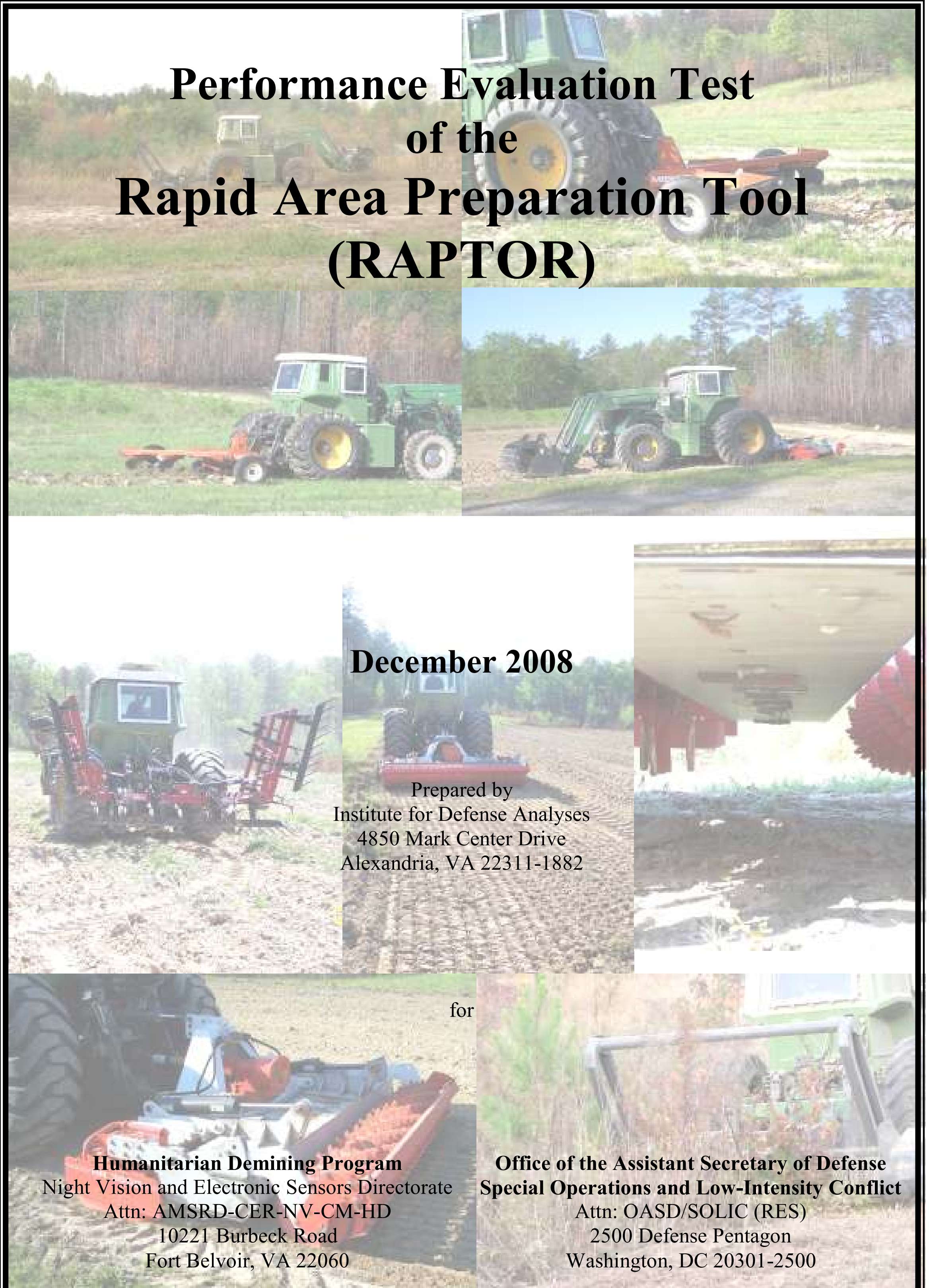

Performance Evaluation Test of the Rapid Area Preparation Tool (RAPTOR)

