Mechanical Assistance Equipment Test and Evaluation Program

Volume 1 - Summary

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Abstract

In a program conducted by the Canadian Centre for Mine Action Technologies in the summer of 2000, four machines were evaluated for their potential as Mechanical Assistance Equipment in humanitarian demining operations. This program also developed test and evaluation protocols and highly realistic but inert "reproduction mines" for use in such tests. This report is prepared in 8 separate volumes. While each volume is intended as a stand-alone document, there are important interdependencies between some of the volumes.

Résumé

Dans le cadre d'un programme mené par le Centre canadien des technologies de déminage à l'été 2000, on a évalué quatre systèmes de déminage pour en connaître le potentiel en tant qu'équipement d'assistance mécanique pour les opérations de déminage humanitaire. Le programme comprenait aussi l'élaboration de protocoles d'essais et d'évaluation et la mise au point de mines de reproduction très réalistes mais inertes à utiliser pour les essais. Le présent rapport compte huit volumes distincts. Bien que chaque volume soit conçu comme un document indépendant, il existe d'importantes interdépendances entre certains volumes.

Executive summary

The Mechanical Assistance Equipment Test and Evaluation Program sought (i) to develop meaningful, standardized test and evaluation protocols and tools for mechanical assistance technology, and (ii) to identify promising technologies and procedures that could be proposed to the humanitarian demining community. In support of these goals a test facility was designed and constructed, test procedures were drafted, standardized test targets were designed, constructed and installed in the test area, and finally, machines were tested.

The test facility proved very useful. Certain aspects of the facility were shown to be suitable in their existing form, while it became clear that changes should be made in other areas prior to being adopted as part of a standardized test program. The test targets developed, the Mechanical Reproduction Mines, were very successful in most respects, although some shortcomings were observed. Potential improvements to the Mechanical Reproduction Mines and associated equipment have been identified. Draft test protocols were developed and refined throughout the program.

Four machines were originally scheduled for testing. The main findings were that:

- The ProMac BDM48 showed very promising results and was considered for additional testing.

- The Schulte Extractor Mine Picker established that a towed machine to extract and sift mines from the soil has merit but most likely in a form somewhat different from that tested.

- The Loken Mine Disker's results were mixed. It exhibited reasonable ability to break up the soil for subsequent manual demining or mechanical soil sifting, but was also prone to disturb many mines, either detonating them or rotating them into undesired orientations.

- Testing of the remotely controlled Omega 5 Aegis slapper-type mini-flail was aborted when the system suffered structural failure and did not adequately perform against the test pieces during preliminary evaluations.

Two additional machines received attention. A rototiller mounted on an ordinary garden tractor was successful at bringing buried Mechanical Reproduction Mines to the surface. A demining rototiller might hold some promise, but this was not pursued at this time. Finally, a standard commercial sorting bucket mounted on a hydraulic tracked-hoe showed exceptional results in excavating a test area and sifting Mechanical Reproduction Mines from the Soil. It also showed promise in sifting through the soil left by other machines.

This report is divided into multiple volumes to adequately deal with the subject matter.

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Sommaire

Le Programme d’essais et d’évaluation d’équipements d’assistance mécanique visait (1) à élaborer des outils et des protocoles d’essai et d’évaluation normalisées et utiles à la technologie d’assistance mécanique et (ii) à déterminer les technologies et les procédures prometteuses qu’on pourrait proposer pour le déminage humanitaire. Dans la poursuite de ces objectifs, on a construit une installation d’essais, élaboré des procédures d’essais, conçu des cibles d’essai normalisés, construit et installé l’aire d’essais et, enfin, essayé des machines.

Les installations d’essai ont été très utiles. Certaines caractéristiques étaient acceptables sous leur forme originale, alors qu’il est apparu clairement que des changements devaient être apportés ailleurs avant d’utiliser les installations pour un programme d’essais normalisé. Les reproductions de mines mécaniques développées furent très réussies à bien des niveaux, malgré certaines lacunes. On a identifié plusieurs améliorations à apporter aux mines factices et au matériel connexe. Des ébauches de protocoles d’essai ont été mises au point et raffinées.

Quatre systèmes ont été testés. Les résultats ont été les suivants :

- Le système ProMac BDM48 est très prometteur. De nouveaux essais devraient être effectués.

- L’extracteur de mines Schulte a démontré qu’un système de déminage tracté extrayant les mines et ratissant le sol présente certes des avantages mais plutôt sous une forme différente du système mis à l’essai.

