



Proof of Performance Test Report

MANTIS

April 2005

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**Proof of Performance Test Report
on
Mine Clearing/Survivable Vehicle
(Mantis)**

April 2005

FOREWORD

The success of the Mine Clearing Survivable Vehicle (MCSV) Proof of Performance Test was the result of the efforts of a large team of people from a number of organizations. The organizations involved were the U.S. Army's Night Vision and Electronic Sensors Directorate (NVESD) Humanitarian Demining (HD) Research and Development Office located at Ft. Belvoir, Virginia; the International Test and Evaluation Program for Humanitarian Demining (ITEP); and Pearson Engineering Ltd, Newcastle Upon Tyne, UK. This test was also a U.S. sponsored ITEP Test (ITEP Work Plan Number 3.2.5.). During the first phase of testing in August 2004, the Project Director, Mr. Charles Chichester, assisted by Ms. Karin Breiter, directed and oversaw the performance test of the MCSV tractor and each of the tools available at the time. During the second phase of testing in early December 2004, which was conducted with tools not available in August, Mr. Peter Reed (NVESD) was the Test Engineer. In addition to the U.S., the other ITEP participant assisting in this test was the UK, represented by Mr. Peter Blatchford and Mr. Steven Bowen from QinetiQ, Ltd., United Kingdom. Mr. Eric Read and Mr. Graham Rutherford from Pearson Engineering, Ltd., provided technical and operational insight and maintenance support for the MCSV tractor and family of tools. The operators were SFC Lawrence Jones, Mr. Christopher Andres, and Mr. Ronald Collins. Mr. Art Limerick, a member of the Development Site test staff, rendered test support in the field. Mr. Harold Bertrand, of the Institute for Defense Analyses (IDA), provided technical test support and was the author of this report.

In addition to the contributions made by the above, equipment used with the MCSV and product information appearing in this report were obtained from Pearson Engineering, Ltd., Wincombe Road, Walker, Newcastle Upon Tyne, UK, pearson@pearson-eng.com.

Authors Note: Subsequent to the conduct of this test and just prior to the release of this report, the MCSV system was named the Mantis. Since the final report had already been printed and was awaiting final assembly, the report, which follows, refers to the Mantis as the MCSV.

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EXECUTIVE SUMMARY

During two weeks in August 2004, the Mine Clearing Survivable Vehicle (MCSV) and a complement of 12 demining and area preparation tools were evaluated under an internationally conducted Performance Evaluation Assessment. Led by the U.S. Army's Communications-Electronics Research, Development and Engineering Center (CERDEC), Night Vision & Electronic Sensors Directorate (NVESD), Humanitarian Demining Branch (HD), the assessment was conducted by HD staff members and supported by engineers from the United Kingdom under the auspices of the International Evaluation Test Program for Humanitarian Demining (ITEP). The test was conducted at a U.S. Army development test site in central Virginia.

The MCSV is an armored John Deere farming tractor with mine-blast survivable SETCO tires and a 180° rotating, armored driver's cab. The MCSV and the tools, 2 designed for mine clearing and 10 commercial off-the-shelf vegetation removal and site preparation tools, were procured from Pearson Engineering, Ltd, in the UK, by the NVESD HD program.

The results of the performance demonstration assessment clearly show, for the soil and vegetation within the limits of that found at the test site, that a single prime mover (the MCSV) with a well thought-out selection of tools can prepare an area for demining, remove antipersonnel (AP) and antitank (AT) mines, and leave an area ready for quality assurance proofing and subsequent use.

Survivability against AP mine blasts for the MCSV, the operator, the mine roller, and the SETCO tires was demonstrated by detonating 250 gram (1/2 pound) TNT charges initiated by a small AP mine under the mine roller and SETCO tires of a moving MCSV. The ability to detonate most AP mines with the mine roller and remove AT mines with the Rotary Mine Comb was demonstrated in simulated minefields in moderate to heavy vegetation. The vegetation clearing and area site preparation tools demonstrated the system's capability for vegetation cutting and removal, and the removal of downed trees, surface metal, and buried mines and UXO.

The results of the performance demonstration assessment supports the premise that a single prime mover with a toolkit of well thought-out selected tools can reliably and rapidly perform the demining tasks of land preparation, mine removal, and area reduction and reclamation, leaving an area ready for quality assurance proofing. As a result, the NVESD Humanitarian Demining Program is planning additional demonstrations of the single-toolkit approach. Later in 2005, the MCSV and the tools tested during this performance demonstration assessment will be sent to Nicaragua for an extensive operational field test in mined areas to further prove out the concept of the toolkit approach to humanitarian demining. NVESD HD will participate in the operational field test and document the performance of the MCSV and the tools.

For additional information on the Nicaragua test, contact Mr. Sean Burke, Mr. Charles Chichester, or Mr. Peter Reed of the NVESD Humanitarian Demining Program Office, Ft. Belvoir, Virginia.

1 INTRODUCTION

1.1 Background

1.2 Objective

The purpose of a *proof-of-performance test* is to define the capabilities and establish the limitations of the Mine Clearing/Survivable Vehicle (MCSV) to address some of the vegetation clearing, soil preparation, and mine removal and neutralization problems associated with humanitarian demining.

This test was sponsored by the U.S. Army's Night Vision and Electronic Sensors Directorate (NVESD) Humanitarian Demining (HD) Research and Development Office located at Ft. Belvoir, Virginia, and jointly conducted by the U.S. HD staff and participants from the United Kingdom under the International Test and Evaluation Program (ITEP).

2 SYSTEM DESCRIPTION

The MCSV is a modified and armored John Deere 6920 farm tractor capable of operating a number of specialized and off-the-shelf commercial implements to address some of the vegetation clearing, soil preparation, area reduction, quality assurance, and mine removal and neutralization problems in humanitarian demining operations. The system is equipped with front and rear power take-offs (PTO), standard three-point hitches front and rear, and a modified loader frame. The tractor was modified, armored, and reassembled by *Pearson Engineering Ltd.*, Newcastle upon Tyne, England, under contract to the US Army NVESD.



Figure 1: Mine Clearing/Survivable Vehicle (MCSV) with Rotary Mower

The intent of the MCSV is to provide a mine-survivable vehicle based on a commercial off-the-shelf (COTS) farm tractor. This tractor has been armored, fitted with a rotating driver's cab and antipersonnel (AP) mine survivable SETCO wheels with an innovative wheel hub interface incorporating a dowel and plate design. This design allows the wheel to separate from the axle in the event of an antitank (AT) mine detonation, thus reducing the shock effect through the axle and the tractor body to the operator. The SETCO wheels are also a commercial product. This vehicle is to act as the prime mover for a toolbox of COTS and specialized implements generally used by construction and earth-moving industries. Along with the mine resistant John Deere tractor, this toolbox currently consists of:



Figure 2: Mine Survivable Tractor



Figure 3: Rotary Mower



Figure 4: Area Reduction Roller



Figure 5: Rotary Mine Comb



Figure 6: Grab



Figure 7: 4-in-1 Bucket



Figure 8: Heavy Cultivator



Figure 9: Bed Formers



Figure 10: Mine Sifter



Figure 11: Tree Picker



Figure 12: Spring Tine Cultivator



Figure 13: Magnet



Figure 14: Hedge Cutter

Specifications of the tractor and implements are listed in Table 1 and Table 2.