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PREFACE

In October 2007 and May 2008, the U.S. Humanitarian Demining Research and Development Program (HD), located at Ft. Belvoir, VA., undertook the testing of the Rapid Area Preparation Tool (RAPTOR). RAPTOR is the latest of a series of area-preparation systems on tractor platforms that HD has developed in the last decade. Systems, including the Severe Duty Tractor and Tools (SDTT) and Mantis, have undergone operational evaluations in Thailand, Nicaragua, and Afghanistan. The RAPTOR was developed by the HD program to handle all area-preparation tasks from vegetation cutting and removal (up to Category 3), to antipersonnel mine rolling, plowing, and cultivating, to metal clutter removal (false alarm reduction). A suite of area preparation attachments on a mine-protected platform, provide versatility and adaptation to the task and environment. In addition, capabilities for neutralization of surface-laid mines and removal of metal clutter have potential to speed mine-clearance operations.

The test assessed the performance of the vegetation-clearance, soil-preparation, and clutter-reduction attachments and the performance of the Fendt Model 918 tractor as RAPTOR's prime mover. Through the course of the testing, the Loftness vegetation cutter, the Krause 4830 chisel plow, the Miskin parabolic subsoiler, the Unverferth spring cultivator, the Army-fabricated Power Harrow with Magnet, and SETCO Jelly Belly AP mine-blast resistant tires were evaluated. Testing at a U.S. Army facility began in October 2007 with vegetation cutting and plowing, but when the ground became too wet for the tractor to operate the plows, the test was suspended until spring. Testing resumed in May 2008 with soil preparation, clutter reduction, and the SETCO Jelly Belly tires, which are designed to perform better in loose and wet soil.

The test was directed by project engineer Michael Collins of Fibertek, Inc, and project lead Ronald Collins. The equipment operator was William Collins. Test site staff members John Snellings and Arthur Limerick provided test site logistical support. Photography support was provided by Tanekwa Bournes of the Camber Corporation. Technical test support, data collection and analysis, and writing of this report were accomplished by Harold Bertrand and Jennifer Soult from the Institute for Defense Analyses (IDA). Technical editing was provided by Tom Milani of IDA and Sarah Heaton of Fibertek.

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1 Test Purpose and Background

The purpose of this test is to assess the performance of the Rapid Area Preparation Tool (RAPTOR). The RAPTOR is designed to address some of the vegetation-clearing, soil-preparation, and mine removal and neutralization problems associated with humanitarian demining.

The test was conducted in two segments. In the first, vegetation-clearing testing was conducted at Test Site A in October 2007. Soil preparation testing with in-ground tools was also begun at Test Site B, but testing was cut short by rain and eventually postponed until spring 2008. In May 2008, soil preparation testing resumed with the solid-soft-core SETCO Jelly Belly tires at Test Site A.

2 System Description

The objective of the RAPTOR program is to provide area-preparation and mine-clearance capability on a mine-survivable vehicle. Figure 1 shows the RAPTOR, a modified and armored Fendt 918 farm tractor capable of operating a number of specialized and off-the-shelf commercial attachments to address challenges when performing vegetation clearance, soil preparation, area reduction, mine removal and neutralization, and quality assurance during humanitarian demining.

RAPTOR is designed for efficient and versatile demining operations. The Fendt 918 tractor was selected because it was the only one of its size that had a reversible operator station, an ideal feature for varied demining operations. The system is equipped with front and rear power take-offs (PTOs) and three-point hitches, as well as a loader frame. The commercial cab, fitted with reversible operator station, has been replaced with an armor-plated cab with armored glass and Lexan polycarbonate windows fabricated by the U.S. Army Night Vision and Electronics Sensors Directorate (NVESD) shop at Fort Belvoir, VA. In addition, the tractor is fitted with solid rubber antipersonnel-mine-survivable SETCO Jelly Belly tires. In HD's technology development program, SETCO tires are standard on wheeled vehicles that enter mine-suspect areas with an operator in the cab. A set of tires with softer internal material composition to enhance outer casing flexure (promotes shedding, the self-cleaning ability of tire tread) were evaluated. Table 1 gives the RAPTOR specifications.

