



**US Army Corps  
of Engineers®**

**ESTCP Project UX-200327  
Remote Excavation of Heavily Contaminated UXO Sites  
The Range Master  
Phase II Final Report**



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Prepared by  
USA Environmental, Inc.  
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## Acronyms and Abbreviations

°F	Degrees Fahrenheit
AEDA	Ammunition, Explosives, and Dangerous Articles
ANSI	American National Standards Institute
AR	Army Regulation
ARAR	Applicable, Relevant, Appropriate, Requirements
ASR	Archives Search Report
BATF	Bureau of Alcohol, Tobacco, and Firearms
bgs	Below Ground Surface
BIP	Blow in place
BRAC	Base Realignment and Closure
BT#2	Bomb Target #2
CA	California
Cal	Caliber
CEHNC	Corps of Engineers, Huntsville Center
CENWO	U.S. Army Corps of Engineers, Omaha District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COE	Corps of Engineers
COTR	Contracting Officer's Technical Representative
CWM	Chemical Warfare Materiel
dB	Decibel
dBm	Power ration in Decibels referenced to 1 milliwatt
DDESB	Department of Defense Explosives Safety Board
DERP	Defense Environmental Restoration Program
DGM	Digital Geophysical Mapping
DGPS	Differential Global Positioning System
DID	Data Item Description
DOD	Department of Defense
DOT	Department of Transportation
DQO	Data Quality Objective
DRMO	Defense Reutilization and Marketing Office
EM	Engineer Manual
EM61	Electromagnetic Sensor Model used for DGM
EOD	Explosive Ordnance Disposal
EP	Engineer Pamphlet
EPA	Environmental Protection Agency
ER	Engineer Regulation

**Acronyms and Abbreviations (Continued)**

ESS	Explosive Safety Submission
ESTCP	Environmental Security Technology Certification Program
FLBGR	Former Lowry Bombing and Gunnery Range
FUDS	Formerly Used Defense Sites
GFE	Government Furnished Equipment
GIS	Geographical Information System
GP	General Purpose
GPS	Global Positional System
GQA	Government Quality Assurance
HAZWOPER	Hazardous Waste Operations
HE	High Explosive
HSP	Health and Safety Program
HTRW	Hazardous, Toxic, and Radioactive Waste
HTW	Hazardous and Toxic Waste
HW	Hazardous Waste
IAW	In accordance with
ID	Identification
IME	Institute of Makers of Explosives
in.	inch
kW	kilowatt
lb	Pound
m	meter
Mag	Magnetometer
MEC	Munitions and Explosives of Concern
mm	Millimeter
MPM	Most Probable Munition
MSD	Minimum Separation Distance
MSDS	Material Safety Data Sheets
mV	Millivolt
mW	Milliwatt
N/A	Not Applicable or Not Available
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Protection Act
NIOSH	National Institute for Occupational Safety and Health
NPL	National Priority List
NTP	Notice to Proceed
OBOD	Open Burning, Open Detonation
OE	Ordnance and Explosives
ORIA	Ordnance and Explosive Risk Impact Assessment

**Acronyms and Abbreviations (Continued)**

OSHA	Occupational Safety and Health Administration
OSIC	On-Scene-Incident-Commander
PAM	Pamphlet
PAO	Public Affairs Office
PEL	Permissible Exposure Limits
PEP	Property Equipment Plan
PLS	Professional Land Surveyor
PM	Project Manager
POC	Point of Contact
PPE	Personal Protective Equipment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
rpm	revolution per minute
RTK	Real-Time Kinematic
SARA	Superfund Amendments and Reauthorization Act
SOW	Statement of Work/Scope of Work
SSHP	Site Safety and Health Plan
SUXOS	Senior UXO Supervisor
TES	Timberline Environmental Services, Inc.
Timberline	Timberline Environmental Services, Inc.
TO	Task Order
TSDF	Treatment, Storage, or Disposal Facility
USA	USA Environmental, Inc.
USACE	U.S. Army Corps of Engineers
USAESCH	U.S. Army Engineering and Support Center, Huntsville
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
UXOQCS	UXO Quality Control Specialist
UXOSO	UXO Safety Officer
V	Volt
W	Watt
WDCMP	Work, Data, and Cost Management Plan
WP	Work Plan