- Les résultats obtenus avec le système Loken Mine Disker sont mitigés. Ce système présente une capacité raisonnable de travail du sol préalable avant le déminage manuel ou à un ratissage mécanique, mais il déplace également beaucoup de mines, les faisant exploser ou les plaçant dans des positions indésirables.

- Les essais du système à fléaux Omega 5 Aegis télécommandé ont cessé suite à un bris de structure et à des résultats inadéquats obtenus avec les mines d’essai factices lors d’évaluations préliminaires.

Deux autres systèmes ont suscité l’intérêt. Une fraise rotative montée sur un tracteur de jardin classique a réussi à déterrer des mines factices enfouies. Ce système semble prometteur mais les essais n’ont pas été poussés plus loin. Enfin, un godet trieur commercial standard monté sur une pelle rétrocaveuse hydraulique tractée a donné des résultats exceptionnels lors de l’excavation d’une zone d’essai comportant des mines factices. Les résultats sont également prometteurs pour le ratissage du sol après le passages des autres systèmes.

Le rapport est divisé en plusieurs volumes traitant du sujet.

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Finally, special mention is given to some of the people who assembled, identified, documented, and buried the Mechanical Reproduction Mines and then located and removed the remains of these devices following the trials. Mr. Jim Roseveare, Mr. Dan Roseveare, Mr. Doug Roseveare, Mr. Paul Schile, Mr. Blair Mullen, Mr. Corry Milner, Mr. Gary Milner, and Mr. Erin Milner all performed these tedious and largely invisible duties with good humour and the greatest co-operation.

1. Document Overview

The documentation of this program has been divided into a number of separate volumes. While each volume listed below is intended as a stand-alone document, there are important interdependencies between some of the documents. For example, the evaluation of the performance of any of the machines is tightly tied to the facilities and types of test pieces used. As each of the machines are intended to perform completely different tasks, no attempt has been made at direct comparisons between the machines. The volumes that make up this document include:

- Volume 1 – Summary
- Volume 2 – Mechanical Reproduction Mines
- Volume 3 – Test and Evaluation Procedures and Facilities
- Volume 4 – Equipment Evaluation (ProMac BDM48)
- Volume 5 – Equipment Evaluation (Loken Mine Disker)
- Volume 6 – Equipment Evaluation (Schulte Extractor Mine Picker)
- Volume 7 – Equipment Evaluation (Omega 5 Aegis Slapper Flail)
- Volume 8 – Equipment Evaluation (Miscellaneous Equipment)

2. Program Overview

Over the past decade, there have been many attempts to introduce mechanical mine clearance equipment to humanitarian demining. Early on, it was hoped that such equipment would replace manual demining, but it was soon realized that the technology could not reliably meet the high quality standards of humanitarian demining. At the same time, it was found that in some cases, if mine clearance machines were used to prepare the terrain prior to manual demining, the latter could be done in significantly less time. Thus was born the concept of "Mechanical Assistance" to manual demining. Some functions that are particularly well suited to mechanical equipment are the removal of vegetation and trip wires or the break-up and processing of the soil.

Private companies, Non-Governmental Organizations (NGOs), universities and government-sponsored organizations, have since proposed a broad range of Mechanical Assistance Equipment (MAE). Often, this equipment is developed from intuition, experience and observations. In some cases, the people designing the equipment have experience in mine neutralization or demining, but many have never seen the effects of a mine explosion on mechanical devices. In other cases, machinery may be developed which is well suited to surviving the effects of mine blasts, but the machine may be unsuited to humanitarian demining operations. As a result, mechanical assistance equipment often find their way to demining organizations before their capabilities and performance have been suitably tested. This is why some equipment fails to live up to expectations in field use – sometimes due to shortcomings in the design and sometimes due to unrealistic expectations. Even in cases where an equipment developer has taken great pains to test a machine before promoting it for humanitarian demining use, there is a clear conflict of interest and a possible credibility gap when the vendor has been simultaneously responsible for the design, construction, testing, evaluation, and marketing of the device. An arm's length relationship between the equipment development interests and the equipment testing interests is essential to maintaining credibility.

It is also important to remember that there are very clear differences between humanitarian mine clearance operations and other tasks such as minefield breaching for military operations; the very characteristics which make a machine or technique suitable for one type of operation may make it completely unsuitable for other types of operations.

