area of shock front. The process is repeated for the second bag.

If the momentum of the slug is transferred to a 100 kilogram mass of water, the water velocity needed to accept the momentum will be only 10 meters per second. The water behaves like the executive desktop toy known as Newton's cradle, which consists of a set of steel balls on pairs of strings swinging in a row. The intact slug in the shape of a carrot will

be found very close to the easel position. Protection works because the expanding shock front transfers momentum to *all* the water.

#### FRAGMENT DRAG

Imagine that a steel munition case round has just exploded. The enormous internal pressure causes cracks to appear between the munition's case and the neighboring fragment at places chosen by the shell designer to produce the most damaging effect. A much lower pressure outside the casing and the large pressure difference means that the case has to do some serious acceleration. Meanwhile, explosive gases with a high density under the same pressure gradient are pouring through the gap between the case and the neighboring fragments giving high aerodynamic drag forces to increase acceleration even further. The casing's shape is such that it will probably have a high drag coefficient.

Now imagine that the event is repeated with a large mass of water touching the outer wall of the case. As soon as the cracks open, the pressure in the water outside rises very fast and quickly approaches the pressure inside. With no pressure gradient, why should the munition bother to do any acceleration? The water from the outside of the enclosing bags can do it instead. Drops of water are held together by surface tension but movement relative to surrounding air creates a force to break them apart. This continues until they are very small and moving with almost the same velocity as the mixture of air and explosion products around them. If the water packing around the charge was incomplete and the round did acquire some velocity relative to the water around the munition case, the drag forces will be 800 times higher than if it were moving through air.

Parkes, Wilkinson, and O'Dwyer did experiments on howitzer shells at the Defence Research Agency (DRA) range at Shoeburyness using extremely sophisticated equipment for measuring fragment numbers and velocity. The results from two unsuppressed events at 6.05 meters range and two suppressed events at 4.5 meters range are shown in Image 1.<sup>3</sup> The fragment screens intercept only a small fraction (1.95% and 3.54% respectively) of the total number of fragments produced by the shell casing but, with an unsuppressed detonation, still enough to be statistically significant.

For both the unsuppressed shells, the velocity distribution shows three distinct clusters between 600 and 800 meters per second for reasons so far unexplained. The two shells produced a total of 186 fragments. However, even with a higher interception angle, there was only one fragment recorded from each of the suppressed events and both the velocities were about 100 meters per second. There were water bags





A pair of water bags mounted on a chip-board easel. The HB 876 has a self-forging fragment that is absolutely lethal and designed to knock out bulldozers as they attempt to fill in bomb craters on runways. The weapon functions when tipped over and sends the self-forging fragment through the bulldozer blade, engine, and the operator. The weapon carries many smaller "pea charges" for AP effect. In the trial, the fragment was actually shattered and its pieces were recovered from the ground at the foot of the range's safety blocks. No damage was occasioned to the blocks. Self-forging fragments are used in many roadside bombs and kill tanks and armored vehicles (and their crews) with ease.

around and above the shell but not below it. It is possible that the fragments that escaped had moved downwards and bounced off the ground. The base plate of an artillery shell must be thick enough to withstand the high breech pressure, and there are accounts of intact base plates being thrown over the heads of observers 1,800 meters away from a shell burst. In the Shoeburyness trials, broken base plates from 155 to 200 mm suppressed shells were found at the foot of the 18 millimeter plywood support of the velocity sensing screens.

Anyone who wishes to repeat the experiment but is not in possession of their own 155 mm howitzer shells and fragment-counting equipment can build a stockade out of four sheets of hardboard and cover a charge with a bag of granite chips from a garden center. Examination of the boards after firing will show many hundreds of penetrations. However with a 200 millimeter thickness of water bags above the granite chips there will not be a single penetration of the hardboard screens, and so the second part of the experiment can safely be tried at home.