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- U.S. Army Engineering Support Center, Huntsville (USAESCH)/Scott Millhouse. USAESCH was also a funding agency, with Scott Millhouse serving as a mentor during the effort. Scott's faithful support was critical in maintaining project momentum and in establishing the Phase I demonstration site.
- Timberline Environmental Services, Inc. (TES). TES, and most notably Mr. Terry Northcutt, was the heart and soul of this project. Range Master is Terry's idea, from start to finish.
- The U.S. Army Corps of Engineers, Omaha District. The Omaha District of the Corps provided the Phase II demonstration site and Ordnance and Explosives Safety support. Their ordnance and explosives contractor, Shaw Environmental, provided critical support in getting the Explosives Safety Submission approved and the demonstration work plan reviewed. Shaw also supported the site soil sieve tests, and provided the pre-excavation and post-excavation site surface sweeps, UXO escort throughout the demonstration, and final assessment of the objects recovered by Range Master. Their Digital Geophysical Mapping contractor, Sky Research, Inc., supported the site soil sieve tests and provided pre- and post-excavation digital geophysical mapping data of the demonstration area.

A full list of project points of contact are included in Appendix A.

## **Abstract**

This project was designed in two phases. Phase I provided the primary technology integration of the base carrier and screening system that was manually operated. Phase II incorporated system armoring and remote control components. This report documents the Phase II results.

The Phase I demonstration was performed at Former Fort Ord, Monterey, CA, in February 2004. The manually operated Phase I Range Master successfully demonstrated the validity of integrating an excavator and screening unit to safely and effectively excavate heavily contaminated sites and to improve the site's geophysical conditions. A limitation in the system hydraulics prevented the operator from adjusting the excavation depth in real time. The excavation paddles or the screen shaker motor had to be stopped to adjust depth of cut. The problem was determined to be in the screen shaker motor valve, which was taking excessive flow from the main hydraulic system. This issue was corrected within the control valve, restoring full hydraulic capability to the operator.

The Phase II demonstration was performed at the Former Lowry Bombing and Gunnery Range, east of Denver, Colorado, in June 2006. The remotely operated and armored Phase II Range Master demonstrated the ability to successfully mobilize from Maryland to Colorado. The system was set up and safely (remotely) excavated four of the intended five 50- x 50-m grids just east of the Bomb Target #2 target center. This live site demonstration, although less effective than the Phase I demonstration, successfully demonstrated that the remote excavation of heavily contaminated UXO sites is possible. The "before" and "after" digital geophysical mapping results reflected a lack of expertise in maintaining a uniform depth of cut. The remote control operation was excellently demonstrated; however, effective excavation and sifting of the top 12 in. of soil was not. Range Master successfully removed and exposed 2,133 ordnance-related metal pieces, totaling approximately 508 lb, from the four grids excavated.

The operational limitations of the Range Master technology include wet and heavy soils (any soil that cannot be effectively power-sifted), excessive vegetation, terrain variations and slopes greater than 30 degrees.

Comparing the Phase II demonstration production costs against the pre-proposal costs of using the Range Master components in an independent excavation and screening project, at Former Fort Ord, shows a significant potential savings (refer to Section 5.2.1). The practical Phase II demonstration production costs were \$115,589.43 for four 50-m grids or \$28,897.36 per 50-m grid or \$46,235.77 per acre. This included all mob/demob, demonstration maintenance and routine inspections, all demonstration labor and per diem, and site restoration. These actual production costs must be tempered with the uncertain excavation efficiency of the Phase II demonstration. The independent "excavate and sift" cost per acre was \$50,328.57 per acre in dry soil conditions. This represents a potential savings of \$4,092.80 per acre. The ability to perform these operations remotely also improves the less tangible costs associated with personnel safety.

## **1.0 Introduction**

### **1.1 Background**

Many Formerly Used Defense Sites (FUDS), Base Realignment and Closure (BRAC) sites, and Active Ranges have areas that are heavily contaminated with Munitions and Explosives of Concern (MEC) or unexploded ordnance (UXO), range residue, and contaminated soils. These areas include Open Burning/Open Detonation (OBOD) areas, old or current target impact areas, strafing ranges, 40 mm ranges, and small arms ranges with very high concentrations of surface and subsurface metallic signatures that would reduce the effectiveness of Digital Geophysical Mapping (DGM). Remediation or maintenance of these sites is hazardous, time consuming, and expensive. Efforts to characterize these sites with DGM techniques can help to confirm the degree of contamination, but are currently unable to provide sufficient resolution to properly estimate remediation or maintenance efforts.

A robust, remotely operated UXO excavation system such as the Range Master, with replaceable armor, chains, paddles, and screens, would provide a cost-effective tool to:

- Remediate heavily contaminated UXO sites to depths of 12 inches (in.) below ground surface (bgs).
- Clear range clutter and UXO for identification and disposal in a single pass.
- Remove polluted soils for treatment or to perform deeper remote clearance operations as a design option to hold and carry excavated soils. Note that additional design and modifications are required to hold and carry excavated soils.
- Prepare and optimize heavily contaminated UXO sites for deeper and more effective DGM characterization and remediation.

