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The HALO Trust uses the MINEHOUND dual sensor detector in Cambodia and Afghanistan to reduce false-alarm rates. MINEHOUND combines a metal detector with ground-penetrating radar to improve efficiency of mine removal in areas highly contaminated with metallic false alarms.

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A MINEHOUND VMR2 is used to find AP mines in Cambodia. The use of this system allows 92% of signals from metallic rubbish to be rapidly excavated.
All graphics courtesy of the authors.

The vast majority of humanitarian mine clearance is conducted by manual deminers primarily using metal detectors. Increasing clearance rates of manual deminers is one of the primary ways organizations can improve effectiveness and efficiency. For this purpose, The HALO Trust (HALO) has used MINEHOUND VMR2 and VMR3 dual sensor landmine detectors in Cambodia since 2010 and in Afghanistan since 2012. The detector proved to be an adaptable and reliable means of increasing manual clearance rates.

MINEHOUND is comprised of an integrated metal detector (MD) designed, developed and manufactured by Vallon GmbH, and ground-penetrating radar (GPR) designed and developed by ERA Technology (now Cobham Technical Services or CTS). The integrated MD was first produced in 2004 and has been continuously improved to meet the needs of demining operators. Vallon and CTS collaborated to conduct initial HALO field trials in Cambodia. Since 2012, the U.S. Army's Humanitarian Demining Research and Development (HD R&D) Program, which extended the project to Afghanistan, have also supported them.

Development

ERA Technology started developing the dual sensor MINEHOUND detector in 2001 based on its expertise in the use of radar for landmine detection and by careful observation of humanitarian deminers in action. The aim was to fully utilize the deminer's skill while avoiding the complexity involved in operating current hand-held GPR systems and reducing reliance on software-driven auto-calibration. Using a radically different approach from conventional GPR designs regarding user interface, the detector employs a novel, audio-interface technique.

The original prototype detector combined output from an off-the-shelf MD and an ERA Technology-developed GPR with the design aim of offering considerable improvements in detection performance and a significant reduction in false alarms. A key element in the design philosophy was the need to avoid an expensive, complex and potentially distracting image display and to implement GPR design that mimics operation of a conventional MD. This was achieved using an audio output in which the pitch of the output represents target depth and amplitude represents target size. The U.K. Department for International Development sponsored the initial trial element of the MINEHOUND project, and proving trials were carried out in Angola, Bosnia and Cambodia between 2005 and 2006.

As the initial trials were successful in live minefields, focus shifted from demonstrating the dual sensor technology (i.e., MD and GPR) to simplifying it for nonscientific operators. Prototypes from 2001 to 2005 were A, B, C and D models, indicating the technology's advancement. The D model was MINEHOUND VMR1, first produced in November 2005. GPR setup required a laptop, which was linked to the detector via a cable. Since multiple setups were needed throughout the day, setup procedure was too cumbersome for routine detector usage.[1]

In July 2006, MINEHOUND VMR2 was fielded; this was the first operable MINEHOUND without using external devices. Due to its capacity for finding not only objects containing metal but completely metal-free objects too, VMR2 was useful during searches for improvised explosive devices or their components.

After VMR2 proved successful, Vallon developed a lighter version using plastic injection-molded casings for the main electronic compartment. At the same time, CTS developed a more powerful GPR subsystem, allowing for implementation of more sophisticated algorithms for signal processing. Vallon and CTS modernized the display and further facilitated the operation, which was integrated into MINEHOUND VMR3. Production of VMR3 started in May 2010.

Technology

MINEHOUND combines advanced technology—a dual sensor MD and GPR—into one system designed specifically for use in humanitarian demining operations. MD and GPR emit audio-signal output to the operator. The detector is designed to operate initially in MD mode, where all metal threats are noted. GPR mode then confirms presence of a threat. MD audio gives accurate positioning information and can indicate a mass of metal. GPR provides accurate positional and depth information, including information on the target's radar cross section. GPR responds to even the smallest mines buried flush with the soil but does not respond to small metal fragments. This results in the rejection of false alarms caused by metallic clutter such as cartridge casings, small pieces of shrapnel and metallic debris.

The operator can choose to work exclusively with MD, GPR or both simultaneously. Furthermore, a gated mode is available in which GPR is only activated when MD detects metal. This mode minimizes the number of undesired GPR alarms, as it is only active when required. VMR3 has a ready-to-use operational weight of just under 4 kg. With more than 8 hours of operation, a customized rechargeable battery powers the detector without requiring frequent recharging.

MD of VMR3 has a semiautomatic setup procedure for mineralized soils, which can adapt to current soil conditions in less than 30 seconds. The specific setup for soil is kept in VMR3's nonvolatile memory, hence setup for mineralized soil is only necessary when soil changes, but not after turning the system on or off.