### CARBON COMBUSTION

Many explosives, TNT in particular, do not contain enough oxygen to react with all the other molecules. Consequently, an explosion generates a surplus of carbon in the form of a cloud of finely divided soot. Some of the energy in the soot cloud can still be useful if the carbon can take oxygen from air and act like a fuel-air explosion. This means that a negative oxygen balance is not regarded as a disadvantage. Alford has pointed out that the presence of water drops, water vapor, and lower temperatures could interfere with the secondary carbon-oxygen reaction.<sup>4</sup> This could provide yet another way for water to affect explosions. Evidence for this is that TNT explosions that have been suppressed leave behind sooty water but relatively clean air. There are many electrostatic effects going on in an explosion and over short distances the forces between small, charged particles can be very strong. The water spray from a suppressed explosion is effective at trapping the dust from a building demolition.

### PRACTICAL STRUCTURES

Suppression has now been tested with a wide range of charge weights and weapon casings up to a Mk 84 Paveway bomb with a 2,000 pound charge. Most of the practical work involves making a structure that can contain and support a large weight of water without itself generating dangerous fragments. The experiments show that it is wrong to try to contain water in any structure that itself might tend to contain the explosion or to interfere with the outward movement of spay. Achieving intimate contact between explosion products and water as quickly as possible is ideal. Water bags made from layflat polyethylene tube are satisfactorily provided that the welding is given careful attention. Even with a thickness of 250 microns, they are sufficiently strong. A fit, rugby-playing Royal Logistics Corps major wearing steel-tipped combat boots could viciously attack a water-filled bag to no effect. Similarly, a tug-of-war team could drag a filled bag over rough gravel without consequence.

An uneven thickness of water allows more ejecta along the direction of the thinner covering, hence a spherical water volume should be centered around the charge. A more practical hemispherical covering over a ground charge

will increase ground shock, but this could perhaps be reduced by a surrounding ditch. The key problem has been to build water bag structures with height. It is possible to draw systems in which the skin tension defines the shape but it is difficult to control the shape of a partly filled structure. A water bag can roll down imperceptible slopes, and the incompletely filled structures can show maddening behavior. Expanded polystyrene foam, glass-fiber tubes in the form of hollow rectangular



Image 2. Saddle bag and polystyrene construction.

beams, cling-film, nets, and the cheapest domestic doors with an internal paper honeycomb filling placed edge on are all suitable supports because they disintegrate into very light particles. Boyer et al. developed a neat basket made from geo-textile mat shaped like a hat with a high rim to support water bags and replicated the Shoeburyness trials with grenades and mortar shells.<sup>5</sup>

For larger structures, Dell Explosives laid duplex water bags so that they straddled a block of expanded polystyrene like saddle-bags over a horse and then filled each bag through a hole at the top. The arrangement is shown in Image 2. This method allows walls with overlapping bags and an airspace between them. Roofs can be made by laying saddle-bags over thin-walled, rectangular-section hollow tubes that are long enough to act as roof beams. The combination of walls and roofs allows the construction of **habitats** in which large weapons can be made safe in the knowledge that any unintended, high-order event (which occurs at about 10% of disposals) will be safely contained within a much shorter evacuation distance than required for an unsuppressed explosion.

While fragment stopping suggests that complete water coverage is desirable close to a weapon casing, the reduction of the speed of sound in water/air mixtures suggests that it might be useful to include some air deliberately in the outer region of the water volume. Polyethylene bubble pack can be used but has an inconveniently large buoyancy. The most satisfactory construction for walls, now supplied by Dell Explosives, uses bales of straw cased in polythene bags made from layflat polythene tubing. The unfilled bales are very light, far lighter than filled sandbags, so that structures are quick to build around objects like the bases of wind turbines. Holes for water pipes are then stabbed through the upper surface of each wrapped bale to allow filling from a hose. Each bale can hold 100 kilograms of water. Additional structural integrity can be obtained by wrapping the walls with a belt of cling film. There is the further advantage that while it is tedious to clean up thousands of fragments of expanded polystyrene after a suppressed explosion, the straw residues are biodegradable. More permanent structures for long-term storage of explosives in crowded sites can be made from polystyrene with water-filled polythene inserts.