An ability to remotely screen and observe excavated objects and suspected UXO items for disposal would improve the efficiency and safety of near-surface (i.e., surface to 12 in. bgs) “Mag and Dig” or mechanical sifting operations.

The optional integration of survey-level differential Global Positioning System (GPS) and Autopilot control equipment could facilitate effective area clearance to customer specifications.

This project was developed in two phases. Phase I provided the primary technology integration of the base carrier and screening system that is manually operated. Phase II incorporated system armoring and remote control components. This report documents the Phase II results.

The project organization includes: Environmental Security Technology Certification Program (ESTCP) as the primary sponsor; the U. S. Army Engineering and Support Center, Huntsville (USAESCH), which provided initial project seed money and provided Contracting Officer Technical Representation (COTR); USA Environmental, Inc. (USA) as the prime contractor responsible for project management and UXO support; and Timberline Environmental Services,



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Inc. (Timberline), who is responsible for system design, fabrication, integration testing, and demonstration operation and maintenance.

The U. S. Army Corps of Engineers, Omaha District, provided access to the former Lowry Bombing and Gunnery Range, Bomb Target #2 (FLBGR BT#2), and the Ordnance and Explosives Safety Officer. Shaw Environmental Services supported the soil screening tests, and provided Ordnance and Explosive escort and any required ordnance disposal. Shaw also performed the initial and final surface sweeps, and recorded all excavation results (recovered object identification and estimated weight). Sky Research, Inc., provided the “before” and “after” DGM of the demonstration site.

### **1.2 Objectives of the Phase II Demonstration**

The Phase II system demonstration was conducted at the former Lowry Bombing and Gunnery Range (FLBGR), Colorado. The specific site selected for the Phase II demonstration was Bomb Target #2 (BT#2). This portion of FLBGR had a high concentration of ordnance, was in the process of being cleared, offered excellent logistic support, and had relatively flat terrain. The objectives for this demonstration were:

- To demonstrate the Range Master’s ability to safely and effectively excavate portions of a live ordnance site
- To demonstrate the success of the project in terms of:
  - Faster excavation and screening time
  - Cheaper excavation and screening costs
  - Improved site conditions for follow-on DGM
  - Identification of design areas that would need to be improved in order to robustly survive the rigors of sustained field work

The specific metrics to be demonstrated are included in Subsection 3.1.

### **1.3 Regulatory Drivers**

Because the Range Master is designed to be operated in heavily contaminated UXO environments, a technology approval by the Department of Defense Explosives Safety Board (DDESB) was required for the Phase II demonstration and will likely be required for each live MEC project site. This was accomplished through an addendum to the existing site Explosives Safety Submission (ESS).

Site sensitivities to local flora, fauna, habitat, and archeological significance must be considered in advance, as the Range Master is an excavation tool. State and local authorities may also need to be consulted for authorization to excavate.

#### 1.4 Stakeholder/End-User Issues

Assessment of stakeholder and end-user concerns includes the following:

- Unintentional detonation of UXO items exceeding the protection limit of the system armor (e.g., UXO larger than a 105mm projectile). It is expected that proper planning should limit Range Master application to areas where the expected range of UXO will not exceed the protection limits. The most sensitive components (e.g., hydraulics and power plant) were armored in Phase II and sacrificial components (e.g., paddles and screens) are field replaceable. In the event of catastrophic damage to the armored prime mover from larger UXO detonations, the Range Master would need to be pulled from the range for repair back along the path it has already cleared. A standard tow point is provided. Note: No unintentional detonations were experienced during the six excavation days at FLBGR BT#2.
- Fuel, oil, and hydraulic fluid spills are a concern with operating heavy equipment in hazardous environments. Industry standard spill containment and recovery equipment were on hand at all times, and exercised during this demonstration.
- UXO areas with environmental sensitivities (e.g., flora, fauna, archeological) will limit application.
- Technology acceptance and utilization by UXO remediation contracting organizations, contractors, property stakeholders, and regulators must be considered. Safety and effectiveness will need to be successfully demonstrated before this technology is accepted for commercial application.
- Area terrain, vegetation, soil conditions, and weather will limit the application of the Range Master. It is expected that the Range Master will operate in terrain with vertical slopes less than 35%. Vegetation must be cleared for soil access (during the Phase I and II Demonstrations, it was noted that the Range Master can clear nominal site vegetation). Site soils must be free of significant roots (e.g., greater than 4 in. in diameter) and noncohesive (e.g., dry loam, sand, or small cobble gravel). Wet and frozen soils will degrade the performance of the Range Master, as shown in the Phase I Demonstration. Sites with loose, dry soils will generate large dust clouds that may require engineering controls or, at a minimum, modified deployment strategies. The site selected for the Phase II demonstration was not designed to validate all of these expected limitations.