GPR of VMR3 has optional, advanced setup parameters, allowing users to tailor the system to the requested detection needs and facilitating the increase of clutter-rejection efficiency. Not only can GPR sensitivity be adjusted but also the detection depth. Two parameters offer selections for detection depth: depth from where to start giving alarms (start point) and depth that will not be exceeded (stop point). Start point is used if detection is carried out under a safe layer, such as snow or gravel. Stop point is used to limit detection depth. If objects below the stop point cause GPR alarms, they are automatically ignored.

AP Minefields in Cambodia

HALO first began MINEHOUND trials in Cambodia in August 2010. Vallon and CTS personnel provided training and technical support in the field. Cambodia was chosen as the location for trials, as HALO has successfully used dual sensor detectors with GPR—the U.S. Army's Handheld Standoff Mine Detection System (HSTAMIDS)—since 2006 in Cambodia. HALO started working with three VMR2 detectors on loan from Vallon and CTS, and from the beginning of 2012, the U.S. Army's HD R&D program provided two additional VMR3 detectors and extra support for the MINEHOUND project in Cambodia.

MINEHOUND detectors were trialed across HALO's area of operations in northwestern Cambodia (Banteay Meanchey, Battambang, Oddar Meanchey and Pailin provinces) on minefields containing primarily anti-personnel (AP) blast mines. The minefields were chosen to provide a range of soil and vegetation conditions as well as varying levels of metal contamination and different mine threats.

For each minefield, a GPR calibration area was created to determine appropriate GPR-sensitivity settings for the mine threat and soil conditions. Calibration test pieces provided with MINEHOUND were used together with nonexplosive mine targets. Smaller mine targets with a reduced radar cross section are more difficult to find with GPR, as are targets flush with the surface of soil. Therefore two calibration targets of each expected type were buried: one flush with the surface and one at the national clearance depth (13 cm in Cambodia). The GPR was then adjusted, so that all targets were audible with GPR while also minimizing the number of false alarms on surrounding soil. HALO's procedures require regular checking of the GPR calibration throughout the work day, since variations in soil temperature and moisture can significantly change sensor performance.

Deminers in Cambodia are taught how to calibrate the GPR on the MINEHOUND VMR3 using buried test targets chosen for the expected threat in the minefield.

HALO's existing linear clearance methods, sometimes called lateral clearance, comprise marking a 70-cm deep strip of uncleared minefield up to 30-m long (a bound) adjoining cleared ground. Vegetation along the bound is removed with a strimmer (brush cutter), and then a deminer searches the area using a standard hand-held metal detector from HALO's existing fleet of Ebinger and Minelab detectors. The deminer places a red wooden disc (chip) on the center of each metal signal, a process known as mapping the bound.

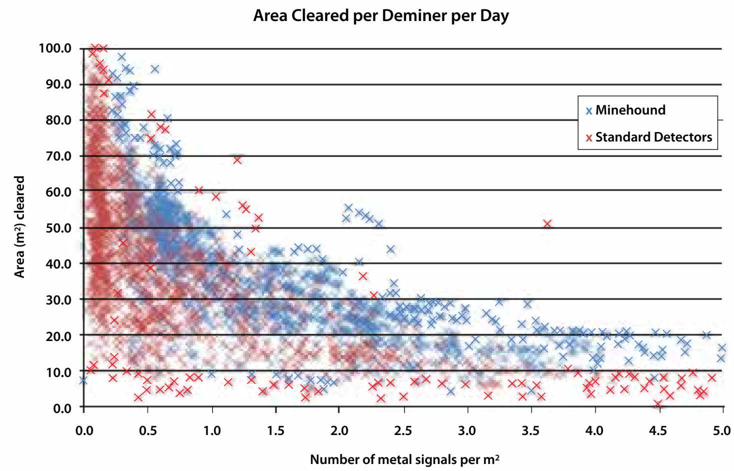

Figure 1. Area cleared per deminer per day.

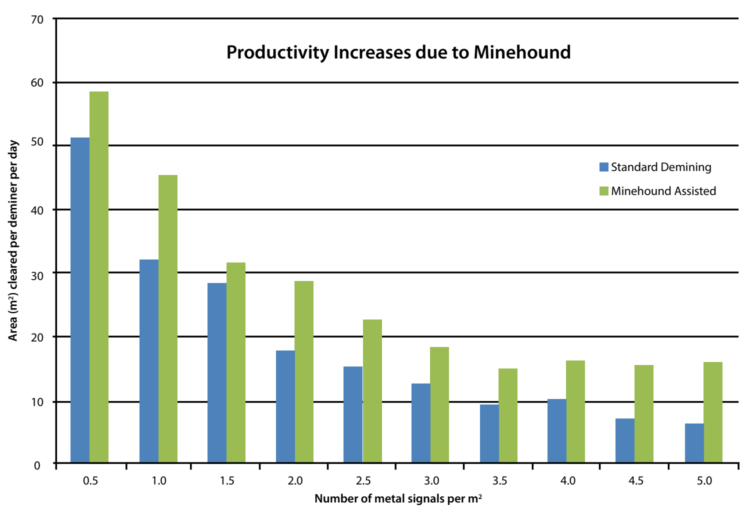

Figure 2. Productivity increases due to MINEHOUND.