To address this situation, demining organizations such as the Cambodian Mine Action Centre (CMAC) have engaged in Test and Evaluation (T&E) activities to assess the performance of the equipment and determine if they should put it to field use. This represents a drain on organizations that are often ill equipped or have little practical experience in T&E procedures or the scientific method. More importantly, there is a lack of agreed international test standards to measure and rank the performance of the machines and the process. Of course, performance should be measured differently for a machine designed to remove vegetation than for a machine designed to process the soil. But in either case, there is a need for procedures that can be quantified in an objective manner and that can be repeated in different locations.

The Canadian Centre for Mine Action Technologies (CCMAT) has taken the first steps on a program to develop and debug test and evaluation protocols for mechanical assistance equipment. Two key aspects of the CCMAT program are:

1. to develop meaningful, standardized test and evaluation protocols and equipment for mechanical assistance technology, and

2. to identify promising technologies and procedures that could be proposed to the demining community.

2.1 Mechanical Assistance Equipment Candidates

Four machines, shown in Figure 1 through Figure 4, were chosen to take part in this initial program. The equipment was selected to represent families of equipment, rather than a selection of 4 different flails, for example. The selection also represented equipment aimed primarily at the low-cost, humanitarian demining operations that are supported by local, indigenous infrastructures. This approach would likely produce different results than if larger, more expensive equipment had been selected, but it was felt that this selection of equipment would better fit the requirements of humanitarian demining organizations.

2.1.1 Loken Mine Disker

The Loken Mine Disker is a device based on a modified agricultural implement. It was initially intended that under some circumstances, it be used together with a second device, the Schulte Extractor Mine Picker, although there are cases where either one could be used alone. The disker is a device that breaks up the soil to some depth while minimizing soil disturbance. A device that turns the soil like a conventional agricultural plough could (i) bury a mine even more deeply, thus making it even harder to detect and remove, and (ii) reorient a mine to the very dangerous position such as where the fuze would be facing a manual prodder. This latter point is particularly important in the case where the demining disker is be used to break up soil to allow faster, easier manual prodding and excavation of mines.

Figure 1. *Loken Mine Disker*

2.1.2 Schulte Extractor Mine Picker

This modified agricultural rock picker is intended to make its way through soft, loose soil, scooping up rocks, debris and most importantly, mines. The mine picker might be used after the demining disker or the modified brush cutter has loosened the soil. It could also be used on its own in soft soil, such as beach clearance, for example.

Figure 2. *Schulte Extractor Mine Picker*

2.1.3 Omega 5 Aegis Flail

Unlike larger military flails, a small, remotely controlled mini-flail such as the Omega 5 Aegis might find use in more confined areas and in situations where the cost, size or support requirements of the larger units cannot be justified. Furthermore, this particular design of flail head presented some innovations relative to existing flails.

Figure 3. *Omega 5 Aegis Mini-Flail*

2.1.4 ProMac BDM48

Stump grinders and brush cutters are used around the world for construction, maintenance of highways and railways, etc. The ProMac BDM48, based on a modified brush cutter, might be used on a variety of prime movers depending on the particular environment. This device may be useful not only to clear trees and brush, but also to grind soil (and mines) down to a specified depth.

Figure 4. *Pro Mac BDM48 Brush Cutting Deminer*

2.1.5 Other Machines

An ordinary, unmodified garden tractor with a rototiller attachment (see Figure 5) was used during the preliminary test activities to process an area containing a small number of targets. This was not a planned part of the MAE T&E program, and was done simply as a matter of interest when the opportunity presented itself.

During testing of the ProMac BDM48 there was discussion of the requirement for a device to process the loose soil from the BDM48. Such a device would sift through the berm to extract pieces of mines which been broken rather than detonated. A commercial sifting bucket attachment for a tracked-hoe (Figure 6) was brought in to examine its effectiveness in combination with the ProMac BDM48. Ultimately this device was used on its own in one of the four standardized test lane "frames." A full set of tests was not performed on this machine however.

Figure 5. *Garden Tractor Rototiller*

Figure 6. *Terra Firma VRL-8 Sorting Bucket*

2.2 Standardized Test Pieces – "MRMs"

2.2.1 The Need

One of the factors that makes the CCMAT program truly unique is the Mechanical Reproduction Mine (MRM). Clearly, testing with real mines provides the most realistic test conditions, but it also presents enormous safety, logistics and cost issues just in dealing with the mines themselves. There is also the issue of the potential damage to the equipment being tested; the machine may be damaged beyond repair before its performance can be properly quantified.

The high fidelity Mechanical Reproduction Mines have been designed to reproduce the mechanical action of the fuzes of their "real" counterparts, but without leading to an explosive event. Their weight, size, strength, and operation are as close as possible to the real mines. This ensures that using the Reproduction Mines to evaluate a machine's performance produces realistic, repeatable results. In addition, hundreds or even thousands of Reproduction Mines can safely be used in each test. This allows the conduct of statistically valid analyses that will produce credible, objective conclusions about a machine's performance.