Figure 1: Rapid Area Preparation Tool (RAPTOR)

Table 1: Fendt 918 Tractor Specifications

Fendt 918 Tractor	**Measurement / Dimension**
Engine	119 kW / 160 hp
Max height, to top of cab	10.15 ft / 3,095 mm
Min working clearances under axles	1.98 ft / 605 mm
Max width	8.17 ft / 2,490 mm
Max length	16.2 ft / 4,938 mm
Max shipping weight	33,520 lb / 15,204 kg
Fuel capacity	530 L
Oil capacity	24 L
Hydraulic fluid capacity	65 L

The current toolbox of attachments includes a grapnel bucket, utility bucket, rock bucket, Loftness vegetation cutter, Krause 4830 chisel plow, Miskin parabolic subsoiler plow, Unverferth cultivator, power harrow with magnet, and an area-reduction roller. The roller, grapnel bucket, utility bucket, and rock bucket were not tested. All attachments but two are commercially available. The power harrow with magnet and the roller were designed by project engineer Michael Collins and produced at the NVESD shop. The segmented area reduction roller is a unique full width mine roller. The roller is divided into six shafts of rolling disks that pivot as the roller travels over varying terrain. The roller can either be pushed or pulled as dictated by the users demining SOP. Figures 2–10 are images of each attachment; Tables 2–10 give specifications for select tools provided in the figures.

Figure 2: Loftness Vegetation Cutter

Table 2: Loftness Vegetation Cutter Specifications

Item	**Measurement / Dimension**
Width	117 in / 2,972 mm
Cutter fielded weight	4,980 lb / 2,259 kg
Width of cut	93 in / 2,362 mm
Number of knives	20

Figure 3: Krause 4830 Chisel Plow

Table 3: Krause 4830 Chisel Plow Specifications

Krause Chisel (Ripper) Plow 4830-730F	Measurement / Dimension
Number of shanks	7
Spacing between rows	30 in / 14.2 cm
Swath width	232 in / 91.3 cm
Spring reset shank shipping Weight	5,364 lb / 2,438 kg
Transport width	138 in / 350.5 cm
Transport depth	93 in / 236 cm

Figure 4: Miskin Parabolic Subsoiler Plow

Table 4: Miskin Parabolic Subsoiler (Model S207) Specifications

Miskin Parabolic Subsoiler	Measurement / Dimension
Number of shanks	7
Spacing	20 in / 7.9 cm
Shank height (point to frame)	32 in / 12.6 cm
Plow shipping weight	2,068 lb / 940 kg
Width	11 ft 8 in / 3.55 m

Figure 5: Unverferth Spring Cultivator Being Extended

Table 5: Unverferth Spring Cultivator Specifications

Unverferth Spring Cultivator	**Measurement / Dimension**
Width (collapsed)	150 in / 3,810 mm
Width (extended)	240 in / 6,096 mm
Folded height	87 in / 2,210 mm
Cultivator fielded weight	2,545 lb / 1,154.4 kg
Number of S-tines	37
Number of leveling bar teeth	40

Figure 6: Power Harrow with Magnet

Table 6: Power Harrow with Magnet Specifications

Power Harrow with Magnet	**Measurement / Dimension**
Width	10.1 ft / 3,087 mm
Number of two-bladed harrow tines	121.5 in / 10
Distance between harrow tines axis	11.8 in / 300 mm
Weight—harrow and magnet	8,300 lb / 3,765 kg
Weight—magnet installation	5,666 lb / 2,571 kg