## 2.0 Technology Description

Range Master uses current proven and mature technologies that are in commercial use today. The base carrier (see Figure 1) consists of a modified Caterpillar 633D Scraper that is manually operated. The modifications for Phase I included: (1) the removal of the scraper's clamshell and its control components, (2) the design, fabrication, and installation of a backing plate to lift site soils to the integrated power screening system, and (3) the purchase, design, and installation of the screening system. The screening system is tilted and provides hydraulic screen shaking. Objects that are too large to pass through the screen network (primary and secondary screens) fall into a wire mesh hopper at the back of the Range Master. The operator controls the hydraulic dumping of the screened hopper contents for examination by UXO personnel. Designed specifically to handle UXO up to 105mm projectiles, the Range Master is physically capable of handling much larger ordnance (e.g., 500-lb bombs) up to the limits of the lifting paddles. Sifted soil drops through the screen unit back onto the site directly under the Range Master. When the screened item hopper is full, the operator hydraulically dumps its contents directly below the Range Master for inspection.

Sacrificial components, such as paddles, chains, and screens, are low cost items. Spares of these items are maintained on-site to minimize down time. In most cases, replacement of these items can be completed in less than 2 hours.

The Phase II Range Master hydraulics, engine, and cab were armored with armor plates and glass over all vital components. The armor plate was mounted outside the existing shielding. An industry standard remote operating system was integrated in Phase II. Armored cameras provided all views (front, back, sides, and screening areas) to the system operator and UXO technician. Selectable sifting screens, down to 0.75 in., can be remotely emptied during operation for a more thorough identification or disposal of discovered UXO. Screened soil is immediately returned to the site.

### 2.1 Technology Development and Application

The Phase II Range Master was developed in two stages. Stage 1 was funded by the USAESCH and prepared the base carrier for the integration of the screening unit. Stage 2, funded by ESTCP, included the screening system purchase, modification, installation, control, system integration testing, and the Phase I demonstration. The Phase I demonstration success resulted in Phase II, where the system armoring and remote control were added and the Phase II demonstration was performed.

#### 2.1.1 Technology Background, Development, Function, and Intended Use

The Range Master integrates a commercial construction excavator with an industry-standard soil screening system. Typically, these functions are performed serially. Site soils are excavated and hauled to the screening system. Soils are then fed and processed through the screen. Sifted soils are typically returned to the site, while screened items are inspected for potential MEC and disposal.

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This serial approach to sifting site soils for potential MEC is time-intensive and costly. The development of the Range Master integrates the excavation and screening unit to optimize operations that require soil sifting. The intended use of the Range Master is to provide a tool that is capable excavating heavily contaminated UXO sites. Excavation includes all site debris larger than the selected screen mesh.

### 2.1.2 Phase I Development

Figure 1 shows the unmodified base carrier. Figure 2, Figure 3, and Figure 4 show the efforts funded by USAESCH, preparing the base carrier for the integrated screening unit. Figure 5, Figure 6, Figure 7, and Figure 8 show the screening unit purchased, the size reduction required to fit into the Range Master and the final Phase I system (Figure 9).



**Figure 1: Unmodified Range Master Base Carrier**



**Figure 2: Removal of the Original Clamshell**



**Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**



**Figure 3: Backing Plate Design and Fabrication**



**Figure 4: Backing Plate Installation - Ready for Screening Unit**





**Figure 5: Screening Unit Arrives**



**Figure 6: Required Size Reduction Shown by Plywood Template**





**Figure 7: Screening Unit Installed Behind Backing Plate**



**Figure 8: Screening Unit with Phase I Demonstration Fine Screen**





**Figure 9: Range Master Ready for Phase I Demonstration (Manual Operation)**

### 2.1.3 Phase II Armoring

During Phase II, the Range Master armoring was designed and installed. The armoring was designed to protect critical system components (e.g., engine, fuel and hydraulic tanks) from an unintentional detonation from UXO up to a 105mm projectile. The cab was armored to protect an operator from an unintentional detonation from UXO up to a 75mm projectile. The armor requirement to protect an operator from the overpressure of larger UXO was too heavy and too expensive for the limited scenarios where the system would be manually operated (e.g., sites where UXO is not expected to exceed 75mm or to retrieve the Range Master off a range over the path it has already excavated, should the remote control fail). Protection from direct blast was accomplished by adding 0.75-in. A527 steel plates. Areas exposed to indirect blast were covered with 0.5-in. A527 steel. The cab windows were replaced with 2.69-in. safety glass. The cab was armored the same as devegetation equipment that is used to clear vegetation on UXO sites. Figure 10, Figure 11, Figure 12, Figure 13, and Figure 14 show the armor design and installation.