2.2.2 Mechanical Reproduction Mines

For this program, six mines were chosen as a representative cross-section of anti-personnel blast mines that are deployed in various theatres. The main objective was to select those mines which represent a significant proportion of the mines present in mine-affected countries. Each mine is a member of a different “family”, where family refers to the mechanical action that causes the mine to function. This list includes:

- PMA-1: This family of mines presents a platform hinged at one end that must be depressed for the mine to function. Fuze initiation results either from crushing a displacement sensitive compound or from the release of a cocked striker onto a percussion cap.

- PMA-2: This family of mines presents a cylindrical body with an exposed plunger that must be driven down for the mine to function. Fuze initiation results from the plunger moving into a channel filled with a friction sensitive compound.

- PMA-3: This family of mines presents a cylindrical body with a tilt plate free to rock into the lower body of the mine. Tilting of the plate shears off a portion of the fuze that bridges between the moving and stationary portions of the mine, thereby initiating the detonation.

- PMN: This family of mines features a circular body containing a plunger and cocked spring. Depressing the plunger releases the cocked striker, allowing the latter to hit a percussion cap.

- PMN-2: Similar to the cocker spring and plunger system of the PMN, this family of mines also contains a mechanism that aligns the detonator with the striker when the plunger is depressed. Because the slider mechanism requires a finite amount of time for the alignment to take place, it gives this family of mines a degree of resistance to blast countermeasures.

- Type 72A: This family of mines presents a cylindrical body with a convex pressure plate that has a striker pin attached to its centre. Pressure on the plate causes the plate to invert, snapping the striker pin onto a percussion cap.

Due to budget and time constraints, the PMN-2 was not developed. In addition, the Type 72A was not constructed in time for these trials, although the design was developed. Clearly the list could be extended to include different mine fuze families such as the PFM (hydraulic action), the VS-50 (pneumatic action), or any of the tripwire operated fuzes. However, the mines selected were considered appropriate to develop and prove the test and evaluation protocols in this program. Figure 7 shows two examples of MRMs against their real counterparts.

Figure 7. *Mechanical Reproduction Mines (left) Mimic Geometry and Operation of Real Mines (right)*

2.2.3 Mechanical Reproduction Mine Interrogator

Another advantage of the CCMAT Reproduction Mines is that each one has an identification device that can be interrogated remotely even after the Reproduction Mines have been buried. This interrogation will reveal the state of the mine (operational or fired) and the unique serial number for that particular mine. Hence the simulated "minefield" can be interrogated before a test to establish a baseline of mine type, position and status. After a mechanical assistance machine has operated on a section of the simulated minefield, the mines can again be interrogated without disturbing or affecting the soil or mines (see Figure 8). This will quickly and accurately reveal what effect the machine has had on the mines for each individual pass.

Figure 8. *MRMs in Test Area Are Interrogated To Determine Live/Dead State*

2.3 Standardized Test Environments

One of the major problems in trying to objectively evaluate and compare mechanical demining equipment is that even when a thorough, rigorous trial is planned and executed for a device, it is impossible to replicate the test conditions used in testing other devices.

Standardized test lanes were designed and constructed by CCMAT to rectify this problem by defining specific soil type and terrain features over which the device(s) could be tested. For the purposes of this first-of-type program, four different environments, shown in Figure 9 were defined.

- Section "A" – Native prairie clay soil excavated to a specified depth, then replaced and packed to defined specifications in a manner that simulated ditches, dykes, and terrain irregularities;

- Section "B" – Native prairie clay soil excavated to a specified depth, then replaced and packed to defined specifications;

- Section "C" – Gravel road prepared to (defined) conventional Canadian gravel road building practices; and

- Section "D" – Native prairie soil left undisturbed with wooden posts driven into the ground to simulate small tree stumps.

These four environments were chosen, not because they represented the complete spread of environmental conditions that should be used, but because they were practical in the geographical and climatic conditions of southern Alberta, and provided a realistic set of conditions, especially for this first-of-type program. Clearly there would be great benefit in including conditions such as wet soil, heavy vegetation, or rocky, mountainous terrain, but the environments selected for this program were practical to implement, sufficient to prove the concept, and adequate to test machinery under a set of realistic, if limited conditions.