For the many hundreds of thousands of suppressions needed for the disposal of surplus munitions, even the consumption of polythene would be undesirable. A team at the University of Edinburgh designed and carried out initial, small-scale testing of water mortars resembling giant water pistols driven by compressed air that would be placed in a ring around a charge. Twenty tonnes of water would converge from all directions just as the charge was fired and the cycle would be repeated every few minutes.

## CONCLUSIONS

Water bags are now in service for explosive ordnance disposal (EOD) and civilian demolition adjacent to valuable installations. The reduction in safety distances and evacuation numbers can provide large savings.

Water suppresses explosions by the

- Rapid cooling of explosion products because of the large surface area of spray.
- Reduction of sound velocity in water/air mixtures to a few tens of meters per second.
- Transfer of the momentum of a fast projectile to the entire water mass.
- Rapid rise of pressure on the outside of a fragmenting weapon casing.
- Increase of drag of fragments in water because of its higher density.
- Suppression of soot combustion in low-oxygen explosives.

To put numerical values on the possible factors listed above, researchers should measure the number, velocity, temperature, and size-distribution of drops inside the expanding water-air mix.

Structures to contain water must not impede the rapid mixing of water and gasses. They must not themselves present any fragmentation hazard. Achieving height is the chief difficulty.

Polythene bags, expanded polystyrene foam, low-density domestic doors, nets, geo-textile baskets, hollow glass-reinforced plastic (GRP) tubes, and straw bales in polythene are all suitable materials.

Water and straw are cheap, rapid to erect with small teams, and biodegradable. For the continuous, production-line suppression needed for disposal of unused weapons, large volumes of spray can be generated by water mortars.

The authors hope that water and water bags with the right supporting structures will make life for both civilian and military explosives engineers much less exciting. ©

*See endnotes page 63*

*As presented at the UK Explosives Mitigation Workshop, RCMS Shrivvenham, 19 June 2002.*

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Stephen Salter served an apprenticeship as aircraft fitter, tool-maker, and instrumentation engineer at Saunders Roe before doing a degree in Natural Sciences at the University of Cambridge. He has worked on mechanics and electronics for robotics in artificial intelligence, mine clearance, renewable energy from sea waves and tidal streams, and now the hardware for marine cloud brightening to reverse global warming. He is emeritus Professor of Engineering Design at the University of Edinburgh.

### John Parkes



John Parkes joined the British army in 1963 at the age of 17 and was promoted to the rank of sergeant at the age of 20 making him the youngest to hold that rank since the end of WWII. He carried out counter terrorist work in Aden in 1966-1967 and was in command of the Brigade's Engineer Support Troop. He has supplied bomb suppression equipment around the world and, in 1996, protection for the demolition of a railway bridge at Yaxley near Peterborough, which was 18 inches away from its replacement.



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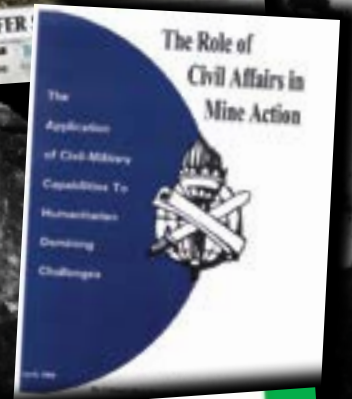
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# ENDNOTES