Table 1: Tractor, John Deere (Model 6920) Measurements

Measurement	Dimension
Max Working Height	9.5 ft/ 2.9 m
Max Shipping Height	9.5 ft/ 2.9 m
Max Width, standard wheels	7.5 ft/ 2.28 m
Max Width, SETCO Wheels	9.2 ft/ 2.8 m
Max Length	17.1 ft/ 5.2 m
Cab Seating	1
Configuration	4 × 4
Max Shipping Weight	22046 lb/ 10,000 kg
Chassis Ground Clearance	13.75 in./ 34.9 cm
Turn, Pivot Radius	See Section 5.2
Fuel Capacity	180 liters
Oil Capacity	19.5 liters
Hydraulic Fluid Capacity	66 liters

Table 2: Tool Measurements

Tool	Max Width ft / m	Max Height ft / m	Max Length ft / m	Max Working Depth in. / cm	Working Width ft / m	Weight* lb / kg	Bucket capacity ft ³ / m ³
Area Reduction Roller (Pearson)	11.17 / 3.40	3.61 / 1.10	2.67 / 0.81	N/A	11.2 / 3.4	7758 / 3520	N/A
Mower Deck (Spearhead 3000 Swipe)	9.84 / 3.00	1.94 / 0.59	8.63 / 2.63	N/A	9.5 / 2.9	1895 / 860	N/A
Grab (Albutt C250)	6.2 / 2.0	2.5 / 0.75	4.0 / 1.2	N/A	6.2 / 1.96	1014/460 (incl. mount)	46 / 1.3
Magnet (Pearson)	9.5/2.9	3.3/1.0	6.9 / 2.1	N/A	9.5 / 2.9	7055/3200	N/A
Hedge Trimmer (Spearhead Excel 605)			13.3/4.06 (boom reach)		5.25 / 1.6	3048 / 1383	
4-in-1 Bucket (L. Albutt AMP31B)	6.60/2.01	2.58/0.79	2.33/0.71	N/A	6.6/2.01	893 / 405	18 / 0.51
Mine Sifter (Standen Pearson Megastar)	9.2/2.8	7.2/2.2	21.3/6.5	14.0/35.1	5.25/1.6	5732 / 2600 (Incl. mount)	N/A
Rotary Mine Comb (Pearson)	12.1/3.7	5.0/1.5	6.0/1.82	15.7/40	10.8/3.3	7163 / 3250	N/A
Soil Loosener (Cousins)	11.48/3.50	4.58/1.40	6.0/1.83	20.1/51	10.66 / 3.25	3070 / 1393	N/A
Heavy Cultivator (Cousins)	11.63 / 3.54	3.90 / 1.19	6.92 / 2.11	5.9 / 15	9.8 / 31	3086 / 1400	N/A
Bed Former (Pearson)	13.0/3.9	4.88/1.46	6.0/1.8	14.0 35.6	13.0/3.9	3078/1393	N/A
Tree Picker	9.68 / 2.95	2.46/0.75	3.61 / 1.1	N/A	1.25/0.381	1213 / 550	N/A

* Tool weight and shipping weight are the same

3 PROOF OF PERFORMANCE TEST SITE DESCRIPTION

The test sites selected at a U.S. Army countermine/demining development center in central Virginia were deemed suitable for assessing the various aspects of the MCSV system capabilities, including but not limited to, staging areas, vegetation clearance sites, both on- and off-road mobility, digging, mine clearing, cultivator demonstrations, brush and tree hauling, roller AP neutralization, and blast testing. (The rare earth magnet and mine sifter were not available for testing in August. However, they did arrive at the test site later in the year and were put through an exhaustive series of tests.) The vegetation on the test site varied from light to heavy vegetation and from light to heavy forest (wooded area with mature trees). Also, the terrain varied from level to hilly and from smooth to rugged ground. Test site surfaces were free from man-made debris but had natural obstacles such as dead-fall, gullies, and rocks. In an effort to minimize the number of descriptors used to define the variety of conditions found on the test site, the vegetation and terrain are characterized into four categories. The categories used for this test ranged from easy (1) to very difficult (4).

All four vegetation categories were represented at the test site and are shown below in Figure 15 through Figure 18. Table 3 gives definitions of each category.

Table 3: Vegetation Categories

Category 1 (Easy)	Category 2 (Moderate)	Category 3 (Difficult)	Category 4 (Very Difficult)
Light vegetation with minimal saplings up to 3 cm diameter	Moderate vegetation with sparse brush and saplings up to 6 cm diameter	Moderate vegetation with brush, saplings and trees up to 10 cm diameter	Heavy vegetation with dense brush, saplings and trees greater than 10 cm diameter
Fairly level terrain with minimal ruts	Level to light rolling terrain with some ruts	Rolling terrain with lots of ruts	Steep hills with lots of ruts, very rugged terrain
Minimal debris and obstacles	Some debris and obstacles	Moderate debris and obstacles	Heavy debris and obstacles



Figure 15: Category 1, Easy



Figure 16: Category 2, Moderate



Figure 17: Category 3, Difficult



Figure 18: Category 4, Very Difficult

4 PROOF OF PERFORMANCE TESTING

Data for the listed MCSV tests will be gathered during the Proof of Performance Test. Some of the tests will result in the direct measurement of the system's performance; data from others will be the result of comments from observers and the operator. The test issues are:

- MCSV on- and off-road mobility.
- Tool operations and operational limitations.
- Operator functions, requirements, and comments.
- Operational consumables, maintenance and maintainability.
- Training and training equipment, manpower and personnel.
- Blast survivability.
- Transportation and transportability.

Each capability of the system demonstrated will be documented. Limitations, where definable without having to test to destruction, will also be noted. Since it is intended, as part of the Proof of Performance test, to more completely define the system's total capabilities, the Proof of Performance test will begin when the equipment arrives at the staging area of the test site and will end when the equipment has been loaded for transport from the test site.

5 TEST RESULTS

5.1 MCSV On- and Off-Road Mobility

The on- and off-road test was conducted on a 2.8 mile track consisting of 1 mile of a graded, rolled, gravel road and 1.8 miles of an unimproved, heavily rutted mud fire road through open hilly terrain, which included marshy drainage areas, a steep sandy rise, heavy field grass, and a serpentine route. The MCSV, with pneumatic tires and three different tool configurations, ran three, 3-lap test runs ($3 \times 2.8 = 8.4$ miles [13.5 km]). Two, 1-lap test runs were made with SETCO tires. Table 4 gives the results.