A test area was set up to accommodate four machines. Each machine received one “lane” made up of four test “frames” where each test frame was one of the environments described above (clay soil, gravel road, etc). The test area was prepared so that the four test lanes were as close to identical as possible, including the soil environments, slope, degree of vegetation, soil moisture content, etc.

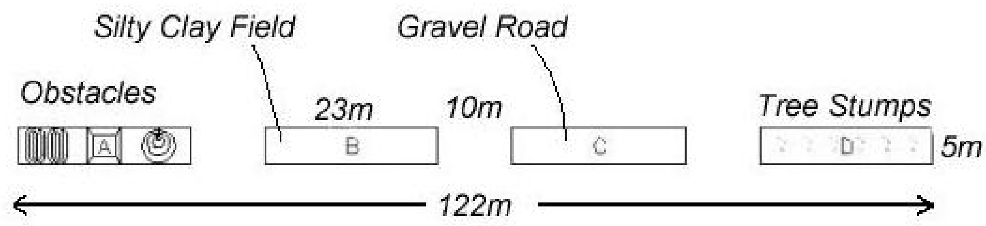

Figure 9. *Test Lane (Plan View) Provides A Variety of Repeatable Soil Conditions*

2.3.1 The "Sandbox" Problem

It is easy to criticise the above approach as being a glorified “sandbox” that does not accurately represent real world conditions. The difficulty is that real world conditions vary so widely from one location to another, even within the same minefield, that it is impossible to get objective, consistent, repeatable data without drawing some limits around the test conditions. One needs to define some (standard) test environments that are similar to the real world environments for a given machine; other standard test environments may be wholly unsuitable for that machine. To use an extreme example, a machine whose purpose is to operate in wet, swampy rice fields might be completely unable to deal with gravel roads. In this situation, while the gravel road environment might still be of use in defining limiting conditions for the machine, a wet, swampy test area would need to be defined, standardized, and built for this type of machine.

2.3.2 The Standard Sandbox

The main benefit to the “sandbox” approach is that if the sandbox and the sandbox testing methods are well defined in terms that have wide acceptance, the results can be meaningfully used by end users. Consider for example an end user who needs a machine such as the imaginary rice-field machine referred to above. Well intentioned machine developers may have conducted all manner of their own tests in sand, gravel, weeds, brush, beaches, ditches, mud, etc. However, if one machine was tested in sandy beach and shallow surf conditions while another was tested by reaching from dry, paved roads into swampy, wet ditches, how can the end user draw any relevant conclusions? It may be that no standardized tests have been developed for his exact situation, but if the two machines had at least been tested against the same environments, there would be something to compare.

2.3.3 The Developmental Sandbox

Where the sandbox testing can be done in a way that avoids using real land mines (while still preserving the fidelity of the tests), the MAE T&E program provides several potential benefits. A machine concept can be developed to determine whether the concept or tool works before undertaking an expensive integration of working tool, electronics, hydraulics, armour protection, remote control, etc. Consider for example some new type of flail. The working elements of this hypothetical new tool might be mounted on a skid steer tractor, a farm tractor, a truck, or any other suitable vehicle and run through the proposed T&E program. This would help to quantify the performance of the working tool without the enormous overhead associated with a complete system suited to the rigours of minefield use.

The observant critic will immediately object that the developer of the machine should have conducted just such tests in his own sandbox before bringing the system to the minefield. This is true; the manufacturer <u>should</u> have conducted such tests, but often this is not the case. Even in the cases where extensive "sandbox" testing has been conducted by the manufacturer, the conditions will almost certainly not have been realistic, nor will they have been standardized in any accepted way. This makes the results of such tests almost impossible to use for the end user.

The proposed CCMAT MAE T&E program allows for the incremental development of promising equipment. This benefits both the machine developer and the potential end user.

2.3.4 Going Beyond The Sandbox

The criticism of "sandbox testing" is real. Where machines do undergo testing, many are tested in controlled, laboratory environments and are then brought out to the field where they fail. Even the standardized "sandboxes" described in this program (including additional standardized environments as necessary), still fall short of actual, real world conditions.

The MAE T&E approach taken in this CCMAT program is different in that it attempts to bridge the gap between the machine developer's laboratory sandbox (assuming there was one) and real world conditions.

This T&E program requires that a machine be run through the controlled test environments prior to, and not "instead of" running it through real minefield conditions. A machine incapable of dealing with controlled environments which approach real world conditions has little chance of being successful in real minefields. In this sense the proposed MAE T&E program works as a filter to eliminate unsuitable machines before the time, money, and resources of the end users are wasted. On the other hand, a machine that appears to deal with the "sandbox" conditions adequately may deserve further development or testing.

