Landmine Detection and Clearance

Introduction

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What is a landmine? || The purpose of a landmine is to disable, immobilize or kill. It is an explosive device activated either by a person or vehicle, or command detonated by electric wire or radio signal. Most landmines are laid on or just below the surface of the ground and are activated by pressure or trip-wire. Normally manufactured from very durable materials such as plastic, bakelite, concrete, glass or metal, landmines are designed to survive the effects of weather, season and time.

Mechanical minelayer mounted on the rear of a Soviet armored vehicle.

Anti-tank landmines (ATM) generally fit into two categories: blast and penetration, while anti-personnel landmines (APL) are generally either blast or fragmentation (see sidebar on page 19). However, these are only the basic categories; there are many other types of landmines, including helicopter mines, sea mines and shallow water river mines. They are commonly designed with simple, reliable fuse mechanisms. However, during the past several decades, increasingly complex fuse systems have been designed and used, making the job of the deminer even more difficult.

How Are Landmines Emplaced? || Both APL and ATM are deployed by a variety of methods. The most basic method is by hand using normal digging tools. A shallow hole is dug, and the mine is carefully positioned in the ground, and armed by removing the arming pin and switching a lever. The mine is then carefully camouflaged, blending into its environment.

This process can be sped up by using mechanical mine-laying devices mounted on a truck or armoured vehicle. A large number of mines are carried in the vehicle and are processed in conveyor belt fashion. The mines are inserted into the ground via a "v"-shaped plough, and are armed and covered in the process. Large tracts of land can be mined with this efficient process.

Mines can also be surface scattered using static or mobile dispensers that either fling mines or project them over a wide area. Dispensers can also be mounted on a moving vehicle, scattering mines over large areas.

Finally, remote mine delivery can be achieved using artillery or rockets. Projectiles are packed with mines and then ejected, or an aircraft can deliver mines by dropping them from specially designed containers over a wide area.

What's the Difference Between Minefields and Mined Areas? || In the ideal world, minefields are designed emplacements, laid by professionals using conventional methods, carefully recording the location of each mine and marking the perimeter of the minefield with warning markers. If the minefield record is made available to deminers and the markings are still in place, the location and neutralization of the hazard is simplified. In today's world, however, very few of these types of minefields are encountered.

Mined areas, on the other hand, are undefined in size, shape or content. Mine contamination indicators such as casualties, dead animals, vegetation overgrowth, mine packaging or military activity may suggest the presence of mines. Mined areas are perplexing problems to address for surveyors and de-miners. Determining the actual boundaries of suspected mined areas is difficult and often amounts to informed guessing. Surveyors conduct intensive surveys (interviews) with locally knowledgeable persons near suspected mined areas and then develop maps of suspected or mined areas.

Typical metal scrap removed from a minefield. Everything from ammunition casings to nails to bicycle parts.

Establishing the boundary of a hazardous area prevents the unnecessary waste of demining resources, which may have been used in clearing tracts of land that were already mine-free. Accurate information and the capability to quickly identify the existence and general location of the threat is the key to successful demining operations. Methodologies and technology that allow for the reduction of the threat area are extremely valuable in the demining process.

Detection: What are we looking for? || Essentially, the two most common components of landmines are metal and explosives. Manufactured mines have casings made from a variety of materials including wood, bakelite, plastic, metal or other synthetic materials.

Debris of War ◆ Battlefields are messy places; shrapnel, barbed wire, corrugated iron and empty shell casings are a few in a long list of debris left by combatants. Over time, these contaminants migrate into the ground and are not visible on the surface.

Concentrations of debris can mask the locations of landmines, complicating detection methods and necessitating multi-clearance operations. Normally, munitions abandoned by combatants are found mixed with the debris. Unexploded ordnance (UXO), including bullets, grenades, rockets and large aircraft bombs can litter former battlefields. Failure-to-detonate rates for munitions are estimated from 10 to 30 percent.

High levels of battlefield debris complicate clearance procedures, slowing progress. Deminers must work through this debris, discerning the location of landmines and UXO among lots of clutter—no easy task.

Metal ◆ From the detection standpoint, metal is the easiest component to detect. Metal detectors (commonly referred to as mine detectors) are now capable of signalling the presence of minute pieces of metal. Metal detectors are expected to perform in ferrous (iron) soils where masking of the mine is common. However, some mines are metal-free or contain virtually no metal. These mines challenge the capacity of current metal detectors, particularly if emplaced in laterite or high ferrous (iron) content soil where their discrimination is difficult to achieve.