## PPE Development and Needs in HMA by Smith [ from page 5]

1. NATO Standardization Agency (STANAG) 2920 PPS (edition 2) Ballistic test method for Personal Armor Materials and Combat Clothing, NSA/0723-PPS/2920, 2003.
2. The author has tested 5mm untreated polycarbonate using NATO STANAG 2920 and found a V50 ranging from 250 m/s to 280 m/s. The uncertain result is probably caused by variations in the ambient temperature or in the temperature of the fragments (which were fired using blanks or by compressed air).
3. Hand-tools are included in IMAS 10.30 PPE because the accident record shows that the use of well designed tools can protect the deminer by distance and by avoiding parts of the tool separating and causing injury.
4. PURE is a polypropylene self-reinforced composite material: see <http://www.ditweaving.com/>
5. This visor was designed by the author and given freely to the manufacturer: See: Security Devices. "SD Platinum Visor." Accessed 12 April 2018. <https://bit.ly/2vghH7B>.
6. The author was invited to advise during a workshop in Norway at the start of the design process for this mask, but does not like the result. For information about the mask, see: Rofi: Protecting People. Accessed 12 April 2018. <https://bit.ly/2vghUrp>.
7. European Committee for Standardization (CEN) Workshop Agreement 15756, now defunct.
8. IMAS 10.30, 2nd Edition, amendment 2, "References to CWA for T&E of PPE were removed from Clause 1 and Annex A" at the start of 2011.
9. The author was an advisor to the project.
10. From IMAS 04.10, Glossary, 2014. This definition is drawn from the International Standards Organization (ISO) Guide 51:1999(E).
11. Left to right, the pictures show a UNADP deminer in Mozambique a HALO Trust and a MAG deminer in Cambodia.
12. Pictures taken in 2017 during specialist IED clearance training conducted in Syria by PCM ERW Risk Management & MAT Kosovo. [www.pcm-erw.com](http://www.pcm-erw.com), email: [info@pcm-erw.com](mailto:info@pcm-erw.com).
13. Lebanon NMAS 04.10 Glossary, February, 2018.
14. Drafted by the LMAC with the author's input, 2018.
15. The most successful of which in terms of sales is the DOK-ING MV4 made in Croatia (which has also supplied U.S. forces in Afghanistan).
16. IMAS 10.30 PPE, Edition 1, 2001. "The frontal protection ensemble provided to employees, whether required to kneel, sit or squat shall be designed to cover the eyes, throat (frontal neck), chest, abdomen and genitals".
17. IMAS 10.30 2nd Edition, 2008.
18. As a member of the IMAS Review Board, the author argued for this change because of the lack of injuries sustained while wearing goggles while excavating with rakes. The wearing of blast goggles during EOD and IED tasks has since become common, which was not anticipated but the author respects the principle of wearer's choice as long as blast visors are available at the task if they choose to wear them.
19. For a formal HMA Field Risk Assessment training course, the author recommends the one that he provided some materials for at GICHD. Contact: [r.evans@gichd.org](mailto:r.evans@gichd.org)
20. Database of Demining Accidents, which is an informative reference in IMAS 10.30, (Annex A) and online at [www.ddasonline.com](http://www.ddasonline.com).
21. International Mine Action Standards Technical Note for Mine Action (IMAS TNMA) TN 10.20 20 2009.

## References

The author has written extensively on PPE in mine action over the past 20 year and has had several relevant papers published in the Journal over that period:

1. Smith, Andy (1998) "Current Situation and Perceived Needs for Head and Face Protection in Humanitarian Demining," *The Journal of Humanitarian Demining*: Vol. 2: Iss. 1, Article 4. Accessed 12 April 2018. <https://bit.ly/2HvwwBh>.
2. Smith, Andy (2000) "The Facts on Protection Needs in Humanitarian Demining," *Journal of Mine Action*: Vol. 4: Iss. 2, Article 11. Accessed 12 April 2018. <https://bit.ly/2qrgDb7>.
3. Smith, Andy (2002) "What Use is a Database of Demining Accidents?" *Journal of Mine Action*: Vol. 6: Iss. 2, Article 21. Accessed 12 April 2018. <https://bit.ly/2JGzCY6>.
4. Smith, Andy (2002) "Developing Safer Demining Handtools in Zimbabwe," *Journal of Mine Action*: Vol. 6: Iss. 2, Article 7. Accessed 12 April 2018. <https://bit.ly/2JEEBZh>.
5. Smith, Andy (2003) "IMAS and PPE Requirements," *Journal of Mine Action*: Vol. 7: Iss. 1, Article. 12. Accessed 12 April 2018. <https://bit.ly/2GTyG4Z>.
6. Smith, Andy (2011) "The Database of Demining Accidents: A Driving Force in HMA," *The Journal of ERW and Mine Action*: Vol. 15: Iss. 2, Article 18. Accessed 12 April 2018. <https://bit.ly/2qpmheS>.
7. Smith, Andy (2014) "Understanding the Use of Prodders in Mine Detection," *The Journal of ERW and Mine Action*: Vol. 18: Iss. 1, Article 14. Accessed 12 April 2018. <https://bit.ly/2JF1qfr>.