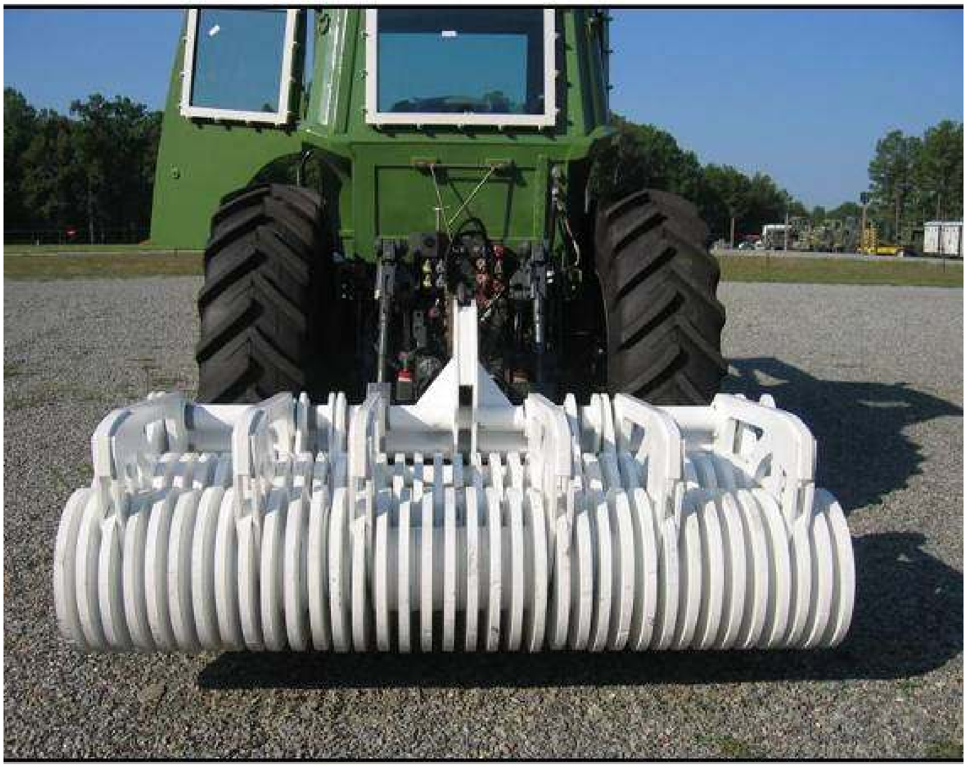

Figure 7: Segmented Area Reduction Roller

Table 7: Segmented Area Reduction Roller Specifications

Area Reduction Roller	Measurement / Dimension
Width	10.5 ft / 3,200 mm
Weight	12,600 lb / 5,715 kg

Figure 8: Quicke Grapnel Bucket

Table 8: Quicke Grapnel Bucket (Model HD) Specification

Quicke Grapnel Bucket	**Measurement / Dimension**
Weight	1,215 lb / 655 kg
Width	79 in / 200 cm
Depth	31.5 in / 80 cm
Volume	40 ft^3 / 1.14 m^3

Figure 9: Quicke Utility Bucket

Table 9: Quicke HD Utility Bucket Specifications

Quicke Utility Bucket	Measurement / Dimension
Weight	520 lb / 235 kg
Width	73 in / 185 cm
Depth	31.9 in / 81 cm
Volume	25.8 ft^3 / .72 m^3

Figure 10: Quicke Rock Bucket (Stone Fork, Model 180)

Table 10: Quicke Rock Bucket (Stone Fork, Model 180) Specifications

Quicke Stone Fork	**Measurement / Dimension**
Weight	630 lb / 286 kg
Width	74.8 in / 2.0 m
Depth	39.4 in / 1.0 m
Height	29 in / 73 cm
Number of times	18

3 Test Site Description

The performance of the RAPTOR and its attachments was evaluated at two test sites at a U.S Army test facility. Test Site A is an area of flat meadowland of Category 1 and 2 vegetation and treed hillsides of Category 3 and 4 vegetation. Test Site A was used in October 2007 to assess the Loftness vegetation cutter and Krause chisel plow and in May 2008 to assess the in-ground soil-preparation tools (Miskin parabolic sub-soiler and the Unverferth spring cultivator), the power harrow with magnet, and the SETCO tires.

Test Site B is a large meadow of gentle rolling terrain covered mostly with Category 1 vegetation. Test Site B was used in October 2007 to test the standard solid SETCO tires with the Miskin chisel plow and Unverferth spring cultivator. Tests of the power harrow with magnet were also conducted in a sand lane at the main test facility.

3.1 Test Site A

Test Site A consists of both Category 1 vegetation on level terrain and Category 3 vegetation over gently rolling terrain. Table 11 describes the four categories of vegetation, and Figures 11 and 12 provide images of Test Site A.

Table 11: 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 11: Test Site A (Category 3)

Figure 12: Test Site A (Category 1)

3.2 Test Site B

Test Site B is a 100 m × 50 m area with little vegetation over flat to gently rolling terrain. The soil contains root systems within a sandy loam soil. Figures 13 and 14 show images of Test Site B.