Table 4: On- and Off-Road Mobility Test

Test No.	Tires	Tools	Distance miles/km	Time Minutes:Seconds	Speed mph/kph
Test 1	Pneumatic	Grab Bucket	8.4/13.5	48:36	10.4/16.7
Test 2	Pneumatic	Grab Bucket & A.R. Roller	8.4/13.5	40:50	12.35/19.9
Test 3	Pneumatic	Rotary Mower & A.R. Roller	8.4/13.5	45:39	11.1/17.9
Test 4	SETCO	Rotary Mower & A. R. Roller	<1.0/<1.6	Aborted	Aborted
Test 5	SETCO	Counterweight & A. R, Roller	2.8/4.5	18:40	8.97/14.5

The MCSV, with SETCO tires and the rotary mower and area reduction roller mounted, got stuck on a section of the cross-country track that approximated a 20-degree slope in soft, damp sand. Getting stuck appeared to be caused by a combination of the rigidity of the solid tires and the molded traction cleats in the rear tires, which are close together, becoming packed solid with soil. This resulted in the rear, heavily cleated tires taking on the characteristics of “slick” tires, with no flexibility to self-clean (see Figure 19). The tractor was able to back out of the ruts, created in its attempt to go forward, after sections of logs were placed into the ruts behind the four driving wheels. A dozer was brought in to repair the damage done to the dirt road over the length of the hill



Figure 19: MCSV Stuck in Damp Sand Hill

Two days later, after the soil had a chance to drain, the run was made again with SETCO tires and the counterweight and area reduction roller attached. There were no problems and not a single hesitation or wheel spin when the MCSV climbed the portion of the hill where it had previously gotten stuck. The run was completed at an average speed of 8.97 mph (14.5 kph).

5.2 Turning Circle Distances

Turning circle distance measurements were made of the MCSV with the rotary mower mounted on the front. Measurements were taken in both 2-wheel and 4-wheel drive modes, to the left and right, with the wheels turning, and in a brake turn. There was little discernable difference between turning circle distance with pneumatic or SETCO tires. The reason for this is that the front tire scribes the larger circle in a turn. While the tractor's width at the rear wheels is greater with SETCO tires, the rear wheel track is still inside of the front wheel track. Table 5 gives the results of this test.

Table 5: Turning Circle Distances

Test	Outside Mower Edge Turning Circle	Outside Vehicle Tire Turning Circle
2WD, Left Turn	54.7 ft./16.7 m	39.4 ft./11.9 m
2WD, Right Turn	59.8 ft./18.2 m	44.5 ft./13.6 m
4WD, Left Turn	55.2 ft./16.8 m	42.5 ft./13.0 m
4WD, Right Turn	55.3 ft./16.9 m	42.3 ft./12.9 m
Brake Turn, to Right	45.3 ft./13.8 m	29.6 ft./9.0 m

5.3 Operator Comments and Issues

- Travel Speed to Work Site: On average, it was estimated that travel speeds to a work site could average 3 to 8 mph (5 to 13 kph), the lower speed for travel cross country if no previously made trail exists.
- When facing forward (operator is looking over the engine cowl), he cannot see the grab or 4-in-1 buckets when tools are on the ground. He also cannot see enough of the rotary mower deck to be able to tell, visually, that the mower deck is on the ground. Experience in using these tools improved the operator's judgment of tool placement. When facing to the rear (and tools rear mounted), the operator could see the exact location of these tools.
- There is a noticeable difference in the quality of the ride between the pneumatic tires and the SETCO tires. Operators tend to reduce top speeds when riding on SETCO tires because of the marked increase in stiffness of the ride.
- For some tools, such as the Rotary Mine Comb, for example, the increased rigidity of the John Deere tractor with SETCO tires improves the operator's handling of the tractor and tool.
- Installation of skids on the Rotary Mine Comb and Rotary Mower, allowing the tool to float, improves the operator's handling of the tool.
- The gear ratio on the electric/manual cab-turning mechanism is not sufficient to allow a heavy (i.e., weighing more than 85 kg) operator to turn the cab from the inside when the tractor is not sitting perfectly level. In such cases, the operator had to exit the cab and turn the cab by hand while standing on the tractor chassis.
- While the MCSV did get stuck in the wet sand on the off-road mobility test, there were no operating conditions where soil, vegetation, or terrain caused the test of a tool to be terminated, curtailed, or test procedures changed.
- There were some driver complaints that the mounting of the brush trimmer control column impeded their movement in the cab while operating other tools.

6 TEST RESULTS - OPERATIONAL PERFORMANCE OF MCSV AND TOOLS

6.1 Rotary Mower, With and Without Area Reduction Roller

The rotary mower worked very well in Categories 1 and 2 vegetation. Mowing in Category 1 vegetation resulted in stubble was between 1 ¼ to 1 ¾ inches (3 – 4.5 cm) high. When encountering an area of tall or dense Category 2 vegetation, the operator found it necessary to make the first cut high (approximately ½ meter) and then remove the area or, for a dense clump, to bring the mower deck down on the area to complete the mowing. This procedure led to the first problem of the test.

When bringing, or more accurately, dropping the rotary mower down on thick clumps of Category 2 vegetation stubble, which were frequently accompanied with local ground heaving caused by a dense root system, the high peak loads on the mower drive train caused the PTO clutch to disengage. When this happens, this procedure is followed:

- Shut off power to the PTO powering the mower

- Raise the mower
- Wait until the spinning blades on the mower come to a stop
- Reengage the PTO
- Bring the PTO RPMs up to 1000
- Lower the mower to cutting height and continue mowing

One such encounter caused the universal joint on the tractor end of the PTO shaft to shear. In this case, the mower was mounted on the front of the tractor, and the tractor was backing down a mowing lane, pulling the mower. The rear of the mower (side closest to the tractor) dug into the ground, causing the front of the mower deck to rise. This put the drive shaft into a bind while under power, which caused the universal joint (drive shaft yoke) to break. Parts were obtained from the local John Deere dealer, and the test continued on the following day.

To demonstrate using the mower in an AP mined area, and to eliminate clutch disengagements in heavy Category 2 vegetation, the mower was used in tandem with the area reduction roller. On the first pass through a Category 2 vegetation area, the roller was pushed through the vegetation (cab facing to the rear and roller mounted on the rear), with the mower following and raised about 6 to 12 inches (15 to 30 cm) off the ground. At the end of the pass, the MCSV operator rotated the cab, dropped the mower to ground level, and retraced the path he had just taken, this time with the mower leading and the roller following. While this double-pass operation increased the mowing time, it resulted in a closer cut area and minimized the chance of the mower deck being caught on dirt or shrub growth, causing shaft damage as described above.

Figures 20 and 21 show the results of mowing with the use of the roller, and of the sheared universal joint (drive shaft yoke).



Figure 20: Area Reduction Roller and Mower Results



Figure 21: Sheared Universal Joint

Two timed mowing tests were conducted to provide planning factors for field operations of the rotary mower. The first test was with the mower only on an area where the vegetation progressed from a heavy Category 1 to a mix of Categories 1 and 2. The area mowed was 1,909 m², the time required was 62 minutes. This equates to approximately 1,850 m² per hour. Figure 22 is a diagram of the mowed area.