2.4 Real World T&E

After filtering out unsuitable devices, a machine may be found which shows promise as a potential MAE system. This particular machine may also have benefited from the incremental development described above in paragraph 2.3.3. At some point it becomes necessary to subject the machine to real world conditions including real mines in real minefields, and with real demining operations and procedures.

The MAE T&E game is not yet over. The benefits of standardized vs. arbitrary testing still apply when the machine enters the realm of real mines and real minefields, although the terrain, vegetation, soil conditions, and other environmental factors may no longer be controllable or repeatable. A recognized, accepted test methodology may make all the difference between a credible test result and one with no real value.

Consider the trite example of two machines in identical physical environments. One machine tested against 100 of one type of mine all buried flush with the ground surface, had the result of 90 mines detonated, and 5 broken or disabled. The second machine was tested against 50 each of 4 different types of mine which were buried to depths ranging from surface flush to 150mm. This machine's results included 162 detonated mines and 19 broken or disabled mines. Even comparing percentages is almost meaningless given the difference in types of mines and depths of burial. The lack of standardized test procedures makes it very difficult to compare the two machines, or even to objectively evaluate either machine on its own.

This CCMAT MAE T&E program includes a test case of a machine being taken beyond the standardized test lanes and into the minefield. DRES report TR01-080 deals with an in-field evaluation of the ProMac BDM48 in Thailand.

2.4.1 Before The Minefield

The proposed CCMAT T&E program extends beyond the standardized test lanes with inert test mines and reaches into real world conditions. A machine which has "passed" the tests in the standardized test lanes must be demonstrated as safe to use and "acceptably" immune to damage from routine demining operations.

The evaluation of a machine's ability to be used safely will depend very heavily on where and how it is to be used. For example, a machine that is to be driven by a human operator must have a particular level of armour protection whereas the same machine operated via remote control would probably require far less armour to be "safe" for the human operator. The armour needed to ensure operator safety also depends heavily on the expected threats. If the system is to be used in an area containing many anti-tank mines or large unexploded ordnance (UXO), a much higher level of protection would be required. Further, the manner of operation may dictate different levels of protection. A device which always keeps the operator in a known "clear" area may not require the same armour protection as a machine which the operator drives through the area being processed.

While the level of protection necessary to keep the operator safe may vary considerably from machine to machine and from one operating environment to another, it is necessary to at least define the assumed threat, and then to test against that threat.

Similarly, the evaluation of what constitutes an acceptable level of damage is very subjective and is highly dependent on the characteristics of the machine in question. A machine which requires repairs after each antipersonnel mine blast may still be acceptable if those repairs are quick, cheap and easy to implement. A similar machine which only needs one repair every 100 blasts may not be acceptable if that one repair is very expensive or time consuming to make. Either machine's survivability may change dramatically as the threats (UXO's, AT mines, etc) change.

DRES report TR01-079 deals with the testing of the armour and protection package developed for the ProMac BDM48 between the inert MRM tests described herein, and the live, in-field testing of report TR01-080.

The question of machine survivability or repairability has not yet been addressed as part of this MAE T&E program. Indeed, it may be so highly variable as to prevent an effective standardized treatment of this issue.

2.4.2 Into The Minefield

Having proven itself against standardized test conditions, and having been demonstrated as "safe" for the operator in real world conditions, a candidate MAE machine must ultimately be tested against real mines in real conditions. The machine must also be able to be effectively integrated into the demining operations in which it is supposed to assist. A machine which survives mine blasts, keeps the operator safe and destroys 90% of all mines may not be of value if it leaves the other 10% so hazardous that the overall operation is slower or more dangerous than without the machine.

As noted above, DRES Report TR01-080 describes the "real world" testing of the ProMac BDM48 System test case. Briefly, the methodology was

- to place mechanical reproduction mines (the inert targets used in the standardized tests lanes in Canada) in real world, but "safe" or non-mined environments;

- to ensure that the machine still operates effectively, or at least predictably against the known inert targets in the "new" conditions;

- to place real mines in the real world, but in safe, non-mined environments to ensure that the machine operates effectively, or at least predictably against the real mines in the "new" conditions; and finally

- to place real mines in real minefields to ensure as complete a degree of fidelity with the real word as possible.

It may seem incongruous to be placing mines in minefields for testing, but this ensures absolute environmental fidelity with known minimum numbers of real mines. Without intentionally placing known target mines, it is conceivable that a machine could operate for weeks or months without ever encountering a real mine; should a mine suddenly detonate, there would be no way of knowing its type, depth of burial or any other relevant piece of information about that mine. Indeed, it is possible that a detonation may have been the result of a UXO instead of a mine; there is no way to know for sure. Hence it is necessary to place known targets in known conditions even at this stage in testing.