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

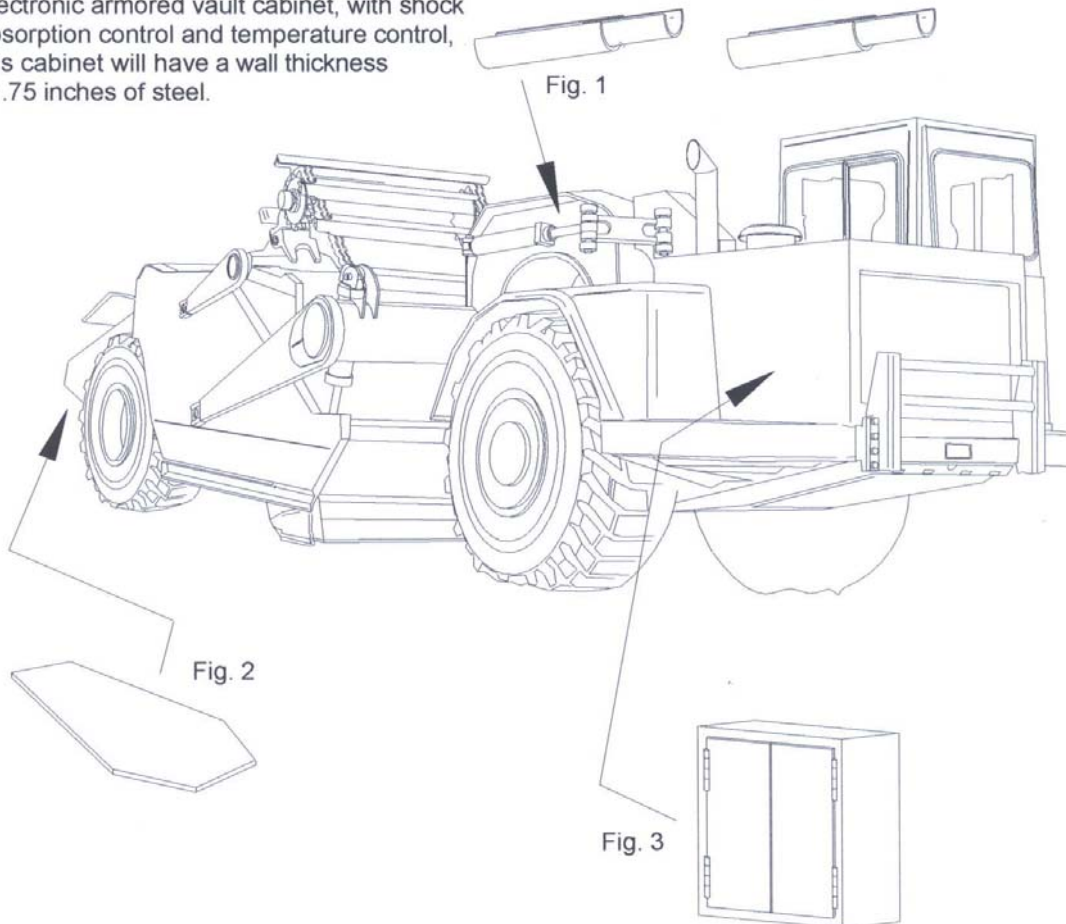
### Armor Cover:

There is approximately 12,240 pound of A572-50 steel that makes up the protection of the vital and exposed components. The areas that can be exposed to UXO will have a thickness of .75 inches and other areas with no less than .5 inches of steel. At this time we can not predict the shape and placement of equipment supplied by other contractors "ie-vidio" we know the camera mounts will need protection. I will point out some of the known features.

Starting with Fig. 1 , these telescopic steel guards are to protect the Steering cylinders. Fig. 2, is the under guarding that will shield the components that are in the rear "stinger" area, such as the mechanism that operates the screened waste containment door, and the hydraulic and pneumatic components that control the Trap door and rear wheel brakes.