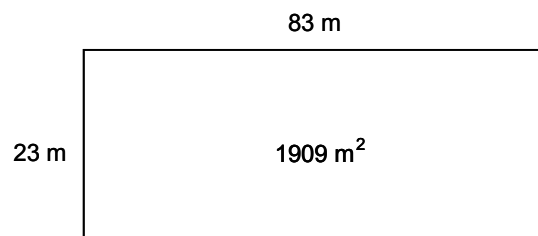


Figure 22: Mowed Area (1900 m²/h), Mower Only, Single Pass

Mowing trials continued with the rotary mower mounted on the front and the roller mounted on the rear of the tractor. For this phase of the trial, the operator was told to deliberately move at a slow pace.

The procedure followed was as described earlier in this section. Therefore, each mowed lane was processed twice, first in one direction with the roller leading and the mower in trail slightly off the ground, and then on a return pass with the mower leading, on the ground, and the roller trailing. The result was an area that was rolled twice and, due to the two stage mowing, had all Category 1 and 2 vegetation cut to a height of 1.5 inches (381 mm). No Category 3 vegetation was mowed in this phase of the trials.

The results (area and time) for this phase of the test are presented in Table 6, below.

Table 6: Mowing Rates, Mower and Roller, Double Pass

Test	Area	Time (min:sec)	Mowing Rate
Lane 1	249 m ²	28:43	520 m ² /hr
Lane 2	249 m ²	24:28	610 m ² /hr
Lanes 3 & 4	498 m ²	57:49	517 m ² /hr

6.2 Roller Test in Mined Area

Tests were conducted to determine the effectiveness of the roller in detonating mines in heavy Category 1 vegetation. Two mined lanes, 3 meters wide, 50 meters long, were measured off in Category 1 vegetation. Forty mechanical reproduction mines (MRM), manufactured by Amtech Aeronautical, Ltd., were buried in each lane, 10 MRMs each of PMA-1, PMA-2, PMN, and Type-72A mines. In Lane 1, mines were buried flush with the surface; in Lane 2, the mines were buried 1 cm below the surface (to top of mine). The layout of the test lanes is shown in Figure 24. Each MRM was fused with a mechanical trigger, which if activated, indicates that a real mine would have detonated. After processing the test lanes with the roller, each mine was dug up and inspected to see if the mechanical fuse had been activated. The results of this test are shown in Table 7.

Table 7: Number of Mines Detonated, by Type

Type of MRM Mine	Lane 1, Flush		Lane 2, 1 cm	
	# Detonated	# Not Detonated	# Detonated	# Not Detonated
Type 72A	2	8	2	8
PMA-1	10	0	10	0
PMN	10	0	10	0
PMA-2	10	0	8	2

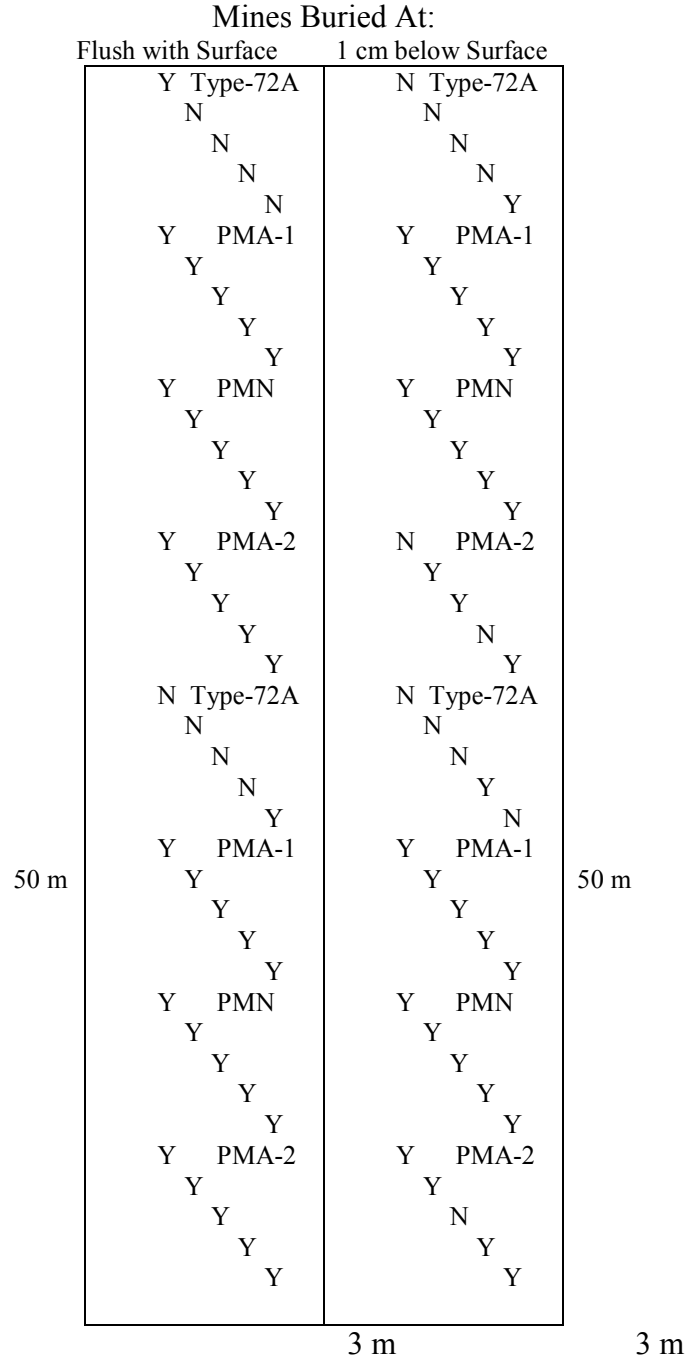
In Lane 1, 80% of the flush-buried mines were detonated. All those not detonated were Type-72A MRMs. In Lane 2, 75% of the mines were detonated. Those not detonated were eight Type-72A and two PMA-2 MRMs.

Blast tests were also conducted against the roller. The explosive, designed to simulate a heavy AP mine, consisted of ½ pound of TNT initiated by a small U.S. AP mine. Three explosive charges were laid with the initiator mine's detonator just above the surface. The tractor, with the roller attached on the front, was pulled over each of the explosive devices. The roller sustained no damage. See Figure 23.



Figure 23: Results of Blast Test Against Roller

Figure 24: Test Lane Configuration and Mine Emplacement



6.3 Hedge Trimmer

The Hedge Trimmer, designed to be mounted on the rear 3-point hitch of the tractor, is powered by the rear PTO. The PTO drives an on-board hydraulic system that controls the movement of the boom and powers the cutter head. The boom allows the hedge cutter to operate over an intervening guard rail or other similar obstacle and cut the vegetation beyond

the obstacle. The cutter is powerful, quiet, with very minimal vibration, indicating excellent balance of the cutting rotor. The cutting rotor has a double row of cutters with 14 cutters per row. The cutting swath is 1 meter. With the boom fully extended, and with no intervening obstacle, the cutting head is able to reach out 13.33 ft (4 m). The Hedge Cutter had no problem cutting Category 1 and 2 vegetation. On Category 3 vegetation, the cutter was able to cut the vegetation down to ground level only by cutting the vegetation in stages, beginning at the top, and working down. The Hedge Cutter was not designed to be operated in this fashion; however, it can be done, albeit awkwardly. The Hedge Cutter appears to be sufficiently robust to operate for extended periods of time against Categories 1 and 2 vegetation. No trials of area versus time were made. No mechanical problems were encountered.