When the candidate machine has completed this final set of standardized tests an end user will be in a much better position to evaluate the relative merits of that machine in the user's particular environment. At this point the proposed CCMAT MAE T&E approach is complete.

3. Program Results To Date

The details of the CCMAT MAE T&E program are found in the companion volumes to this report. The summary of the various results is as follows.

3.1 Overall Program Summary

Volume 1 (this volume) provides an overall summary of the program without attempting to discuss technical details. Generally speaking the program is considered to have been successful. Standardized targets, procedures, facilities and test environments were developed, tested and modified as necessary. Potential candidate machines for use as mechanical assistance equipment were tested with one of the machines progressing on to more in-depth trials involving real mines. Finally, a second iteration of the program is scheduled to commence in the fall of 2001 or the spring of 2002.

3.2 Mechanical Reproduction Mines

Volume 2 describes the utility of the Mechanical Reproduction Mines. These devices appear to provide excellent results when used in the testing of “non-destructive” machines. When used with “destructive” machines whose purpose is to physically break up mines, the MRM’s provide good results in terms of live, functional mines vs broken, non-functional mines, but the results can be ambiguous with respect to what kind of Explosive Ordnance Disposal (EOD) problem (fuzes, boosters, detonators, partial mines, etc) might be created.

The system used to examine the MRMs during testing included an identification device encased in the MRM and a reader or interrogator. The hand held interrogator was used in much the same manner as a metal detector except that it ignored everything but MRMs. The system worked well but would have benefited from some modification which have been incorporated into the design of the second generation MRM interrogators and MRMs.

3.3 Test and Evaluation Procedures and Facilities

Volume 3 of this report describes the overall test and evaluation procedures, the facilities and the issues relating broadly to the program as a whole. The T&E process is broadly broken down into three phases. The first phase is a preparatory phase in which candidate machines are examined, and evaluated in a subjective manner using small numbers of MRMs to ensure that the machines/concepts are sound and that further testing is warranted. The second phase is the one in which the standardized tools, facilities and procedures are used to test and evaluate the machines in an objective, repeatable, and credible manner. This is also an “inert” period of testing which makes use of large numbers of MRMs to give statistically significant data. The third and final phase is the one in which promising machines are taken into “live” testing scenarios which include real mines, real minefields and real humanitarian demining operations. The first two phases have been completed in this first iteration of the CCMAT MAE T&E program and are dealt with herein, while the test case for the third phase is covered in reports TR01-079 and TR01-080.

The processes by which the various machines are tested will necessarily require some tailoring as each machine will present its own unique characteristics, requirements and limitations, but the overall procedures used in phases 1 and 2 were shown to be largely satisfactory. The layout of the test areas with the standardized test lanes and soil conditions was also shown to be satisfactory, although some changes have been implemented for the next iteration of the program. These changes are designed to enhance the realism of some of the test conditions, and also to improve the efficiency with which the testing and evaluation can be carried out.

The list of defined, standardized test environments could certainly be expanded to include, as noted above, wet or swampy soil, heavy vegetation, rocky soil, steep hills, and many other conditions. Clearly few locations will be able to support all necessary test environments and it may be necessary to conduct some trials in one location and others in a completely different location. These factors underline the importance of a widely accepted set of T&E protocols that will be adhered to regardless where the testing is done and by whom.

3.4 Equipment Evaluation (ProMac BDM48)

Volume 4 describes the test and evaluation of the ProMac BDM48. This system was equally effective in all of the standardized test conditions. It was highly effective in "neutralizing" over 99% of all MRMs used in the program. The only serious questions coming from this "inert" portion of the T&E program were whether broken MRMs equated to detonated mines, and if not, what kind of EOD problem would remain from fuzes, detonators, boosters, partial mines, etc. The inability to answer this question is a function of the MRMs, rather than being an evaluation of the machine's abilities.

The performance of the ProMac BDM48 in the initial "inert" part of the MAE T&E program was encouraging enough that it was recommended for further development and ultimately testing against real mines in real-world conditions (see DRES Reports TR01-079 and TR01-080).

3.5 Equipment Evaluation (Loken Mine Disker)

Volume 5 describes the Loken Mine Disker test and evaluation. This device was found to have limited value in its existing form, although certain aspects of its design were beneficial. No further testing or development of this equipment is recommended at this time.