Figure 13: Test Site B

Figure 14: Test Site B

4 System Testing

Performance testing of the RAPTOR included testing the Loftness vegetation cutter, the Miskin parabolic subsoiler and the Krause chisel plow, the Unverferth spring cultivator, and the power harrow with magnet. The RAPTOR is designed to fill a number of roles in demining operations, including area reduction, area preparation, and quality assurance. In an unpatterned AP minefield with light to difficult vegetation, rolling terrain and sandy, loamy soil, it is recommended that the vegetation cutter, plow, spring cultivator, and power harrow with magnet be used in the order given. By first using the vegetation cutter, the amount of vegetation present in an area is reduced to mulched debris. The parabolic subsoiler plow is then used to provide the initial breakup and loosening of the soil. Follow-up with the spring cultivator provides further soil loosening. The final step, using the power harrow with magnet to turn the soil and attract any accessible metal objects to the magnet, greatly reduces the number of false alarms encountered by deminers. In a humanitarian demining context, the RAPTOR's area-preparation operations (as evaluated in this test) may be followed by mine detection or soil sifting or grinding. Although it was not evaluated during this test, the area-reduction roller should be used initially to detonate any surface-laid mines.

4.1 Loftness Vegetation Cutter

The Loftness vegetation cutter, shown in Figure 15 attached to the rear of the RAPTOR, is best operated at a forward speed of 1.5–3 kph. Operating speed depends on terrain (e.g., flat, rolling, etc.) and the category of vegetation being cut, where Category 1 vegetation allows for faster forward-moving speeds and Category 3–4 requires slower forward movement. For Category 3–4 vegetation cutting, it is recommended that the

RAPTOR's cruise control be used to ensure that vehicle speed and PTO rpm are maintained so that as much vegetation as possible is cut and mulched on one pass.

Figure 15: Loftness Vegetation Cutter

October 2007 Vegetation Cutting: A timed cutting test was conducted at Test Site A for a period of 1 hour. The area cut was primarily Category 2–3 vegetation with a few Category 4 trees. The area cut was at the bottom end of a small hill. The soil composition was sandy loam with a covering of leaf and pine needle compost. The total area cut in one hour was 1,440 m^2. Figure 16 shows the layout of the area cut.

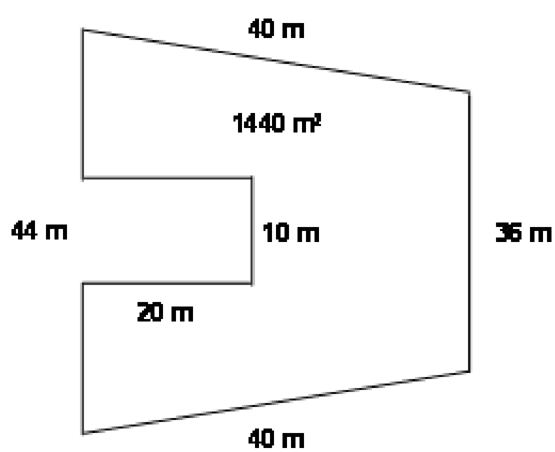

Figure 16: Configuration of Cut Area

The cutter was attached to the rear PTO, but the operator's station was reversed so that the cutter was "carried" in front of the vehicle's path during operations. Except for the cutter and roller, all of RAPTOR's attachments are pulled behind the vehicle. For the vegetation cutter, the first step was to determine how much ground clearance was needed to avoid ground scalping during cutting operations. The first pass of the cutter over Category 1–2 vegetation (at the bottom of Figure 11) left a debris layer measuring 3–4 in. (7.5–10 cm) above the ground. A subsequent pass (performed in the opposite direction to that of the first pass) further reduced the debris and brush height to about 2 in. (5 cm). At times, small trees cut during the first pass of the vegetation cutter fell onto the ground parallel to the cutting track and were not further cut or mulched during the second pass of the cutter because of the ground-clearance allowance. (See the result in Figure 17.)

In a few areas where ground scalping did occur, the cutter generated a cloud of dust around the equipment that led to concerns of impaired visibility for the vehicle operator, although the operator said that he could see well enough to maintain his track through the dust cloud. In dusty conditions it is recommended that the vehicle's air filters be checked and possibly cleaned on a more frequent basis.

Figure 17: Debris Remaining after Vegetation Cutting

4.2 Krause 4830-730F In-line Ripper (Chisel Plow)

A plowing test of the Krause 4839-730F in-line ripper (chisel plow) was conducted at Test Site B in October 2007. Soil is sandy loam and was slightly damp. The test field had been plowed in the summer of 2006, so the field grass and its root system had a year, with excellent rainfall, to reestablish itself. The test site measured 48 m by 82 m for a total of 3,936 m^2 (42,366 ft^2).