Explosives ◆ The explosive is the one common ingredient that is found in all mines. Detecting explosives, however, is a complicated process. Modern airports have explosive detectors, which can detect small traces of explosive in suitcases and other containers.

Locating traces or the odor of explosive in an open field demands technology that can operate in an unlimited variety of environmental conditions and that are subject to wind, water and soil changes and variations. Air sampling systems have been developed that find explosive traces in air over a large area. These systems cannot pinpoint landmines but do provide valued assistance for deminers by directing their efforts towards verified hazard areas.

Explosive detection under field conditions has recently become the purview of mine detection dogs. A dog's nose has proven to be a very sophisticated and reliable sensor; however, handling mine

Alone at the end of a clearance lane in a minefield, the deminer focuses on finding landmines before they find him.

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The Detection and Clearance Process

(Top) An array of hand tools carried by deminers to cut vegetation, excavate and probe for landmines.

(Bottom) Heavy duty magnet, a manual deminer's favorite machine to remove metal from the soil.

detection dog teams and ensuring consistent behavior in varied hazard scenarios is a complicated and demanding task.

Distance and Stand-off Detection ◆ Obviously, getting close to landmines is dangerous business. A preferred method for pinpointing landmines is to use detection devices that locate landmines at a safe distance from the deminer. Using detection devices that pinpoint landmines and un-exploded ordnance from a distance, either overhead or at ground level, is the best possible way to determine a hazardous area or the actual location of individual landmines. Once the threat is located, a close detection device that analyzes the threat and provides multi-dimensional infor-mation provides the ideal risk reduction capability.

Currently, stand-off detection is performed by trained surveyors gathering information from a wide variety of sources including aerial photos, battle maps, and terrain analysis techniques.

New sensor systems under development seek to reveal the location of landmines using infrared, thermal, ground penetrating radar and other technologies. These technologies detect change or anomalies in the terrain, for example a change in temperature or density between the soil and a mine casing. The developing reliability and accuracy of these new sensor systems shows promise for future deployments.

Close Proximity Detection ◆ Closing the final distance to the mine is the most hazardous task of demining, exposing the deminer to the mine and its deadly effects. The time-tested method of systematically probing the ground with a sharp stake or metal prodder and excavation tool (trowel), slowly edging forward with the excavation tool until the mine is located, is still the most reliable method and considered the safest way to close the final distance to a landmine.

Most mines contain metal and are readily detected using electro-magnetic induction or metal detectors. However, some mines have been developed with sophisticated fuses containing little or no metal at all. Over the years, metal detectors have incrementally improved to meet the requirements of locating low metal content mines in high ferrous (iron) content soil.

A significant drawback to the metal detector is that it only provides an audible signal of the general location of a metallic object. The signal does not indicate three-dimensional information such as depth, size or shape of the target. Further investigation is required to determine whether the signal is a piece of scrap metal or a mine. New technologies combining metal detection, ground penetrating radar, explosive sensors and other signal-producing "signatures" are showing promise, giving deminers the hope for a future multi-sensor array, enabling a three-dimensional search capability in the minefield.

How is Mine Clearance Currently Being Conducted? || A series of analyses and decisions is necessary before a decision is made to deploy deminers or commit mine clearance assets. "Who will benefit?" and "Who will be at risk?" are prime considerations when deciding to proceed with mine clearance operations. Prioritizing needs ranging from emergency relief to infrastructure development is necessary to reduce risk and exposure to the threat while systematically returning communities to a state of normality.

The employment of valuable demining resources demands careful analysis of the threat conditions and the need to clear an area. The following sequence of activities describes the holistic approach to

This mechanical assistance machine operator clears mines from behind armored glass and steel plate protection.

conducting a mine clearance campaign.

The Survey ◆ This information gained through the various levels of surveying becomes the basis for prioritizing which areas and people are most affected, in order to deploy appropriate mine clearance assets to remove the hazards. The techniques involved in conducting these surveys are covered in a separate section in this booklet, so we need only observe here that the Technical Survey aims for no less than defining the perimeter of suspected mined areas and creating boundary markers. The results of this survey, drawing the line between "mined" or "not mined" areas, is the most difficult and hazardous task of mine clearance operations. Mistaking the precise location of the perimeter can result in unnecessary waste of mine clearance resources, cause further suffering for the local population and culminate in a loss of confidence in the entire operation.