## Advanced Geophysical Classification of WWII-era Unexploded Bombs Using Borehole Electromagnetics by Beran and Billings [ from page 12 ]

1. Strategic Environmental Research and Development Program (SERDP), and Environmental Security Technology Certification Program (ESTCP). "Munitions Response." Accessed 11 April 2018. <https://bit.ly/2qnj9zP>.
2. Beran, L., B.C. Zelt, and S. D. Billings. "Detecting and Classifying UXO." *Journal of ERW and Mine Action* 17.1 (2013): 57-62. Accessed 11 April 2018. <https://bit.ly/2qoIF7Q>.
3. "Theater History of Operations (THOR) Data: World War II." *Data.world*. Accessed 11 April 2018. <https://bit.ly/2EEghmu>.
4. Holm, C. "Germany's WWII Duds Get Deadlier." *Spiegel Online* (2012). Accessed 11 April 2018. <https://bit.ly/2EE4O6r>.
5. Billings S. D. Discrimination and Classification of Buried Unexploded Ordnance using Magnetometry. *IEEE Transactions on Geoscience and Remote Sensing* 42 (2004) 1241-1251.

## Lessons from the Past: The Rapid Clearance of Denmark's Minefields in 1945 by Evans [ from page 19 ]

1. See Hovedpunkter til Orientering for Pressen ved Møde i December 1945, paragraph 1-3, p. 1-2 for how much land was contaminated. See also Kaptajn D.A.Wieth-Knudsen, *Minerydning i Danmark*, "Tidsskrift for Ingeniørofficerer" 14. Aargang, p. 136. The figure of 1000 km<sup>2</sup> with only 10% actually containing mines is given. This is remarkably close to the proportion of modern pattern minefield CHA that is often eventually cleared using land release best practice.