The test proceeded with relatively few problems, and those that occurred were associated with slowing of the tractor, equipped with Jelly-Belly SETCO tires, due to root drag on the plow. In a couple of instances, the tractor wheels lost traction and started to spin. This was corrected by raising the plow to allow the tractor to regain traction, reinserting the plow, and continuing the plowing. Multiple plowing passes were made to ensure that all the soil had been turned and was ready to be worked by the cultivator. Total plowing time was 74 minutes for 3,936 m^2, a plowing rate of 3,191 m^2 per hour.

4.3 Miskin Parabolic Subsoiler Plow

According to the manufacturer, "the Subsoiler frame…is angled back 45 degrees so that it requires less horsepower and fuel, and allows travel at a faster speed. The first parabolic shank cracks and lifts the ground. The second shanks break up the ground partly cracked by the first shank. The third shanks break up the ground that was cracked by the second shanks, and so on." Before operations, the height of the plow's tires is adjusted to ensure optimal ground-engaging depth of the digging shanks. This adjustment took approximately 7 minutes to complete and was set to give a shank digging depth of approximately 12 in. Images of the adjustment are shown in Figures 18 and 19.

Figure 18: Height Adjustment, Miskin Subsoiler

Figure 19: Height Adjustment, Miskin Subsoiler

Plowing depth was set by driving the RAPTOR forward to force the plow shanks to engage the soil until the depth wheels rode on the ground (see Figure 20).

Figure 20: Operating Position, Miskin Parabolic Subsoiler

During the May 2008 testing of the Miskin parabolic subsoiler, plowing was conducted on a 5,000 m^2 field. In four instances, shank shear bolts (grade 5 bolts) sheared as a result of encounters with tree roots or stones. Although each replacement took less than 5 minutes, the break in plowing momentum added to the required operational time. Determining that a bolt had sheared was obvious, as the affected shank swung up out of the ground and dragged along the surface. Replacement shear bolts had a higher shear strength rating (grade 6) than the original bolts, and no replacement bolts sheared during the test.

Root entanglement occurred in areas of the test site where trees had been cut in previous tests and thick root systems still remained in the soil. Evidence of root entanglement included visual detection of roots being dragged by the plow and, in a couple of instances, when the RAPTOR was brought to a complete stop and the tractor wheels spun. Serious root encounters were cleared by lifting the subsoiler clear of the ground and restarting the plowing process.

In total, the 5,000 m^2 area was plowed in 116 minutes. This time includes two full passes of the plow over the test area and does not include any stopped times for replacing shear bolts or freeing the plow from roots. The resulting plowing rate is 2,586.2 m^2/hr. Figures 21–23 are images of plowing operations.

Figure 21: Miskin Subsoiler Operations

Figure 22: Miskin Subsoiler Operations

Figure 23: Ground After Plowing Operations, Miskin Subsoiler

4.4 Unverferth Spring Cultivator

The Unverferth cultivator has two hydraulically operated hinge points that allow the cultivator to be transported with a reduced width (see Figures 24–26). The cultivation configuration has the sides fully extended, allowing each tine to contact the ground.

Figure 24: Unverferth Cultivation, Closed Fully

Figure 25: Unverferth Cultivation, Partly Open

Figure 26: Unverferth Cultivator, Fully Open

Testing of the cultivator was conducted in Test Site A after the completion of plowing operations with the parabolic subsoiler. The parabolic subsoiler left the soil well plowed, and there were no bogging or other operational issues during cultivation. The cultivator completed two passes of the 5,000 m^2 in 37 minutes, for a cultivating rate of 8108.1 m^2/hr. Figure 27 is an image of the ground after cultivating operations.

Figure 27: Ground After Cultivation, Unverferth Cultivator

4.5 Power Harrow with Magnet

The power harrow with magnet concept was conceived and designed by Michael Collins, an engineer with Fibertek, Inc., and manufactured and assembled in NVESD's machine shop. The requirement was derived from the demining community's need for technology capable of removing buried debris/clutter from mined areas. The methods currently used (by hand) are slow and laborious. This technology has demonstrated a process for assisting demining teams in reducing false alarm detection rates thus expediting the quality assurance process.