Fig. 3, is the Telemetry Guidance System and Electronic armored vault cabinet, with shock absorption control and temperature control, this cabinet will have a wall thickness of .75 inches of steel.



**Figure 10: Range Master Armor Design 1 of 2**

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

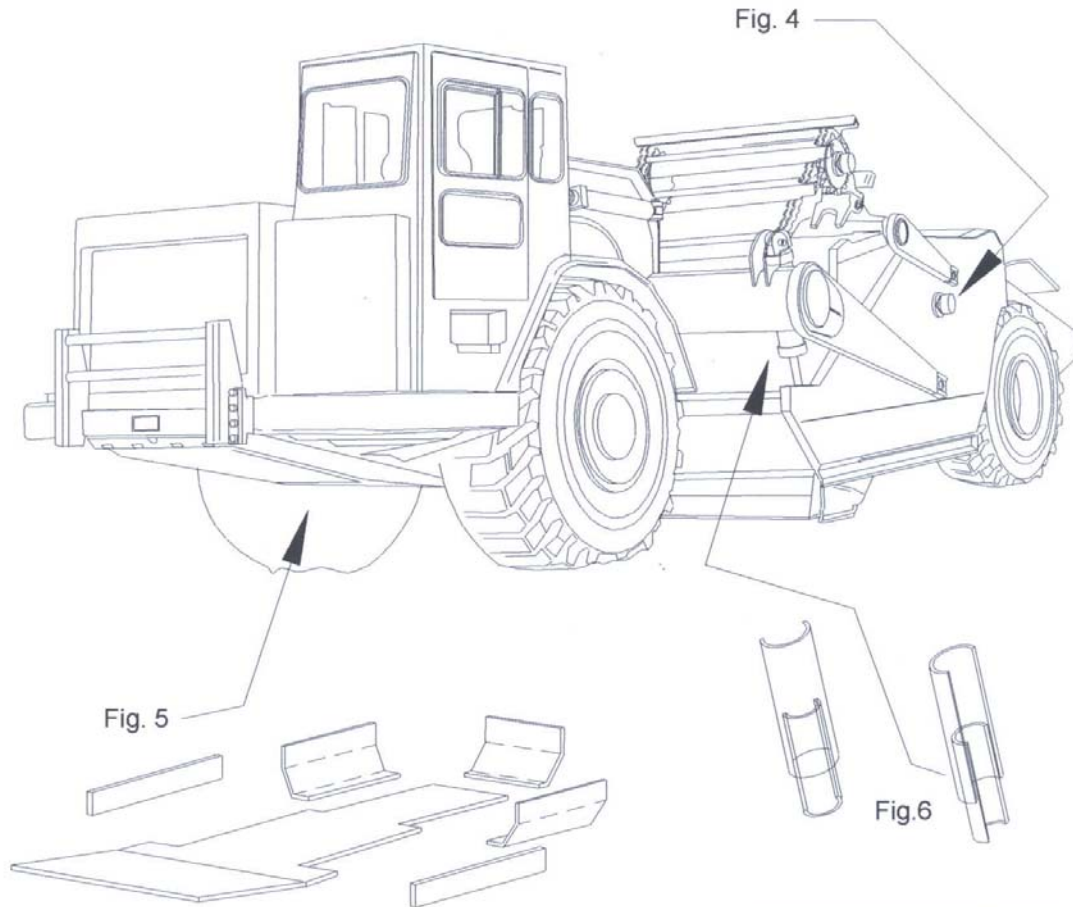


Fig. 4, Is the Power Screen Drive and it is exposed outward of the machine side body, the lead-in hydraulic lines and motor will be shielded by .75 and .5 steel plate

Fig. 5, Is the the most completed part of the armor cover, this has to segmented for access to major machine components, drive differential, transmission, lower power train, power takeoff and, hydraulic drives - pumps. All steel is .75 inch thickness.

Fig. 6, These are telescopic shields to protect the "bowl" hoist hydraulic cylinders, also additional shielding around the pivot points, and elevator Idler bearing supports. Not shown are shielding around some of the the most soft and thin wall hydraulic lines. Fuel tank overlay armor plate is allso included.