2. Beretning over Mine- og Sprængkommandoens Arbejde I Tiden fra 10.05.1945 - 22.12.1947. p.7
3. <https://web.archive.org/web/20070517235645/http://www.law.ou.edu/ushistory/germsurr.shtml>
4. Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. p. 134
5. Hovedpunkter til Orientering for Pressen ved Møde i December 1945, paragraph 4, p.2
6. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 4, p.2 A follow on organization, Sprengkommando Dänemark started to be formed in August 1945 and continued until July 1947. See Zusammenfassender Bericht, p.1
7. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 4, p.2
8. Beretning over Mine- og Sprængkommandoens Arbejde I Tiden fra 10.05.1945 - 22.12.1947. p.1
9. Footage of Major Holland and Hauptman Geuer discussing the minefields of the Skallingen peninsula in Jutland can be found at <http://www.sculptingthepast.dk/Film-oversigt/Besaettelsen/Livsfare---Miner.aspx>
10. Orientering vedrørende 'Minekommando Dänemark"', 18 June 1945.
11. Orientering vedrørende 'Minekommando Dänemark"', 18 June 1945.
12. Arbeitsplan für das Räumung von Minen auf der Halbinsel Skalling. Pionier-bataillon 1060, Minenkommando Dänemark, pp.2-3.
13. <http://www.sculptingthepast.dk/Film-oversigt/Besaettelsen/Livsfare---Miner.aspx>
14. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 1, p.1 See also Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. p. 142
15. The best post war demining records were probably kept by the Draeger Brigade in the Netherlands in 1945. The Brigade, commanded by Wehrmacht Engineer, Lieutenant Colonel Draeger, had over 3300 men who were, as in Denmark, self-administered and were largely left to get on with the job. The records the Brigade kept could not be matched by many national authorities and a number of operators today. In six months 1'162'458 mines were cleared (60% AP/40% AT). Booby traps were fitted to 1.4% of mines. Email from Antoon Meijers, author of Achtung Minen, 14 February 2018. See also Antoon Meijers, Achtung Minen - Danger Mines, Het ruimen van landmijnen in Nederland 1940-1947 (Soesterberg, 2013), pp. 138-139. On average 100 mines were lifted for every sixty two man hours. Of the 3300 men, 179 were killed and 381 injured. Records were kept of what mines caused what casualties. Schu mines had a fatality rate of 2%, S-mines 31% and all AT mines 60%. Again many national authorities and operators would be unable to produce equivalent figures for the last 25 years of mine action. See Military Operational Research Unit Report no. 7: Battle Study, Minefield Clearance and Casualties. Date: 03 May 1946. Stichting Geschiedkundige Verzameling EOD, Netherlands.
16. Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. Appendix 1.
17. Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. Appendix 2.
18. Email from Dan Mouritzsen, 10 February 2018
19. Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. p. 133 – 152
20. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 4, pp.2-3 See also Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. p. 146
21. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 4, pp.2-3
22. <http://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=2773&context=cisr-journal>
23. Convention (III) relative to the Treatment of Prisoners of War. Geneva, 12 August 1949. Article 52.
24. Email from Antoon Meijers, author of Achtung Minen, 14 February 2018. See also Antoon Meijers, Achtung Minen - Danger Mines, Het ruimen van landmijnen in Nederland 1940-1947 (Soesterberg, 2013), pp. 138-139
25. Croll M. Landmines in War and Peace: From Their Origins to the Present Day. Yorkshire: Pen and Sword, 2009; 100
26. <https://www.halotrust.org/media-centre/news/halo-ceo-calls-for-action-on-landmines/>
27. John Jensen, Der er mere Under Sandet – minerydningen efter besættelsen.
28. In Holland the British and Canadians calculated that "well recorded minefields were cleared at about three times the rate of poorly or unrecorded ones." Military Operational Research Unit Report no. 7: Battle Study, Minefield Clearance and Casualties. Date: 03 May 1946. P.3 Stichting Geschiedkundige Verzameling EOD, Netherlands. In the modern day context the multiple is likely to be even greater.
29. Hovedpunkter til Orientering for Pressen ved Møde i december 1945, paragraph 2, p.1
30. Hovedpunkter til Orientering for Pressen ved Møde i December 1945, paragraph 3, p.2
31. Small groups of German Surrendered Enemy Personnel stayed until 1948, the last leaving in October that year. Their duties involved "call outs" to mines and ERW. Dienstgruppe Dänemark Rapport, 1948, pp 12-14.
32. Declaration of Completion of Implementation of Article 5 of the Convention on the Prohibition of the use of Stockpiling, Production and transfer of Anti-Personnel Mines and on their Destruction, Denmark, 21 June 2012. Para 4, p.1
33. Kaptajn D.A.Wieth-Knudsen, Minerydning i Danmark, "Tidsskrift for Ingeniørofficerer" 14. Aargang. p. 148. See also Letter from Oversergent Frost tp Pionerkommandoet 21 September 1945, papa ad.a.4.p.5
34. <http://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=2773&context=cisr-journal>
35. Email from Martin Jebens to the author, 09 February 2018.
36. Declaration of Completion of Implementation of Article 5 of the Convention on the Prohibition of the use of Stockpiling, Production and transfer of Anti-Personnel Mines and on their Destruction, Denmark, 21 June 2012. Para 4, p.1 and Annex I p.7
37. Article 7 of the Mine Ban Treaty involves transparency measures that, among other things, include the accurate recording of all mined areas. Ideally it would require recording of individual landmine locations. This best practice is now normal amongst leading operators who use this information to better inform and guide subsequent survey and clearance.

