Appendix W

CONTACT METHODS

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INTRODUCTION

Although a small number of landmines were introduced into modern warfare during World War I, the tactics of landmine use, both in the deployment and removal, did not become clear until World War II. By 1939, the German and Italian armies had developed both antitank and antipersonnel landmines, which were used effectively against the Allied forces. Naturally, the Allies developed techniques for defeating the defensive barricade presented by a well-laid-out minefield. The obvious array of flails, rollers, and projected charges were used. However, "the first, and throughout the entire war, the commonest procedure was to locate the mine, neutralize it if necessary and remove it by hand"[1]. Although metal detectors based on the principle of heterodyne oscillation were used to rapidly scan an area, the final approach to a landmine prior to neutralization inevitably used a pointed stick, such as a bayonet.

As discussed in Russell [1], "a bayonet, held obliquely in the hand and prodded into the ground in an arc-like pattern, was the best available means of mine location. Many a sapper or infantryman played out his luck when the bayonet struck the prongs of an S-mine." The S-mine 35 was a bounding cylindrical steel German antipersonnel mine, four inches in diameter and five inches high. At the time, metal cased landmines were not the only threat. The Italian antipersonnel landmine was a small Bakelite box, and the Russian

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army fielded several landmines of low metallic content. In the final years of World War II, various metal detectors were developed using the principles of heterodyne oscillation, super-regeneration, and the well-known inductive bridge (first used in World War I). Since then, the conventional metal detector has seen some technological improvement that has increased the sensitivity and improved the ergonomics of fielded systems.

Conversely, the tool used to precisely localize a landmine remains a derivative of the pointed stick. Very little advancement has been made in regard to the soldier's bayonet. The modern military uses a conventional lightweight nonmagnetic probe (prodder). Humanitarian demining organizations use a wide variety of tools that range from the military prodder to the ordinary screwdriver or some locally fabricated device consisting of a metal rod and a wooden handle. Although the tool may vary, the technique remains the same. Once a suspect area has been localized with a metal detector or some other similar tool, a person with a prodder gingerly probes and excavates the ground until a positive and unequivocal identification can be made of the buried object.

It is still a researcher's dream to wave a Star Trek tricorder at a heavily forested area and produce a detailed map of all the unseen hazards. If, in fact, this were possible, the final task would still remain; the buried objects would require precise localization prior to removal or neutralization. Although one can envision the use of mechanical equipment to remove intact, undetonated landmines, the logistical support is usually problematic in third-world countries. As a result, mechanized removal systems have not been fielded by demining organizations.

BASIC PRINCIPLES

Manual prodding and excavating is conceptually a simple process. Simple tools, such as a trowel and a screwdriver, are used to gently probe the ground until a solid object is contacted. Material surrounding the buried object is carefully removed until a positive identification can be made. This process is repeated for each buried object until the area is cleared.

As described in Gasser and Thomas [2] and Gasser's *Technology for Humanitarian Landmine Clearance* [3], the human operator is intimately involved in the prodding process. Landmines are typically activated by pressure fuses and this requires the operator to limit the amount of force applied to the prodding tool. In many cases, the operator exceeds the force required to activate the landmine [4], but fortunately the contact point of the prodding tool is not usually on the fuse mechanism.

STATE OF DEVELOPMENT

The conventional prodder has been improved from the original "soldier's bayonet" to a lightweight, nonmagnetic, and wear-resistant instrument. There are many styles of these prodders available from such companies as RUAG Munition (Switzerland), Ribbands Explosive (United Kingdom), and Dyno Nobel (Denmark) with minor variation in the handle, length, and hand protection. Some, such as the HARC #3 from the University of Western Australia, are a combination of a prodding and digging tool with limited blast protection.

There have been some attempts to increase the sophistication of the conventional prodder. For example, the Croatian army introduced a hollow tube prodder where the impact noise of the probe tip contacting a buried object could be easily heard. In addition, the operator could scrape the surface of the buried object. Different material would emit characteristic sounds and the operator could use this information to make an educated guess about the buried object.