Mechanical Assistance ◆ Numerous mechanical systems, ranging from flail systems to soil grinders, are operational worldwide. Unfortunately, however, no mechanical system has reached 100 percent clearance reliability due to the complex nature of the mine/UXO threat and variable terrain conditions. Hence the term "mechanical assistance" explains that these systems, while complementary to manual deminers and mine detection dog teams, cannot yet replace them in their hazardous tasks. Mine clearance requires a toolbox approach using machines with different capabilities to contend with both mine/UXO hazards and terrain challenges.

For instance, employing machines to clear away thick overgrowth and cover large areas of ground is efficient. Mechanical assistance provides the most cost-effective method of area reduction and locating the perimeters of mine-fields or mined areas.

Mechanical assistance is similar to road construction in which a variety of earth moving capabilities are employed to shape the earth into a road. By using mechanical means to clear away vegetation and process the ground, the perimeters of the mined area can be ascertained quickly. Working from the edge of the mined area, mine detection dog teams can quickly focus on individual mines and UXO, specifying their location for deminers. Manual deminers now need to deal with only a few square meters of clearance. This relieves the deminer of 80 percent of the work and allows him to focus on the mines themselves.

Terrain Analysis ◆ The nature of vegetation and soil has a profound effect on clearance operations. Thick vegetation hinders the deployment of dogs and man. Whether the detecting sensor is a dog's nose or metal detector, getting the sensor to ground level is all-important to ensure maximum efficiency of the detection system. Soil variables influence the detection of mines; for example, hard compacted soil or high ferrous (iron) soil can hinder detection of mines.

Mechanical Vegetation Removal ◆ Removal of vegetation is the first step in preparing terrain. Vegetation prevents close inspection of the ground while locating landmines. Manual deminers can spend up to 80% of their efforts gingerly removing vegetation while exposed to landmines. This hazardous task can be accomplished with greater efficiency and safety using

The TEMPEST (below) works by remote control without exposing the operators to danger.

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The Clearance Team

mechanical brush-cutters to remove vegetation.

Armored brush cutters using hydraulic arms to reach into, or directly enter, hazardous areas in order to clear away vegetation achieves two aims: both the removal of vegetation and the activation of trip-wires and detonating mines. Both of these activities contribute to identifying the actual location of mines or the minefield perimeter and preparing the terrain for deployment of manual deminers and mine detection dog teams.

Mechanical Soil Processing ◆ Typically, mines are buried only a few centimeters below the surface. Soil type and hardness can mask the location of landmines. Heavy vegetation and contamination of metal fragments slows the work. Laterite or high ferrous (iron) content soils mask the presence of low metal content mines, increasing the hazard where metal detectors have difficulty locating mines. Modifying the soil conditions, often involving digging up or exploding landmines, can increase the efficiency of man and dog to complete the job of locating and neutralizing landmines.

Steel wheels capable of absorbing the effects of AT mines on this SDTT enable it to cut vegetation safely.

Common mechanical systems include flails, rollers, and soil grinders. Each system brings a unique method of activating landmines by detonation or breaking the mine into pieces. Manipulating soil by flailing, rolling or grinding detonates mines, revealing the general location of hazardous areas. Identifying with accuracy the parameters of a mined area is critical to the deminer and cost-effective use of limited demining resources.

Mechanical soil preparation enables deminers and mine detection dogs to access the hazardous area, deploy and locate remaining mines or components of mines without the tedious task of removing brush and attempting to probe through difficult root structures and rock hard soil. Machines generally require armor protection for the crew and other major working components from the explosive and fragmentation effects of mines.

Mine Detection Dogs ◆ “Man’s best friend” has found a noble role in humanitarian mine clearance. Natural hunting characteristics and extraordinary tracking or sniffing capability makes the dog an excellent sensor or mine detector. A dog can reputedly smell a thousand times better than man. His ability to trace faint odors of explosives makes the dog ideal for locating mines or UXO.

Dogs are used as part of the deminer’s toolbox. They can locate mines under difficult conditions and cover large areas faster than standard manual searching methods. Dogs can also locate mines where other technologies fall short, such as on railway lines or other metal contaminated areas where metal detectors are challenged.

(Left) Man's best friend joining him as a Mine Detection Dog Team.

(Right) Obedience drills in preparation for advanced mine detection training.