**Figure 11: Range Master Armor Design 2 of 2**





**Figure 12: Phase II Armor Installation**  
**(Note Steel under Neck, behind Engine and Depth Ram)**

Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

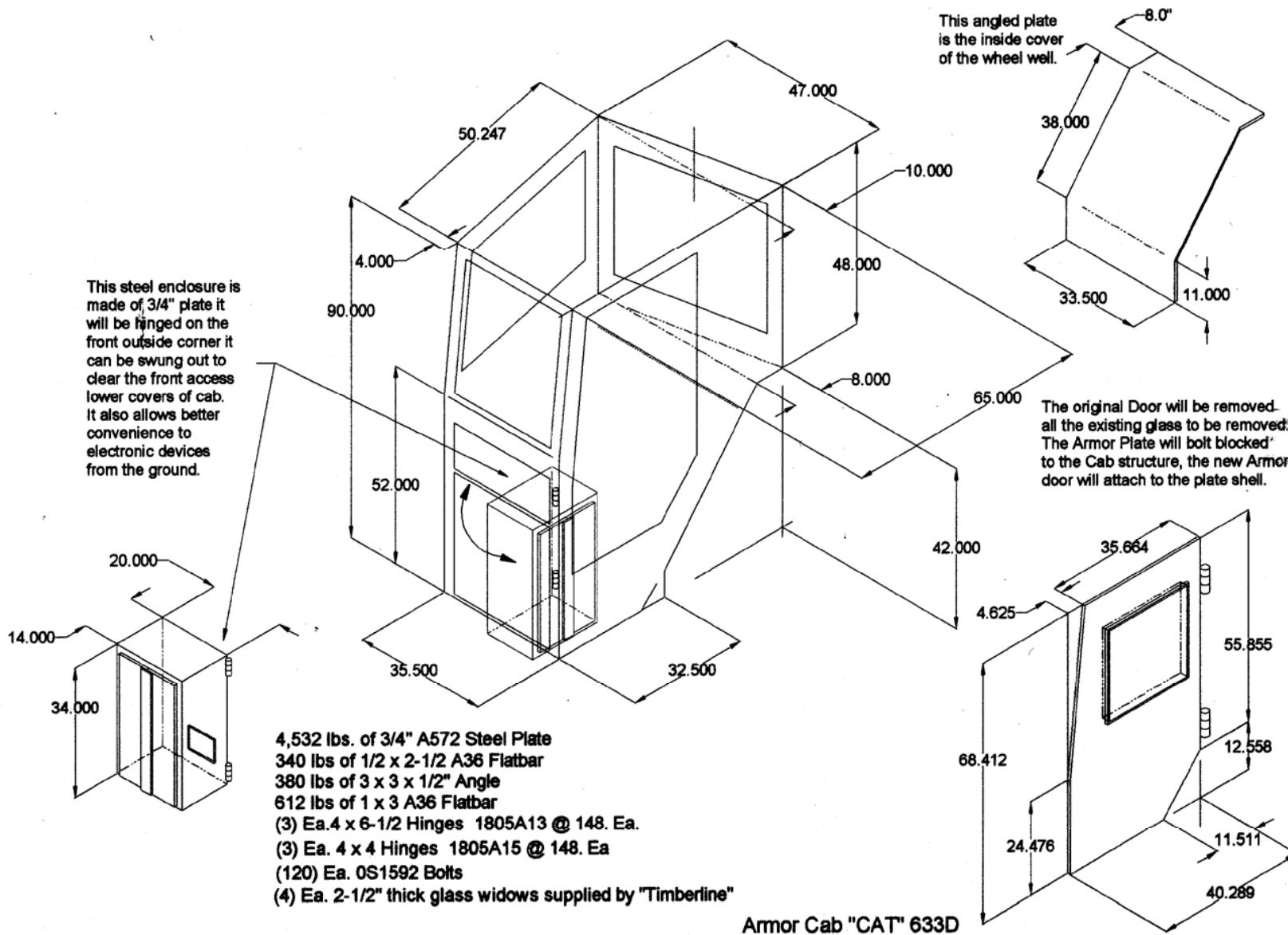


Figure 13: Range Master Phase II Cab Armor Design



**Figure 14: Range Master Cab Armor**

#### **2.1.4 Phase II Hopper Upgrade**

The Phase I screened hopper design was modified so it did not contact and drag on the ground when fully open. Figure 15 shows the original hopper design and the Phase II design. The upgraded hopper design increased the hopper capacity from 3.34 cubic yards to 3.44 cubic yards.