More advanced prodders have been developed. The use of the "feedback prodder" in Afghanistan was reported by Gasser [4]. He discovered that deminers "(1) repeatedly used more force than is required to activate some mines and (2) consistently underestimated the force they were using by large amounts, often thinking they were using about half the actual force." Gasser concluded that an improved feedback prodder could be a valuable training tool for the development of prodding techniques that limit the force applied by the operator.

For a brief period, DEW Engineering and Development Ltd. (www.dew.ca) manufactured a prodder with an ability to discriminate between plastic, rock, and metal. The SmartProbe™ was based on technology developed at Defence R&D Canada (www.suffield.drdc-rddc.gc.ca) where an acoustic pulse is used to characterize the material under contact.[2] The device was tested at the Cambodia Mine Action Center in 1999 with positive feedback from the deminers. The U.S. Department of Defense (DoD) Humanitarian Demining Technologies Program also evaluated the SmartProbe with mixed results [5]. The Canadian Armed Forces conducted the last known test of DEW's prodder in September 1999 [6]. Although the Canadian army highly rated the concept of operations, several shortcomings in the ergonomic design, ruggedness, and performance discouraged the acquisition of the SmartProbe for field use.

The Canadian Centre for Mine Action Technologies (CCMAT) supported HF Research Inc. (www.hfresearch.com) in 2001 to improve upon DEW's SmartProbe. HF Research combined the acoustic pulse with a force feedback system in an attempt to address some of the performance limitations. The prodder was tested at CCMAT's facilities in September 2001 with very promising results [7].

CURRENT CAPABILITIES AND OPERATING CHARACTERISTICS

The current capability of the conventional prodder is excellent. A well-defined user community has directed the design from the original "bayonet" to the modern lightweight, nonmagnetic, and wear-resistant prodding and digging tool. Useful prodders can also be fabricated in-country by local deminers using readily available materials.

As measured in Melville [6], the conventional prodder detected 100 percent of the buried objects at a rate of 1.58 sq m per hour. The ground was easy to prod and the soldiers used the standard Canadian Forces prodding technique (2-cm prodding grid and 30° prodding angle in combat dress). The probability of detection (PD) and the false alarm rate (FAR) are meaningless when evaluating the

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[2] U.S. patents 5754494, 5920520, 6023976, and 6109112; Canadian patents 2218461 and 2273225.

conventional prodder because they merely represent the distribution of targets versus nontarget objects. However, that being said, the PD, FAR, and the probability of false alarm (PFA) can be calculated and the results are presented here. All 38 landmines were found (100-percent PD) as compared with the 119 rocks (FAR of 4.1 FA per square meter) that were placed in the lanes. The soldiers were also given the opportunity to identify the buried object before it was uncovered. They correctly declared 20 out of 38 objects as mines and 110 out of 119 objects as rocks (PD ≈ 53 percent and PFA ≈ 8 percent).

Advanced or instrumented prodders are still in their infancy. As discussed in *Technology for Humanitarian Landmine Clearance* [3], instrumented prodders provide an opportunity for very “close-in” location and discrimination. The prodder is capable of delivering sensors to close proximity of buried landmines. Instruments based on the principles of acoustics, electromagnetics, thermal conductivities, chemical analysis, and nuclear techniques can all benefit by the reduced standoff offered by the prodder. For example, chemical analysis techniques using a prodder as a sampling tool would greatly benefit from the relative abundance of explosives in the soil as compared with explosive vapors found at the soil surface. In addition, other technologies, such as electrical conductivity and spectral analysis, can be used when the probe is in contact with an object.

The DEW SmartProbe demonstrated in Melville [6] a discrimination capability where 84 of 105 objects were correctly identified as mines (PD ≈ 80 percent). Rocks were correctly identified 298 times out of 468 encounters (PFA ≈ 36 percent). The SmartProbe had an advance rate of 1.31 sq m per hour. The Canadian Forces test results agreed with laboratory measurements provided by the manufacturer. Inexplicably, the tests conducted by the DoD Humanitarian Demining Technologies Program produced drastically different results. One hundred forty two of 205 objects were correctly declared mines (PD ≈ 69 percent) and 2 of 50 objects were correctly declared rocks (PFA ≈ 96 percent).