Once the mapping is complete, the MINEHOUND operator goes to each red disc first to check the signal location with the metal detector function of MINEHOUND and then to check for a GPR return. The detector head's center is scanned over the red disc from two different angles to ensure signal level consistency. If any GPR sound is heard, which might indicate presence of a mine, the red chip is left in place. If no GPR audio signal is emitted, the red disc is replaced with a blue one. Once this chip-flipping process is complete, the ground under the red discs (the true alarms) is investigated using standard manual excavation methods. The blue discs (false alarms) are then rapidly excavated using an adapted brush cutter with a digging head, (also known as a clutternator).

This clearance method allows one MINEHOUND operator to check signals in the bounds of up to five other deminers and thus increase clearance rates, as the majority of signals are checked and excavated in a matter of seconds rather than minutes.

Results in Cambodia

Trials in Cambodia started in August 2010, and the initial three months were conducted as a data-collection exercise in live minefields. This was done without rapid excavation of blue chips, which was introduced in October 2010 after sufficient confidence had been gained in the system's capabilities and reliability. Since then, all clearance has been in fully live conditions.

Teams with MINEHOUND support cleared 573,109 sq m from August 2010 to December 2013 and encountered 661,890 metal signals, of which 92% were marked as clutter with blue chips. In addition, 845 landmines and other explosive remnants of war (ERW) were correctly identified. There have been no incidents where the detector has incorrectly indicated a metal signal when it was actually a landmine. The vast majority of ERW found were AP blast mines (Type 72 AP, PMN, PMN-2, MD-82B, MN-79, PMD-6), but some were fragmentation mines (Type 69, POMZ), anti-tank (AT) mines (TM-46) and other ammunition, such as mortars.

The proportion of metal signals that were not mines, yet were correctly marked with blue chips and could be rapidly excavated, increased from a low of 78% in 2010 to 95% in 2013. Overall this clutter-rejection rate is not expected to increase significantly in the future, although some variation exists between minefields and conditions.

The area of ground cleared by a deminer each day heavily depends on signal density: the number of metal signals in the soil at the site. Heavily contaminated areas require more time to excavate metal signals and thus less ground can be cleared per day. This is true even when a proportion of the metal signals can be rapidly excavated as is possible when using MINEHOUND. Figure 1 shows the results of MINEHOUND teams in 2012 and 2013. Each cross represents one day's work for a MINEHOUND team. The overall trend in productivity as signal density increases can be clearly seen. Figure 1 also reveals that, most of the time, the teams worked in areas with signal densities within the range of 0.5–2.5 signals per sq m. The red crosses in the same figure show a sample of comparative results for standard metal detectors. These are clustered much more in the range of 0.0–0.5 signals per sq m; at higher signal densities the MINEHOUND clearance rates are generally higher.

Although like-for-like comparisons have somewhat limited value due to the number of variables affecting clearance rates, Figure 2 illustrates the relative productivity of different methods for different signal densities. When metal signals are relatively few, the advantage of using MINEHOUND is small and usually involves a 10–20% boost in clearance rates. However, productivity is doubled in areas with more metal. A standard clearance team consists of nine deminers, one of whom is usually cutting vegetation with a strimmer. While MINEHOUND teams also have nine deminers, one uses MINEHOUND and another conducts rapid excavation of blue chips. These productivity figures consider each deminer equally.

Limitations

In general, HALO found MINEHOUND to be effective for the majority of Cambodia's terrain types and mine threats. However, it cannot be efficiently used in some conditions. In minefields with very rocky ground, it is not always possible to find space to swing the detector head over metal signals at the optimum height for GPR to function correctly. Such metal signals cannot be marked as clutter, negatively affecting the clutter-rejection rate and thus the overall clearance rates. Moreover, soil with a very uneven surface—for example, old plowed furrows hardened over time—can be very challenging for GPR. In these conditions, tuning out false alarms from the soil surface is sometimes impossible while correctly identifying small AP mines flush with the surface. Both of these minefield types are the exception rather than the rule in HALO's area of operations in Cambodia; hence, moving teams to areas where they can be more effective is possible.

Good MINEHOUND performance almost entirely depends on correct GPR calibration. This procedure is somewhat subtle, requiring a detailed understanding of various settings and factors that can affect radar signal. Learning how to do this takes time, but HALO's Cambodian training team has taught new operators effectively. Actually using the detector to check metal signals is very straightforward and does not require any difficult techniques.