#### **Minefield Sketch Maps in Humanitarian Mine Action by Hamlin and Jaupi [ from page 34 ]**

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**Mitigating Adverse Environmental Impacts in Mine Action by Jebens and Maspoli [ from page 40 ]**

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**Clearing Safe Spaces for Drought Affected Communities in Somaliland by Lajoie and Dwyer [ from page 46 ]**

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**Determining the Value of UAVs in Iraq by Alford, Curran, and Cole [ from page 51 ]**

1. A defect in an image cause by differences in positions in a camera.
2. 4K is 3840x2160, while is 2.7K is 2704x1520.

**WHY IS WATER SO EFFICIENT AT SUPPRESSING THE EFFECTS OF EXPLOSIONS? BY SALTER AND PARKES [ FROM PAGE 56 ]**

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# THE JOURNAL

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## CALL FOR PAPERS

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The Journal invites government bodies, nongovernmental organizations, military personnel, researchers, academics and industry experts to contribute their articles or case studies. We are actively looking for theoretical and practice-based non-promotional contributions.

#### EDITORIAL

##### What are the Future Challenges in HMA?

As the field of humanitarian mine action (HMA) evolves, what are the main challenges that NGOs, international agencies, and government entities will face in the next 5 to 10 years? What challenges and lessons learned can we share with the wider HMA community to mitigate future threats while improving operational efficiency? What steps are HMA organizations taking to circumvent these threats? Possible discussion points include funding, improvised explosive devices (IEDs) and HMA, relationships between international NGOs and local/national government institutions, information management systems, extending HMA efforts to rebuild communities, understanding and addressing asymmetrical tactics, and maintaining physical security and stockpile management (PSSM) best practices in unstable regions.

#### SPOTLIGHT

##### Iraq and Syria

The explosive contamination left behind by the Islamic State of Iraq and Syria continues to pose a significant threat to regional security and post-conflict recovery. What obstacles are organizations facing in Iraq and Syria, and what lessons learned can we pass on to the rest of the community? Are there measures we can take to ensure the humanitarian response maximizes the safety of those returning home? What kind of scenarios have humanitarian actors encountered and what questions do they raise for how we conduct future operations? Specific topics include technical and non-technical survey, targeted clearance, risk education, land release and risk management, training and equipping operators for C-IED efforts, and capacity building.

#### FEATURE

##### Incorporating IED Disposal into HMA

Modern conflicts and evolving warfare continue to widen the scope of HMA. What is the process for HMA organizations seeking to include IEDs into their areas of expertise?

As separate groups define IEDs differently, what steps can we take to ensure effective inter-organizational communication? This is increasingly important given the need for accurate risk assessment. How do we differentiate landmines from IEDs? How do the weapons' means of construction, emplacement, and initiation factor into their definition? Does this matter for effective risk education? Regarding operations, do definitional differences impact risk assessment? How do HMA organizations factor this into training and equipping their operators? What materials and techniques have been successful in terms of educating the local populations? How do organizations navigate the risk of being perceived as taking sides in conflicts, and what lessons learned can we share with the broader community?

#### SPECIAL REPORT

##### Safe and Secure Management of Ammunition

Unplanned explosions at munitions sites worldwide, as well as the ongoing illicit proliferation of ammunition due to poor (PSSM) practices at arms depots, highlight the need for increased international cooperation to combat these threats. Is more widespread application of the International Ammunition Technical Guidelines (IATG) the solution? What can be done to make the IATG more user-friendly and applicable for States with limited resources and training? And how can organizations that conduct safe and secure management of ammunition translate their experience into lessons learned that serve the broader community?



Risk education to children in Iraq.

Photo courtesy of NPA.

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**Field Notes:** This section of *The Journal* features articles, case studies, and experiences by practitioners and subject-matter experts. Field Notes accepts articles on a variety of subjects on a rolling basis.

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