HF Research’s improvements were tested using a bench prototype prodder in September 2001 [7]. The improved prodder correctly declared 256 of 264 objects as mines (PD ≈ 97 percent) and identified 480 objects out of 792 as rocks (PFA ≈ 39 percent). The report indicates that the eight missed mines were large rusted metal mine surrogates. None of the plastic or wooden mines was missed. The advance rate of the improved prodder was not measured. However, because the operator is not required to change his or her grip to see the indicator LED [light-emitting diode] as on the DEW SmartProbe, it is expected that the improved prodder has a faster advance rate.

The prodder advance rate suggested by Melville [6] for both the conventional prodder and the SmartProbe should only be used as a preliminary indicator. The soldiers involved in the tests did not treat the unknown objects as hazardous after a declaration was made, and the object was quickly uncovered, identified, and recorded. In any case, the advance rate was dominated by the 2-cm prodding grid (≈ 2,500 prods per square meter).

KNOWN OR SUSPECTED LIMITATIONS OR RESTRICTIONS

The conventional prodder is limited by the available training tools and the lack of a discrimination or precise localization capability. In addition, manual prodding is limited by certain environmental factors, such as ground hardness and dense root structures. A few manufacturers do consider the possible side effects of the prodder becoming a deadly projectile upon any accidental detonation of the landmine. However, a large percentage of the available prodders do not gracefully react to a mine blast and result in more severe injuries to the deminer.

Instrumented prodders are limited by the imagination of the academic and demining community. It is technically possible to construct a prodder with an electromagnetic induction system that will allow the precise localization of small metal fragments. The design of conventional metal detectors allows the operator to localize a small signal to an area under the detector head, usually about 100 sq cm. However, a significant amount of time is spent prodding the area to locate the source of the signal. In some occasions, the soil is sifted through the metal detector head to find the small metal fragment.

The instrumented prodders from DEW and HF Research use the acoustic impedance mismatch between differing materials as the basis for their discriminating capability. The mismatch is directly related to the material hardness and the contact pressure. Plastic and wood are softer than rocks, while metals are generally harder than rocks. The classification boundary between rocks and light metals (such as aluminum) is not well separated and this is one of the limiting factors of the acoustic prodder.

One of the largest barriers to the adoption of instrumented prodders by the demining community is the rigid adherence to existing operating procedures. The demining community views the current operating procedures as “safe” and resists the introduction of new equipment that does not have a preexisting safety record. In addition, although a demining organization is technically tasked to remove all the buried ordnance, quality control is usually based on random spot checking with a handheld metal detector. As a result, some demining organizations concentrate on removing all pieces of metal. It is unclear if an instrumented prodder based on an acoustic principle would assist in this task.

ESTIMATED POTENTIAL (TWO TO SEVEN YEARS)

Other than the “feedback prodder” proposed by Gasser [4], training of the operator is provided through the observations of an instructor. As suggested by Gasser and observed by HF Research [7], the operator of a prodder is a critical part of the system.

> Manual prodding/excavating is commonly used to find and identify the mines/[unexploded ordnance] and metal fragments initially located by metal detectors, although it is frequently regarded as outmoded, unsophisticated, dangerous and in urgent need of replacement. A more careful investigation reveals that it is a very subtle and complex process, and humans are extremely well adapted to performing this task which involves fine tactile control with simultaneous observation and decision making. [3]

Improvements to the training tools, such as force indicators or pressure-sensitive dummy mines, can be realized within a few years.

The current standards used to develop NATO and other armed forces’ prodders can be expanded to include a testing methodology that considers the effects of an accidental blast. Current activity within the International Test and Evaluation Program has demonstrated that an antipersonnel mine strike against a deminer during the prodding task is survivable with minor injuries, given a small blast mine and a prodder that deforms gracefully under the force of the blast. The results of these activities can be integrated into existing International Mine Action Standards.

A survey of the demining community can guide the development of instrumented prodders. The survey can be used to guide the creation of an acceptable operating procedure where an instrumented prodder can be utilized to its full potential. Although not all demining situations can benefit from an improved prodder, it will be useful in some cases. It is important to know what type of instrumented prodder could be used in which situation. A comprehensive user survey of existing demining organizations can be completed within a year.