Figure 25: Brush Cutter Operations

6.4 Spring Tine Cultivator (Light Cultivator)

The Spring Tine Cultivator, a commercial farming tool, was mounted on the MCSV with SETCO tires. The test area was hard-packed sandy clay soil. At the start of the test, when the MCSV operator tried to control the tractor throttle and depth of the cultivator manually, the cultivator operating depth varied as the surface of the field rose and fell, and the MCSV was brought to a complete standstill at low tractor speeds by the drag of the cultivator. However, when the tractor was put into Economy Drive (similar to cruise control), the cultivator allowed to ride on the depth-control wheels installed on the cultivator, and the desired tractor speed set, the MCSV fuel-control system and engine computer automatically adjusted the fuel flow to keep the tractor moving as the cultivator load on the tractor varied. When driven using Economy Drive, the tractor was able to cultivate the soil to a depth of 6 inches (15.25 cm) on all three rows of tines. No time trial measurements against area cultivated were made.



Figure 26: Spring Tine Cultivator Demonstration

6.5 Soil Loosener (Heavy Cultivator) and Bed Formers

Based on the experience with the Spring Tine Cultivator, the performance test of the Soil Loosener made use of the installed depth-control wheels to control the tool's operating depth, and the Economy Drive system was engaged. Trials were conducted in dry, compacted sandy clay soil with no vegetation and in an area where Category 1 vegetation had been cut with the rotary mower. At both sites, the MCSV had no trouble pulling the Soil Loosener at an operating depth of approximately ½ meter.



Figure 27: Soil Loosener in Packed Clay and Heavy Sod

The Bed Formers were installed on the Soil Loosener frame once the Soil Loosener blades were removed. The two Bed Formers are shaped like plows and are so spaced that the distance between their center points is equal to the tire track width of both the MCSV and the Soil Sifter. The Bed Formers, capable of operating up to a depth of 14 inches (35.6 cm), move the broken-up soil (preprocessed by the Soil Loosener) into windrows measuring 7.48 feet (2.28 meters) wide from the center of one trough to the next. SETCO tires can also be mounted on the MCSV without the blast-off mounting hub.



Figure 28: Bed Formers Installed on the Soil Loosener Frame

6.6 Grab

The Grab, designed to pick up cut brush, debris from forestry operations, or any loose material resulting from a vegetation-clearing project, is mounted to the tractor using the Universal Mount. Although operator visibility of the tool is limited when the tool is on the ground, with a minimal amount of experience the operator is able to use the tool with no trouble. As can be seen, lifting capacity, by weight, is sufficient to handle large debris-clearing jobs. No tests, other than the demonstration shown, were conducted.



Figure 29: MCSV with Grab

6.7 4-in-1 Bucket

No tests were conducted with the 4-in-1 Bucket.

6.8 Rotary Mine Comb

The Rotary Mine Comb, designed and built by Pearson Engineering, Ltd., is an adaptation of an old idea for a garden tiller. The two sets of counter-rotating tillers, canted slightly outward, bring mines to the surface and then slowly, and gently, move the mines to the sides of the tiller and deposits them in windrows. Throughout the demonstration, the Rotary Mine Comb handled all vegetation conditions, ranging from dense Category 1 to very heavy Category 3, with ease. The 40 cm operating depth of the cultivating tines removed not only the above ground vegetation, including 15 to 20 ft (4.6 to 6.1 meter) tall trees up to 3 inches (7.6 cm) in diameter, but also dug up the trees' root systems. This tool, without exception, was the best area-proofing and mine-removal tool tested during the MCSV proof of performance. Pictures showing the Rotary Mine Comb in action and the results of its operation are shown in Figure 30.



Figure 30: Rotary Mine Comb Demonstration

During the performance demonstration in heavy Category 2 and Category 3 vegetation, the operator had trouble steering in a straight line with the mine comb pulling the tractor on a gentle curve to the left. If the ground is not level, the Rotary Mine Comb digs more deeply on the low side. This in turn exerts a pull to that side causing the tractor to

follow. To overcome this, Pearson has designed skids which keep both sides of the mine comb at equal depths by following the surface of the ground. At this point in the proof-of-performance demonstration, the skids were installed to control the depth of the mine comb. There were no more problems with the mine comb pulling to either side.

An operational transit problem presented itself and a workable solution was devised. In the full-up position with the Rotary Mine Comb out of the ground and the PTO shaft connected to the Rotary Mine Comb, the Rotary Mine Comb clears the ground by scant inches. When moving from a staging area to a work site over anything other than a flat, smooth surface, the Rotary Mine Comb digs into the ground as the MCSV pitches and sways over the uneven surface. Since the PTO shaft is the limiting link in determining ground clearance in the all-up position, it is recommended that the PTO shaft not be connected until the Rotary Mine Comb is at the work site. This allows additional ground clearance when in the all-up position. When departing a work site, the PTO shaft should be disconnected.

6.9 Magnet

Tests of the magnet were limited to assessing its ability to pick up various sized pieces of ferrous material from a field-grass-covered area and the ease with which the retrieved items could be removed from the magnet. The magnet, a large rare-earth permanent magnet, had no trouble picking up all the ferrous scrap distributed in the test area. There were, however, problems with removal. The face of the magnet is covered with a large sheet of stainless steel. Recovered ferrous scrap, attracted to the magnet through the stainless steel, will adhere to the underside of the stainless steel. In principle, when the stainless steel shield is offset from the magnet, the recovered scrap should be beyond the influence of the magnet and fall to the ground. In fact, only the larger pieces of ferrous scrap broke free by virtue of their own weight. The smaller pieces were still caught in the magnetic field and had to be removed by hand.

6.10 Mine Sifter

The Mine Sifter was the subject of a week-long assessment devoted to training in the use of the sifter, developing an operational procedure in conjunction with other attachments, and determining the sifter's ability to remove AP mines. Mines were surface laid and buried at various depths down to 6 inches (15 cm).

Before using the sifter, the soil was broken up by the MCSV pulling the Soil Loosener. After breaking up the soil, the soil-breaking wedges were removed from the Soil Loosener frame, and two bed-forming v-shaped plow implements attached. The area to be sifted was formed into windrows using the bed-forming v-shaped plows. The design and spacing of the plow attachments allow the wheels of the MCSV and the sifter to ride in the troughs between the windrows, sifting one windrow at a time. The sifter can be set to sift to a maximum depth of 14 inches (35.6 cm). The pros and cons of using this attachment are discussed below.

As a soil-sifting implement, one could not ask for a better tool. Anything larger than the size of a walnut is sifted out of the soil and deposited on top of the sifted soil out the chute

at the rear of the sifter. Experience showed that the sifter was much more efficient when operated at the lower of the PTO speeds (540 rpm vs. 1000 rpm). At a forward speed of 1 mph (1.61 kph), the sifter is capable of sifting 3,033 square yards per hour (2,773 square meters per hour).