A MINEHOUND VMR3 in an AT minefield in Afghanistan. The large size of the expected mines means that the GPR can be calibrated to ignore nearly all other signals.

AT Minefields in Afghanistan

In Afghanistan, HALO is trialing MINEHOUND detectors to assist with clearance of minimum-metal AT mines. This work is concentrated in the western province of Herat, where the Mujahedeen sparsely laid minimum-metal AT mines, in particular the Italian TC series and other low-metal AT mines, over large areas in the 1980s to impede Soviet military action across the desert plains. Although the density of mines is very low, they continue to cause accidents, often with multiple fatalities, and block access to valuable agricultural land.

The mine threat and very different soil and conditions, which include dry sandy soils and gravel with rocks but little vegetation, provide a different challenge for MINEHOUND when compared to Cambodia. HALO has two VMR3 detectors in Afghanistan as part of an operational field evaluation in conjunction with HD R&D. They are currently used in minefields that do not contain AP mines. Method of use is similar to Cambodia in that MINEHOUND checks positive signals that were previously identified by Minelab F3S detectors, which are sensitive enough to find all AT mine types required.

However, calibration of MINEHOUND's GPR in Afghanistan is different than in Cambodia. Two explosive-free TC 2.4 AT mines, with their main explosive charge replaced with lime mortar, were used as calibration targets. One was buried at a depth of 20 cm, while the other was flush with the surface of the soil. This calibration meant that only very large anomalies in the soil or large metal items would give GPR return. The TC 2.4 is used for calibration, as it has the smallest cross section of the expected mine types.

MINEHOUND detectors in Herat are deployed in support of manual deminers who are searching ground using Minelab F3S detectors. The deminers place red chips on metal signals, and MINEHOUND is then used to check for a GPR return. If GPR return is positive, the operator leaves the red chip in place; if negative, the operator leaves a blue chip. Red chips are investigated carefully using standard excavation techniques; blue chips are removed rapidly using a shovel. One MINEHOUND can support more than 20 deminers employing this methodology.

Trials have been conducted on MINEHOUND GPR ground-search methods that omit use of a metal detector. Although believed to be reliable, this method is not suited for most scenarios, as the detector can only sweep relatively slowly due to GPR's limited detection area. This means that a single MINEHOUND can only cover about 250 sq m per day. While this may have an advantage in areas with very high levels of metal contamination, it is more efficient to have MINEHOUND support 20 other deminers marking positive signals using other detectors in areas with less metal. In this way MINEHOUND can assist with clearance of more than 700 sq m of ground per day.

Results in Afghanistan

From the beginning of the trial in September 2012 through the end of December 2013, two MINEHOUND detectors checked 197,044 metal signals and marked 99% as clutter. Six minimum-metal AT mines were found, and 432,082 sq m of minefield were cleared. On average, 32,841 metal signals were encountered for each mine found; all except 321 of these could be excavated by shovel.

The Afghanistan results show a generally higher clutter-rejection rate than in Cambodia. This is most likely due to larger radar cross section of AT mines, which effectively increases probability of detection while also reducing probability of a false alarm. Because the calibration targets are much larger, GPR can be set at a far less sensitive setting than if AP targets were used. The consistent minefield terrain, weather conditions and lack of vegetation and roots likely contributed to this. The large, flat areas forming the majority of the minefields in Herat make them ideal for MINEHOUND. The few false alarms giving a GPR return were most often large pieces of metal fragmentation, scrap or plastic containers with a foil layer.

Conclusion

Trial results reported from Cambodia and Afghanistan show that MINEHOUND is extremely effective in reducing the false alarm rate encountered by generic metal detectors. Average reduction in false alarm rate was better than 90% in Cambodia on AP minefields and 99% in Afghanistan on AT minefields. HALO's method of operation is a major component of this outcome. Using MINEHOUND as a confirmatory detector to filter out false alarms enables a highly cost-effective deployment. Rapid excavation of false alarms is the main reason for increased productivity. HALO is actively looking at extending trials and deployment of MINEHOUND to other parts of its global operations to take advantage of customizable GPR.

Although the MINEHOUND is significantly more expensive to purchase than standard MD, the improved productivity and reduction in labor required for clearing highly contaminated minefields should cover the cost of the initial investment within one to two years. In the future, overall cost per square meter should be reduced in areas with high signal densities compared to using standard MD alone.

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See endnotes page 51

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Land Release Liability by Moorhouse [from page 4]

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Conventional Weapons Destruction Response to Ammunition Depot Accident Clearance by Zahaczewsky [from page 7]

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Building National EOD Capacity in Mali by Dieu [from page 13]

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