Creating a man-dog team is a complicated process. While the dog must be screened and tested for above-average working characteristics, careful selection of a dog handler with suitable patience and temperament to work with animals is also critical. The key concept is to train the dog along with an experienced dog trainer, expert in developing dog sniffing behavior. Initially, dogs receive training in obedience and open area search by expert trainers to develop protocol. When dog training is approximately 70 percent complete, a new dog handler replaces the expert trainer and team training begins. Team training starts by block searching and finally simulated minefield searching. The training and team bonding process takes six months to develop an efficient man-dog detection team.

Perfect unison of the team is vital to their safety and to locating landmines. Mine detection dog (MDD) teams are used in survey, mine clearance and quality assurance operations. After vegetation has been removed by machines, MDD teams can cover suspected areas quickly. Suspect areas are divided into a grid designed for MDD teams. Each block of the grid is systematically searched by the MDD, one meter lane by one meter lane. A second MDD team is used to cover the same ground again, double-checking the first MDD team, ensuring a high-quality clearance effort.

The most common breeds of dog used in mine detection are Dutch & German Shepherd and Belgian Malinois. These dogs have consistently proven their robustness and loyalty when working in this dangerous task. MDDs are now considered to be a reliable component in the deminer's toolbox.

Man against Mine || Manual Clearance, the Basic Process ◆ Pitting man against landmine in varied environments is the essence of manual clearance. A simple process to locate, identify and neutralize mines has been used from the very beginning of dealing with landmines. This process has had to be improved over time due to the difficulty in detecting low metal content mines and coping with increasingly sophisticated landmine fuses. Learning lessons has been costly; deminers have paid for this knowledge with lives and limbs.

Mine clearance usually boils down to an individual effort. In a minefield, the deminer is alone; his sole audience is his partner or supervisor safely 25 meters away. The deminer cannot see the mine that he must find before it finds him; mental concentration is totally focused on survival.

The Clearance Operating Sequence ◆ Systematic procedures establishing the operational area and start lines for clearance are painstakingly laid out in detail. Areas where no mines are reported or suspected are marked with colored tape denoting safe areas and the perimeters of mined areas. Deminers are closely supervised, working either singularly or in pairs deployed along a baseline on or near the edge of the suspected area. The following description is for the "One-Man" manual demining drill.

1) Deminers approach the baseline wearing personal protective equipment (PPE) consisting of face shield and body

A Mine Detection Dog Team looks down a lane to be cleared.

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The Deminer's Mission

(Top) A deminer places one meter sticks to mark the parameters of the search area.

(Bottom) Using overlapping sweeps with a metal detector, a deminer listens for signals from metal or suspected landmines.

armor. Entering the minefield, the deminer is fully equipped with vegetation cutting tools, probe and excavation tools, trip wire feeler, metal detector, mine markers and mine tape. His tools are placed in the safe area within reach behind him as he prepares to start work.

2) His first act is to visually scan an area approximately one meter wide by half a meter deep looking for evidence of landmines, i.e. exposed fuses, mines, UXO, tripwires or surface scrap metal. This small area represents a depth and width that does not cause excessive leaning into suspected areas.

3) Satisfied that no mines are present on the surface or in the vegetation he will sweep the area with his tripwire feeler looking for wires barely visible to the naked eye. This process is conducted in several sweeps over the search area and flanks.

4) Next, he carefully removes all vegetation to ground level, using a variety of cutters, ensuring no piece of brush falls onto the ground and gently places the cuttings behind him in the safe lane. Now the search area is prepared for unhindered sweeping with the metal detector.

5) The deminer calibrates his metal detector for both sensitivity and ground compensation.

6) Moving the detector head in overlapping patterned sweeps, he covers the search area, listening intently for the barely audible signal indicating the presence of low metal content mines.

7) If a signal is heard, the sweeps will be orientated to identifying the center and edge of the target. Once the target is identified, a marker is placed identifying the target location.

8) In signal-free ground, the deminer excavates a small wedge-shaped trench up to 20cm deep. Next, he gently inserts his probe (similar to a knitting needle with a handle) at a 30-degree angle into the face of the trench at the bottom edge. Systematically, he probes and excavates the face of the trench, slowly edging towards the target until the probe hits something solid.

9) Carefully, soil is removed to expose enough of the mine to identify its type and allow enough room for a demolition charge to be properly placed.

10) The preferred method of dealing with a detected mine is to destroy it in place using an explosive charge at the end of daily operations. Neutralizing or defusing mines is avoided to reduce risk exposure to the deminer. However, under certain extreme conditions deminers can neutralize mines by removing fuses or replacing safety pins.