There are four drawbacks to using this attachment, one potentially serious, three easily correctable. The serious drawback is that the MCSV would have to drive over a mined area to prepare the soil with the Soil Loosener and Bed Formers prior to using the Mine Sifter. The second drawback involves the rear-facing chute. Because of its width, mines can be deposited in the trough between the sifted windrows and might be covered with a thin layer of soil that slides down the sides of the sifted windrows. This can pose a hazard to deminers who would walk in the troughs looking to recover sifted mines. An easy correction to keep the mines on top of the sifted windrow is to install a choke in the discharge chute, ensuring that the mines are deposited in the center portion of the windrows. The third drawback is that the MCSV operator cannot see what is being deposited by the rear facing discharge chute, and therefore alert waiting deminers of a sifted AP mine. It is thought that an observer using binoculars should be able to spot sifted mines. Finally, SETCO tires with standard hubs, and not the blast-off hubs, have to be used to match the tire track width of the sifter.



Figure 31: Mine Sifter in Operation

6.11 Tree Picker

The Tree Picker, also supplied by Pearson Engineering, Ltd., is a hydraulically actuated attachment that mounts to the MCSV using the standard 3-point hitch on the front of the vehicle. The picker is actuated by two electronically controlled hydraulic feed lines off the MCSV's hydraulic system, mounted one on each side of the 3-point hitch. These operate the left and right power outriggers on the picker as well as the central tree-grabbing mechanism. Limited training on and use of, the tree picker occurred during the assessment. However, the demonstration did include the removal of a 12 inch (30.5 cm) diameter tree well in excess of 60 feet tall.



Figure 32: Tree Picker in Operation

Two operational issues were noticed during the demonstration assessment, which included using pneumatic tires on the MCSV. The first is that the pressure placed on the front tires during the tree extraction process and later by the weight of the extracted tree was sufficient to almost totally collapse the front tires. Therefore, it is recommended that the tree picker be used with the SETCO tires installed on the MCSV. The second is that forward moment caused by the weight of the extracted tree made the MCSV very light on its rear tires. Therefore, any extracted tree should be lifted slowly to make sure that the weight of the tree does not cause the rear wheels to lift off of the ground.

6.12 SETCO Tires

Two blast tests were conducted against the left rear SETCO tire. The two explosive charges used were (1) $\frac{1}{4}$ pound TNT initiated by a small U.S. AP mine, and (2) $\frac{1}{2}$ pound TNT initiated by a small US AP mine. The explosives were buried with the AP mine pressure plate at ground level. The SETCO tires sustained some surface scuffing and localized charring from the blasts. While there was more surface scuffing caused by the $\frac{1}{2}$ pound explosive charge, neither blast area showed significant damage. Given the size and the surface area of the tires, each tire could probably sustain hundreds of such blasts before consideration might be give to changing them.



Figure 33: Blast Test, SETCO Tires

7 OPERATOR FUNCTIONS

Comments on operator function and issues are based on observations and input from operators during and after each tool demonstration.

1. Complexity: Each operator had some experience operating farm and construction equipment. None had experience with the particular model John Deere tractor, and none had experience with the complete range of tools offered with the MCSV. However, no training problems were encountered. Observers saw operator skill in using the various tools increase, particularly with those tools that required some operator control or manipulation while operating the tractor.
2. Operator Environment: (1) The noise level did not pose a problem in communicating with the handset radios during the demonstration. Note, however, that it was not always clear if the MCSV operator heard the radio call or received a visual cue that the test controller was talking into the radio, at which point the operator then activate his radio. It is recommended that a radio set with earphones for the operator be installed and that the operator be instructed to keep his earphones and radio on at all times. (2) There appears to be adequate room for the operator in the cab, but given the manner in which the test was conducted, there was no need for the operator to spend more than 1 hour in the cab at any time, and most in-cab stays lasted less than ½ hour.

There was no opportunity to stress either the air conditioning or heating system. There is some question in one observer's mind whether the air-conditioning system will hold up in 35° to 40° C temperatures given the construction and color of the cab. (3) Positioning of the Hedge Trimmer control column did interfere with the movement of the operator and was removed until the Hedge Trimmer was mounted on the MCSV. (4) A heavy operator (one weighing more than 85 kg) will have trouble using the mechanical cab rotating mechanism to rotate the cab if the MCSV is not on level ground. This will require the operator exiting the cab to complete the rotation by hand.

3. There were no problems with any man-machine interface.
4. Although there were no serious problems with the documentation provided with the system and tools, it was helpful to have a factory representative present to inform the operator of nuances in the system's operation that were not apparent. For example, the representative telling the operator to engage the Economy Drive when using the cultivator to activate the automatic fuel control feature.
5. The need for special training aids was not apparent. All training can take place in a field environment. One week should be sufficient for anyone having some experience with farm or construction equipment.
6. NVESD/HD personnel can handle training. However, it is recommended that a contractor be present for the first training session.

8 OPERATOR REQUIREMENTS/LIMITATIONS/ASSESSMENT/COMMENTS

1. It is recommended that three people be trained to operate the system. While normal operations should use two operators, having the third person allows for adequate coverage should one operator be sick or injured. One week of training should adequately cover training three people, provided they have some farm or construction equipment experience. Two operators will allow for rotating operators every 2 hours. This help to prevent laxity or inattention that can set in when working in a confined area with a constant, above normal, noise level.
2. There were no indications of operator stress caused by performing multiple tasks or by cab environment. However, the longest period of time spent in the cab by one of the operators without a break was 1 hour, and that was on the on-and off-road mobility test.
3. One of the operators, a military man, remained in the cab during one of the blast tests on the area reduction roller. He did admit that the blast was louder than he expected it to be and that it would take a few encounters to get used to the noise.
4. The operator did comment that there is a noticeable difference between the ride with pneumatic and SETCO tires. On rough roads and cross-country travel, the SETCO tire ride is considerably harsher. On the other hand, when operating some of the tools, the

Rotary Mine Comb in particular, the tractor is more stable with SETCO tires due their rigidity.

5. The operator said that it took awhile to judge the location of the Rotary Mower with respect to the ground when mounted in front of the tractor since only one corner of the mower can be seen from the cab. One solution would be to mount the mower in the rear and reverse the cab for mower operations. The issue of increased fuel consumption should be addresses for operating for extended periods in reverse gear. Another solution would be to place wood or metal skids on the sides of the Rotary Mower and then place the mower directly on the ground, letting the skids provide the mower deck ground-standoff clearance.