3.6 Equipment Evaluation (Schulte Extractor Mine Picker)

Volume 6 describes the Schulte Extractor Mine Picker test and evaluation. This device was found to have limited value in its existing form, although certain aspects of its design were beneficial. Numerous other soil sifting devices based on rock pickers and potato harvesters have been developed over the years and few have proven particularly effective. No further testing or development of this equipment is recommended at this time.

3.7 Equipment Evaluation (Omega 5 Aegis Flail)

Volume 7 describes the Omega 5 Aegis flail test and evaluation. This device suffered failures of mechanical, hydraulic and electronic systems in preliminary testing and was never subjected to the standardized test environments. It was found to be ineffective against MRMs in the very limited preliminary tests. No further testing or development of this equipment is recommended at this time.

3.8 Equipment Evaluation (Miscellaneous Equipment)

When the opportunity came up to use an ordinary, unmodified garden tractor with a rototiller attachment against a small number of MRM's, it was discovered that all but the deepest buried MRMs were brought to the surface using this machine. No formal testing was done, nor was the machine exposed to the standardized test environments. Any such system intended for humanitarian demining would have to be completely reconfigured to be of any use. A modified rotary tiller of some description might be contemplated in future work.

The Terra Firma VRL-8 Sifting Bucket was brought into use as a possible companion piece to the ProMac BDM48. This device appeared to be very effective in sifting through the dry prairie clay soil and extracting pieces of broken MRMs. To capture smaller MRM fragments a smaller mesh screen could be used in the bucket, although this would clearly affect the speed, and possibly the effectiveness of the machine's sifting ability. Its utility in wet or highly cohesive soil is unknown, but it is suspected that it will not perform well in such conditions. Ultimately this device was used on its own in one of the four standardized test lane "frames." This abbreviated test showed that the device might have merit as an MAE device in its own right in certain limited circumstances.

The evaluation of both the rotary tiller and the sifter bucket are described in Volume 8 of this report.

4. Conclusions and Recommendations

The CCMAT MAE T&E program has made significant progress toward the establishment of standardized environments, tools, and procedures for the test and evaluation of a variety of Mechanical Assistance Equipment candidate machines. None of these escaped the first iteration intact; rather, areas of improvement and refinement have been identified that will help ensure that the process is generic enough to apply to a wide variety of machines, and specific enough to give meaningful, useful results to the humanitarian demining community.

It is recommended that a second phase of the "inert" MAE T&E program be undertaken in which different equipment can undergo test and evaluation with the modified procedures, tools, and environments.

Contingent on the successful completion of the "live" component of the MAE T&E test case (the ProMac BDM48), it is recommended that other machines which look promising be taken beyond the "inert" phase of T&E and into the real world of "live" T&E. This is a serious and potentially expensive and time consuming activity which must not be undertaken lightly if the overall process is to retain its value.

It is also recommended that steps be taken to promote the CCMAT MAE T&E process as the baseline for international co-operation in the test and evaluation of potential candidate machines for humanitarian demining assistance. This may be through the auspices of the International Test and Evaluation Program (ITEP) or a similar organization.

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List of symbols/abbreviations/acronyms/initialisms

DRES	Defence Research Establishment Suffield
CCMAT	Canadian Centre for Mine Action Technologies
CMAC	Cambodian Mine Action Centre
MRM	Mechanical Reproduction Mine
MAE	Mechanical Assistance Equipment
T&E	Test and Evaluation
BDM48	Trade name of ProMac “brusher-deminer”
VRL-8	Trade name of Terra Firma sifting bucket
EOD	Explosive Ordnance Disposal (see Glossary)
UXO	Unexploded Ordnance
ITEP	International Test and Evaluation Program

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Glossary

Technical term	Explanation of term
Berm	The pile or ridge of soil and debris remaining after a machine has processed an area.
EOD	“Explosive Ordnance Disposal” is used herein (inaccurately) to refer to pieces or fragments of mines left after a machine’s operation which must then be handled in some manner to render an area “clear” or safe.

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In a program conducted by the Canadian Centre for Mine Action Technologies in the summer of 2000, four machines were evaluated for their potential as Mechanical Assistance Equipment in humanitarian demining operations. This program also developed test and evaluation protocols and highly realistic but inert “reproduction mines” for use in such tests.

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Mechanical Assistance Equipment
Test and Evaluation
Mechanical Reproduction Mine
Anti personnel landmine
Humanitarian demining
Neutralization
ProMac BDM48
Loken
Schulte
Omega 5
Terra Firma