The design started with a commercial power harrow (Kuhn, Model HR 3000) with trailing soil roller. The power harrow and roller were separated, and a 3,680 lb (1,672 kg) rare-earth magnet was installed between the two (see Figure 28). The magnet is housed in a 3/16 in. (4.7 mm) thick stainless steel pan. The harrow loosens the soil ahead of the magnet, and the clutter (ferrous metals) is gathered on the lower face of the stainless steel pan. The metal can be released by activating 2 hydraulic cylinders and pivoting the magnet out of the pan. The success of this idea is borne out by the test results reported below.

However, before testing with the harrow with magnet could begin, the optimal spinning speed for the ground-engaging harrow tines located ahead of the magnet (see Figure 28), the optimal vehicle forward speed, and the optimal magnet-to-ground clearance had to be determined. Adjustment of the harrow tines is achieved by adjusting the rpm of the PTO. In preliminary tests in the test facility's sand lanes, it was noted that slowly spinning tines do not turn the soil well enough to expose a maximum amount of soil/buried metal to the magnet, but tines spinning too fast throw dirt, resulting in contact issues between metal objects and the magnet. Taking these issues into account, the tine spinning speed was eventually set at about 220 rpm (about 880 rpm for the PTO), forward vehicle movement was kept around 0.5 miles per hour, and the magnet-to-ground clearance height was 12.5–15 cm (5–6 in).

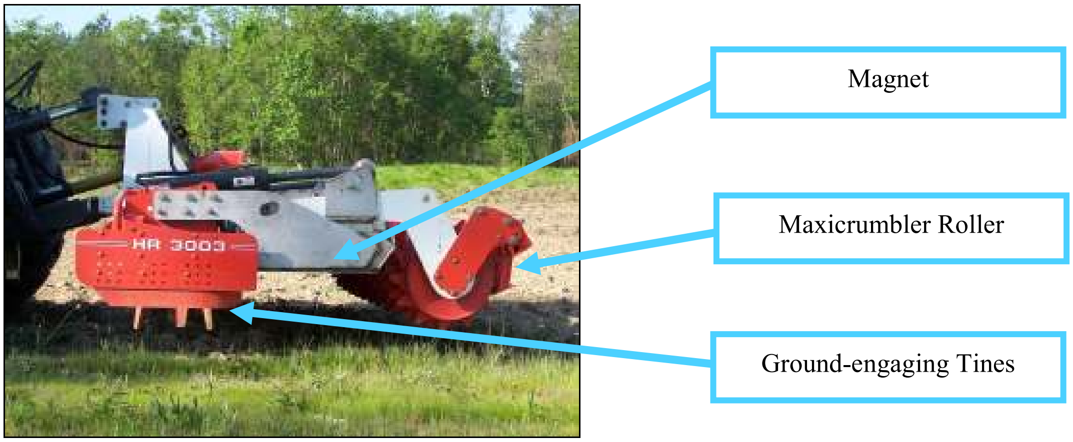

Figure 28: Power Harrow with Magnet

Once the harrow and vehicle speeds were established, testing began in the plowed and cultivated test area at Test Site A. Pulling the harrow/magnet, the RAPTOR moved in straight lines down the test area, periodically dumping any collected metal at the test area boundaries.

Figure 29 shows various metal objects (three steel plates, five metal bolts, two spikes), that were placed randomly on the surface or up to two inches below the surface of the soil in the test area in front of the RAPTOR's path to gauge the effectiveness of the harrow/magnet. After one emplacement of these items, all items recovered. In a second emplacement, all items except two bolts and one spike were recovered. Additional metal pieces were recovered from the test area. Before becoming a military installation, the test site was a privately owned farm and has since been used for training and testing. Additional metal recovered was mostly corroded metal scrap and objects that ranged in size from a few millimeters to several centimeters. One pass of the power harrow with magnet over the 5000 m^2 test area removed 402 pieces of metal clutter from the ground (see Figure 30). The test was completed in 158 minutes, a clearance rate of 1,898.7 m^2/hr. Figures 31–34 are images of harrow/magnet operations.