9 OPERATIONAL CONSUMABLES/LOGISTIC ISSUES

1. Total engine hours logged on MCSV during the 23 to 31 August 2004 proof-of-performance demonstration was 25.1 hours. Total fuel consumed was 76.1 gallons (288 liters). Average fuel consumption was 3.03 gallons (11.5 liters) per hour.
2. No engine oil or hydraulic fluid had to be added.
3. PTO, 3-point mount, and other control-arm grease fittings were checked daily. Air filters in front of engine were checked daily and cleaned, on average, every second day.
4. Since area reduction or site preparation can require the use of more than one tool, having the ability to deliver the additional tools to a working site by trailer, pulled either by the MCSV or another vehicle, can save tool change-out time.
5. If the portable fuel tank is shipped with the MCSV, it would be helpful if the pump on the fuel tank could be reversed so that it could be used to fill the portable tank or drain the MCSV fuel tank if necessary.
6. It appears that one of the first things that will be lost once the equipment is sent to the field will be one of the balls that slides on the mounting pins. Next will be one of the pins. It is suggested that one set of spares be shipped with each tool.
7. Because no tool used was mounted more than three times (rotary mower), and the same people did not participate in each mounting, the times recorded to mount the tools were not considered valid test data. However, even though the time required ranged from as little as three minutes to mount the rotary mower, four minutes for the roller, and five minutes for the Rotary Mine Comb, at no time was the mounting time thought to be excessive. While the operator can make most 3-point attachments, some of the tools are more easily attached with assistance from one person on the ground.
8. During the morning inspection and servicing of the tractor, evidence of a fuel leak, in the form of a small pool of fuel, was found under the vehicle in the location of the fuel

tank. Its presence was pointed out to the Pearson factory representative, who informed us that it was, in fact, a fuel tank leak and that he knew the source of the leak. During manufacture of the fuel tank, stud holes were placed in the bottom of the tank to accommodate structural mounting. A redesign did away with the need for these holes and they were welded shut. Pearson experienced leaking from some of the welded holes before shipping the tractor and attempted to seal the holes with a commercial fuel tank leak sealer. The MCSV test engineer made the decision that there would be no more testing until the fuel leak was resolved. The following steps were followed in the repair procedure.

- a. Fuel tank completely drained.
 - b. Disconnected all vehicle electronics (five different systems) which required removal of the driver's seat to access the electronic control connectors.
 - c. Removed the skid plate covering the bottom of fuel tank.
 - d. Cleaned bottom of the fuel tank to remove rust, dirt and excess weld slag from the factory repair.
 - e. Purged fuel tank with argon gas and maintained positive argon pressure while all stud holes were rewelded (arc welded).
 - f. Refilled fuel tank and checked for leakage.
 - g. Lapsed time for the repair was 8 hours, with one to three people working at all times.
9. It was noticed during the inspection of the MCSV, after the on- and off-road mobility trials, that the wheel lugs on the rear SETCO tires had worked loose. The lugs nuts were tightened and the trials made with the heavy cultivator. Inspection of the lug nuts showed that they had again become loose, some as many as three and four complete turns of the nut. The nuts were again tightened, using a large breaker bar with a 4-foot extension pipe. The lug bolts were marked and checked three to four times a day for the remainder of the demonstration. There was no further loosening of the lug nuts. See Figure 34. The offset of the black lines on the stud and lug nut indicates a loose lug nut. As can be seen, the bottom lug nut has backed-off at least three full turns.



Figure 34: Loosening Lug Nuts

10 MAINTENANCE/SUPPORT AND TEST EQUIPMENT/SUPPLY/FACILITIES (TO INCLUDE PACKAGING, HANDLING, AND STORAGE)

10.1 Changing Tires

Changing of the rear SETCO tires requires some means of lifting the tires and two to three strong men to position them on the axle. During the proof of performance demonstration, a forklift was used to lift the tire into position. See Figure 35.



Figure 35: Mounting SETCO Rear Tires

10.2 Support and Test Equipment

A shop-set of mechanic's hand tools and special tools will be shipped with the MCSV. A complete list of the tools procured for shipment with the MCSV is presented in the

Appendix. In addition, a complete set of manufacturer’s operator and maintenance manuals will be included.

10.3 Facilities

If there are existing maintenance and training facilities similar to those used for construction, farming, or road grading equipment, they will satisfy the requirements for the MCSV. Equipment to lift heavy pieces of equipment (chain fall, small crane, fork lift, etc.) is necessary. A roof-covered maintenance area is desired. Some form of security is also necessary for the tools and equipment.

11 SYSTEM SAFETY

While AP mine blast tests were conducted against the SETCO tires and the Area Reduction Roller, ITEP recommended blast tests against a 0.56 kg (TNT) bounding fragmentation mine at 2 meters was not conducted.

12 TRANSPORTATION AND TRANSPORTABILITY (TO BE DONE AT BELVOIR-SHOP/OFFICE)

For overseas or long-distance in-country shipment, the MCSV tools and attachments will be loaded into two, 40 foot long CONEX containers according to the loading plan shown in Figure 36. The tractor will be driven into or onto a ship, flatbed rail car, or flatbed trailer and chained in place for shipment.

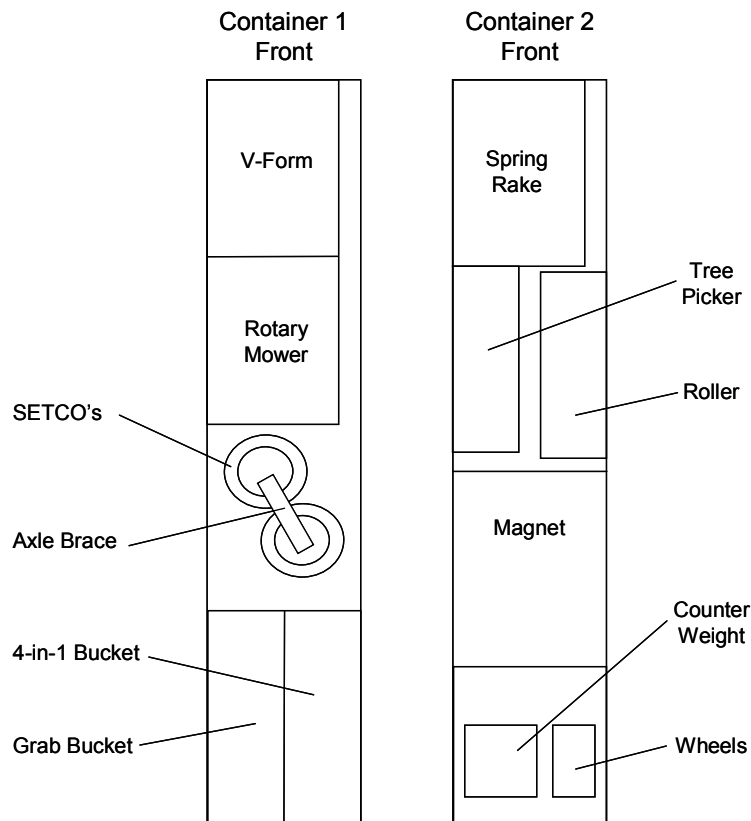


Figure 36: MCSV Load Plan: Two 40-foot Containers

13 MANPOWER/PERSONNEL/TRAINING

Based on comments from the operators during the test program, if any continued use of the MCSV is contemplated, it is recommended that 3 operators be trained. One or two mechanics trained to maintain heavy construction equipment and diesel engines will be adequate.