Basic research in other technologies for very "close-in" technologies can realize significant gains over the next few years. Traditional military research programs tend to concentrate on various orders of standoff capabilities with the goal of eliminating the landmine threat while traveling at high speeds (greater than 20 km per hour). Active deminers within humanitarian organizations routinely work very carefully and slowly within inches of the explosives. Improvements to "prodder-like" tools can immediately aid the deminer by providing improved safety, localization, and discrimination. For example, the existing instrumented prodder could be augmented with a combination of a ground-penetrating radar, an electrical conductivity sensor, and/or an electromagnetic induction system to aid in the localization process. In addition, the prodder is an excellent tool to deliver confirmation sensors, which have the ability to detect explosives (chemical analysis, various nuclear interaction techniques, and nuclear quadrupole resonance).

OUTLINE OF A RESEARCH AND DEVELOPMENT PROGRAM

While it is possible to propose some research and development (R&D) programs without considering details, such as the end user, it is not possible in the case of the prodder. The interaction between the prodder and the deminer is extremely complex and, as a result, the R&D program cannot work without user input. As such, the following outline does not propose basic theoretical research but concentrates on delivering existing technology and know-how into the hands of deminers. Although difficult to estimate, previous experience has shown the following tasks could be completed within seven years for approximately $6 million. It should be noted that engineering development is a significant portion of the estimate. Manufacturers are reluctant to invest heavily in equipment development because of the limited market potential provided by the demining community. Instead, manufacturers rely on donor organizations' or governments' support to develop equipment that is not destined for the military market.

1. Investigate the possibility of a standard for testing landmine prodders. The mechanical construction, localization, and discrimination capability should be considered by the standard. This will provide a benchmark by which the deminers can evaluate the prodder before making procurements and attempting to use the equipment in the field. It will also guide the manufacturers by providing an acceptable baseline for their development.
2. Survey the user community to develop effective operating procedures for instrumented prodders. In the foreseeable future, the deminer will remain "in the loop" while using some form of scanning/confirmation detector along with a probing/digging tool. A successful prodder cannot be developed without considering the system within which it operates.
3. Design a training package for the conventional prodder. The training package should contain tools that allow the instructor to measure the effectiveness of the students. Force indicating prodders or pressure-sensitive dummy mines are possible items for the training kit.
4. Based on the survey of the user community, develop a ruggedized version of HF Research's instrumented prodder. As discussed in the company's report [7], several technical challenges remain.
5. Investigate the possibility of incorporating a ground-penetrating radar, an electrical conductivity sensor and/or an electromagnetic induction system into a prodder-like package. Each of these technologies, including the existing instrumented prodder, are well understood, but the major difficulty involves the development of the appropriate ruggedized package.

REFERENCES

1. L. Russell, "Detection of Land Mines (Part I)," *Canadian Army Journal*, No. 1, November 1947. Available on a CD-ROM entitled "Information Warehouse (LLIW/DDLR) Version 4.0," distributed by the Army Lessons Learned Centre of the Department of National Defence of Canada.
2. R. Gasser and T. Thomas, "Prodding to Detect Mines: A Technique with a Future," in *2nd IEE International Conference on Detection of Abandoned Landmines*, Edinburgh, United Kingdom, October 1998.
3. R. Gasser, *Technology for Humanitarian Landmine Clearance*, Ph.D. thesis, University of Warwick, Coventry, United Kingdom, 2000.
4. R. Gasser, "Feedback Prodders: A Training Tool to Improve Deminer Safety," *Journal of Mine Action*, No. 5.2, 2001. Available at http://maic.jmu.edu/journal/5.2/features/prodders.html.
5. U.S. Department of Defense Humanitarian Demining Technologies Program, *Operational Capabilities Demonstration and Test Report: Smart Mine Probe*, U.S. Army Communications and Electronics Command, Night Vision and Electronic Sensors Directorate, Fort Belvoir, Va., August 1999.
6. D. Melville, *User Evaluation Report: SmartProbe Instrumented Prodder*, Land Forces Trials and Evaluation Unit, Oromocto, Canada, October 1999.
7. HF Research Inc., *Force and Temperature Compensation for the Instrumented Prodder*, Contract Report, CR 2002-114, Defence R&D Canada–Suffield, 2002.