Figure 29: Recovered Metal

Figure 30: Emplaced Metal Objects

Figure 31: Power Harrow with Magnet Operations

Figure 32: Power Harrow with Magnet Operations

Figure 33: Metal Attracted to Magnet

Figure 34: Ground After Harrow/Magnet Operations

4.6 SETCO Jelly Belly Tires

While SETCO's standard solid-rubber, antipersonnel-mine-blast-resistant tires have proven to be a great asset to HD's vehicle systems, they have limited utility on a vehicle that requires good traction to pull in-ground soil-preparation tools. Because the rubber of the standard SETCO solid-core tires is so firm, they do not deflect as a pneumatic tire does to induce self-cleaning or dirt/mud shedding. In HD's experience, standard SETCO tire treads can fill with soil and mud, resulting in loss of traction. At the request of HD project engineer Michael Collins, SETCO designed and fabricated a set of Jelly Belly tires whose inner core is of a softer rubber that allows some flexing of the outer tire casing to induce self-cleaning.

Although no specific test was conducted to evaluate the self-cleaning aspects of the new tire design, the mobility of the RAPTOR was monitored throughout the test. The only incident of the Jelly Belly tires losing traction was the result of the parabolic subsoiler encountering a snarl of tree roots that the RAPTOR could not break. There was no indication that soil buildup in the tire treads contributed to the loss of traction in the incident. Overall, the Jelly Belly tires and their treads appeared to be self-cleaning, an improvement over the standard SETCO tires.

A blast test of the new SETCO tire is scheduled for the spring of 2009.

5 Conclusion

Throughout the total test program, all tools performed as well as or better than expected. The vegetation cutter, which has been in use by HD since late 2006, is very powerful and capable of thoroughly mulching Category 3 vegetation. The succession of plows tested broke up the hard ground well. The HD-designed power harrow with magnet worked as intended and has the potential to dramatically reduce metal clutter. Significant improvement in tractor mobility was observed with the SETCO Jelly Belly tires. The new composition allowed the treads to flex and shed accumulated soil as a pneumatic tire does. The soft, solid-core SETCO tires perform better than previously tested models.

There were no operational limitations encountered during the test that require a cautionary advisory being included in this report. Evident limitations for the RAPTOR tractor and current toolbox of attachments include severe vegetation, steep terrain, and very rocky soil.

Equipment reliability was outstanding, with the only unscheduled maintenance being replacement of the sheared parabolic subsoiler shear bolts. The shearing was corrected by using a bolt with a slightly higher shear rating. The RAPTOR Fendt 918 tractor and the commercially available tools in this test are supported worldwide by dealer networks. Table 12 gives the operational performance of each tool, as well as a calculation of the time required to process 5,000 m^2 in conditions like those of the test.

Table 12: Summary of RAPTOR Area Preparation Tools Performance

Tool Tested	Tool Performance	Time to Process 5,000 m^2
Loftness vegetation cutter, Cat. 2-3	1,440 m^2/hr	3.47 hr
Krause In-Line Ripper (Chisel Plow)	3,191 m^2/hr	1.57 hr
Miskin parabolic subsoiler	2,586 m^2/hr	1.93 hr*
Unverferth spring cultivator	8,108 m^2/hr	0.62 hr
Harrow/magnet soil processing	1,898 m^2/hr	2.63 hr
Harrow/magnet metal retrieval	402 pieces	---
Total time to area prep 5,000 m^2	---	**8.29 hr**

*Not included in total.

The RAPTOR tool kit also includes a utility bucket, a grapnel bucket, and a stone bucket. These tools would be used to remove debris from an area before manual demining begins. Since these are common construction-type tools, there was no need to test or demonstrate their functions during this program. The HD-designed roller was not tested because it was infeasible to recreate the required minefield conditions at the test facility. An operational field evaluation of the RAPTOR will provide a full assessment of the suite of attachments, including the roller.

Finally, Table 13 gives some additional data taken throughout this test on the RAPTOR and its attachments.

Table 13: Time and Speed Measurements

Description	Measurement
Time to attach/detach Miskin parabolic subsoiler	3.0 / 4.0 minutes
Time to attach/detach Unverferth cultivator	2.0 / 4.0 minutes
Time to attach/detach harrow/magnet	10.0 / 5.0 minutes
RAPTOR maximum road transit speed (note: harrow/magnet tool was attached but not in use during this measurement)	9.6 mph