14 BLAST TESTS

The Area Reduction Roller was subjected to blast tests from three AP mine explosive equivalents. The SETCO tires were subjected to blast test from 2 AP mine explosive equivalents. The armored John Deere tractor was blast tested by Pearson Engineering, Ltd. Copies of this report can be requested from Pearson Engineering, Ltd., in care of Mr. Eric Reed at pearson@pearson-eng.com.

15 SUMMARY OF PERFORMANCE DEMONSTRATION

The overall assessment of the performance demonstration is that the MCSV and the tools tested are ready for deployment to humanitarian demining organizations and government centers for use, with selection of the proper tool, as a system for:

- Area reduction
- Area preparation tool for demining
- Demining
- Vegetation debris removal
- Land reclamation preparation

The prime mover, a commercial John Deere 6920 tractor, has a proven history of reliability and is supported by a worldwide network of commercial dealer organizations. The tools are off-the-shelf and commercially available, with spare parts support direct from manufacturers and dealers. During the performance demonstration, there was not a single unscheduled maintenance incident on either the tractor or any of the tools. The one repair to the tractor, the fuel tank leak, was caused by a change in design during manufacturing and resulted in the rework of a single item. The need for this rework will not be necessary on subsequent vehicles, thus eliminating the possibility of it happening again. The shearing of the PTO universal joint was the result of inexperience with the system and the tool.

Operator, vehicle, and tool safety and survivability were satisfactorily demonstrated against a large AP mine blast. While the Rotary Mine Comb can be used for AT demining, no AT blast test were conducted during these trials. Pearson Engineering, Ltd., has conducted blast tests against the armored John Deere tractor, and the results of the test can be obtained directly from the manufacturer.

In summary, NVESD/HD program is confident that the MCSV and its associated tool kit, when used as intended, will provide the humanitarian demining community with a highly reliable, cost efficient system to augment their current catalogs of demining tools and expand their area reduction and demining capabilities.

GLOSSARY

A/C	air conditioner
AP	anti-personnel
AT	anti-tank
cm	centimeter
COTS	commercial off-the-shelf
ft	feet
HD	humanitarian demining
IDA	Institute for Defense Analyses
in.	inch
ITEP	International Test and Evaluation Program
kg	kilogram
km	kilometer
kph	kilometers per hour
lb	pound
m	meter
MCSV	Mine Clearing/Survivable Vehicle
mm	millimeter
mph	miles per hour
MRM	mechanical reproduction mine
NVESD	Night Vision and Electronic Sensors Directorate
POC	point of contact
PTO	Power take off
RMC	Rotary Mine Comb
RPM	revolutions per minute
TNT	trinitrotoluene

APPENDIX
MCSV TOOL ORDER

APPENDIX
MCSV TOOL ORDER

Order From Grainger Industrial Supply

Item Description	Quantity	Part #	Price Each (\$)	Total (\$)
7–27 mm Combination Wrench Set, 17 pieces	1	4PL91	47.50	47.50
25–32 mm Combination Wrench Set, 6 pieces	1	4PM12	47.50	47.50
3/4" Drive Socket Set, 21 pieces	1	4YP83	211.25	211.25
1/2" Drive, 16" Breaker Bar	1	5MR52	35.10	35.10
Crescent Wrench, max opening 1.5"	1	6X317	23.16	23.16
Crescent Wrench, max opening 2.0625"	1	2A490	71.85	71.85
Tool Box	2	5HM80	34.15	68.30
Strap Wrench, 2" diameter capacity	1	4A505	26.05	26.05
Strap Wrench, 5" diameter capacity	1	4CW49	52.85	52.85
Slip Joint Plier Set of 2	1	4PL95	9.46	9.46
Channel Lock Set of 2	1	4PL96-A	16.52	16.52
3 lb Sledge Hammer, 16" handle	1	4YR67	11.57	11.57
12 lb Sledge Hammer, 36" handle	1	5ML26	24.31	24.31
Pry Bar Set, 4 pieces	1	4PM09	31.65	31.65
51" Pinch point bar	1	3FE95	26.65	26.65
Work Bin	1	1RG71	59.95	59.95
Grease Gun	2	4BY81	30.00	60.00
Grease	12	4ZF44	2.44	29.28
Digital Multimeter	1	4KD96	29.00	29.00
Funnel, plastic, 36 ounce, Extra long neck	2	4ZH72	2.54	5.08
Steel Funnel, 1 quart, Flexible neck	2	4F391	6.23	12.46
Plastic Funnel, 6 quart	1	6Y805	6.69	6.69
Flashlight	2	2V620	4.71	9.42
Batteries for flashlight. D Cell, pack of 12	1	4WT07	11.30	11.30
Work Gloves	20	5JK50	0.67	13.40
1/2" Drill, DeWalt	1	4LF73	109.00	109.00
Drill Bit Set	1	4GB66	62.95	62.95
Tape Rule, 25 ft	2	3TB93	13.05	26.10
Caliper, Digital	1	4LB11	35.99	35.99

Item Description	Quantity	Part #	Price Each (\$)	Total (\$)
Miller Bobcat 250 Welder	1	4TY29	3349.00	3349.00
Welding Accessory Kit, Welding Leads	1	1EC88	138.50	138.50
Welding Rod, 1/8 7018	4	2C040	19.67	78.68
Welding Rod, 5/32 7018	4	2C042	19.24	76.96
Cutting Rod, 1/8"	2	2CO96	37.15	74.30
Welding Helmet, auto. Dark.	1	5ZF83	159.50	159.50
Welding Helmet	1	4T542	35.60	35.60
Welding Glove	2	3AJ33	9.95	19.90
Welding Jacket	1	2AG83	64.30	64.30
Welding Hammer	1	5LD33	19.62	19.62
Plastic 5 gallon Gas Can	2	3BE11	8.31	16.62
Air Compressor. IR Gas Powered, 5.5 HP	1	4YW08	799.00	799.00
1/2" Drive Impact, Wrench	1	5ZL17	102.50	102.50
1/2" Drive Impact, Socket Set, 10 pieces, Deep Well	1	4JX20	81.80	81.80
1/2" Drive Impact, Socket Set, 15 pieces	1	4JX18	82.85	82.85
3/4" Drive Impact, Wrench IR	1	6W380	399.00	399.00
Air Ratchet, 3/8"	1	5ZL11	46.20	46.20
Air Blow Gun	1	2X492	7.68	7.68
Air Tool Oil, 1 quart	1	4ZF22	4.78	4.78
1/4" coupler, air hose (F)	4	6CX02	5.93	23.72
1/4" coupler, air hose (M)	10	2X169	1.01	10.10
Coupler, 1/4" 3/8 M NPT	1	4X793	5.18	5.18
Compressor start up kit, lubricants	1	5ZL97	49.95	49.95
Teflon Tape	3	3AB55	0.36	1.08
Air Hose, 3/8", 50 ft	2	6Z788	22.99	45.98
50 ft. Extension Cord, 12 Gauge	2	3EB10	38.70	77.40
Angle Grinder, DeWalt, 4.5"	1	3MJ25	61.95	61.95
4-1/2" Grinding Wheels, DeWalt	10	4WM67	2.29	22.90
16' Booster Cables, AWG 4	1	3UY43	36.10	36.10
			Total =	7065.49