This painstaking process is repeated meter by meter, clearing ground to "metal-free" status, ensuring no mines are present. If a mine is overlooked or missed, it is normally the deminer who will pay the price, since his work requires him to walk repeatedly up and down his lane. Missing a mine exacts a heavy—usually lethal—"penalty."

Documentation, Data and Information ◆ The task is not complete, however, until the paper work is done. Careful recording of the entire mine action process is necessary to document the effort, record the standard of clearance, and exact boundaries of the cleared area and residual hazards to the community. This all-important process enables communities to identify the cleared areas and those areas still containing hazards, so that the cleared land may be used with total confidence and appropriate precautions taken with regard to areas still contaminated.

Integrated Operations: "Men, Dogs and Machines" || Manual clearance is effective, safe and reliable, although when conducted alone, it is inefficient and slow. The advantage of combining

This deminer is working to help turn minefields into green fields so that civilians can use them again.

manual clearance with mechanical assistance and mine detection dog teams makes the work safer and faster. However, manual clearance remains the final and definitive step in clearing ground. Man must prove the ground where mechanical assistance and mine detection dogs have worked, providing confidence to the mine clearance process. Balance between mechanical assistance equipment, mine detection dog teams and manual demining teams is an efficient formula to effectively deal with a wide array of mine and UXO hazards.

A team of 30 deminers working though the dense vegetation of a former battlefield contaminated with low metal content mines would normally progress at approximately 1000 square meters a week.

The Bottom Line: Being Free from Fear || Millions of people live in the proximity of mined areas. Generations are growing up living under a perpetual threat of being landmine victims. Landmines victimize whole communities by denying access to markets, inhibiting growth and precluding the productive use of land. People cannot wait a lifetime for assistance in removing this life-threatening hazard; speed is necessary to relieve poor rural peoples who are at risk now. Immediate response and assistance is needed to reduce risk and create environments where people can go about their lives free from the threat of landmines.

In order to meet this need, mine action has woven a multitude of tasks into a singular strategy to meet this humanitarian demand over the past decade. While landmine clearance has developed incrementally since the inception of the modern landmine, it has cumulatively come a long way, especially in the area of integrating diverse methods into an effective anti-landmine strategy, which promises to be a recipe for success.

Editor's Note: To learn more about emerging technologies which may be used to enhance mine clearance operations, see the chapter on research and development (page 38).

Types of Mines by Dave McCracken

Anti-tank mines generally fit into the following two basic categories:

Blast || Blast type anti-tank mines are pressure-activated and designed to immobilize a vehicle. They are normally designed with fuses that require 150–300kg pressure to activate and have approximately 5–15 kilograms of explosive charge, ensuring that the resulting explosion will break a tank track or destroy a truck. The vehicle occupants are commonly injured or killed in the explosion.

Penetration || These mines have a specially shaped charge that directs the force of the explosion into a searing, hot stream that penetrates through armor plate into the tank or vehicle. The results normally destroy the tank and kill the crew. Penetration type anti-tank mines can be activated by pressure, tilt rod, pneumatic hose or magnetic influence fuzes, which attack the full width of the vehicle rather than just the wheels or tracks.

Anti-personnel mines generally fit into the following two basic categories:

Blast Mines || Blast mines are pressure-activated devices containing explosives in bulk or shaped charges. The explosive content, ranging from 20 grams to 200 grams, is designed to remove or damage a person's foot or lower leg. Blast mines can be laid on the surface but are usually laid a few centimeters underground. The pressure required to set off a blast mine ranges from 3–15 kilograms, making them easily activated by children.

Fragmentation || Fragmentation mines are normally metal-encased explosives designed to detonate by activating a trip wire. Fragmentation mines can be of several types:

Stake Fragmentation Mines ♦ Mounted on a stake above ground level, these mines are similar to a grenade on a stick. Activated by trip wire, stake fragmentation mines send lethal fragments in all directions.

Bounding Fragmentation Mines ♦ These are specially designed mines, buried with a fuze connected to a trip wire for victim activation. When activated, these mines are propelled out of the ground approximately one meter, detonating when the mine reaches full height, sending lethal fragments up to 50 meters in all directions.

Directional Fragmentation Mines ♦ Directional fragmentation mines have a shotgun effect. They are placed above ground and aimed to cover a large area. These mines are either victim-activated by trip wire or command detonated by electric wire. Releasing hundreds of metal fragments in one general direction, this mine causes death or injury up to 200 meters away.