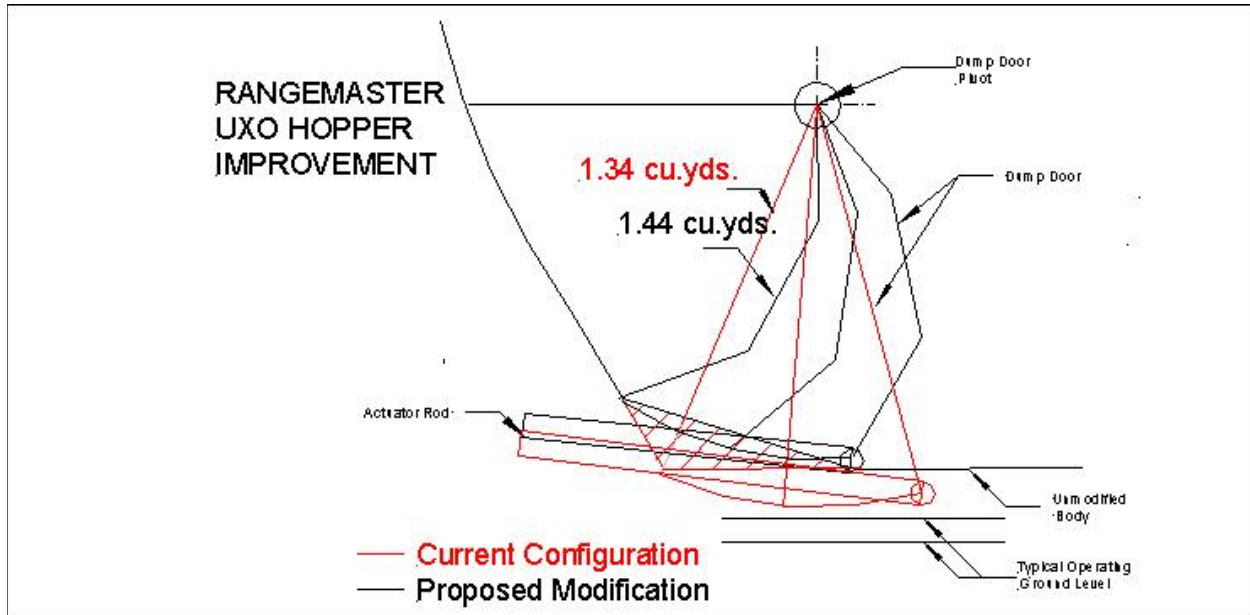


Figure 15: Phase I and Phase II Hopper Design

### 2.1.5 Phase II Video and Remote Control

The Phase II remote control system was designed and implemented. This design provides video and control over two Radio Frequency (RF) links to the Remote Control Platform. The video link is provided by a commercial-off-the-shelf RF link operating in the 2.3- to 2.55-MHz range. The effective power of each video transmitter is approximately 4 Watts (W). Six cameras were mounted on the Range Master. Camera 1, wide angle forward looking, provides the primary navigation view. Camera 2 is a pan, zoom, tilt camera mounted high on the front to provide a 360-degree view. Camera 3 monitors the cutting blade. Camera 4 provides a view of the power screen and allows real-time monitoring of recovered objects if the dust is not too great. Camera 5 is the rear view camera for backing up and monitoring excavation results. Camera 6 is mounted inside the cab and provides a view of the instrument cluster [e.g., engine revolutions per minute (rpm), temperature, hydraulic pressure] to the remote operator. Figure 16 schematically shows each camera position. Figure 17 shows the schematic video monitors inside the remote control platform. Figure 18 shows the monitors during the Phase II demonstration. Note the Camera 6 insert on the front monitor showing the Range Master instrument cluster. In this view, the operator is backing up and looking at Camera 5's output (rear view). The operator can switch any of the cameras to any of the monitors.

The remote control platform hosts a safety key lock as the master on/off switch. This key is taken by the UXO Safety Officer whenever the Range Master needs to be serviced, preventing any possibility of unintentional operation. The telemetry provides control of all Range Master functions, including engine on/off, throttle, steering, breaking, blade control, shaker on/off, and

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

hopper open/close. A flashing beacon on top of the Range Master indicates that the vehicle is under remote operation. A mechanical telltale provides visual confirmation that the hopper is closed. As a safety feature, the telemetry system shuts down if the telemetry radio link is broken. This precludes a runaway Range Master. Additionally, there are three mechanical emergency stop switches mounted on Range Master that can be manually activated, as well as an emergency stop switch on the operator's console. These switches turn off the engine and interrupt power to the remote control. Figure 19 and Figure 20 show the telemetry schematics. Figure 21 shows the operator control station. Figure 22 and Figure 23 show the electronics installed in the Range Master armored enclosure and the remote control platform enclosure, ready for installation.

The remote control telemetry link is a commercial-off-the-shelf Ethernet radio operating in the 902- to 928-MHz range, with output power typically less than 1 W (see Table 1. The remote control platform is designed in the rear portion of a mobile home and is powered by an auxiliary 5.5-kilowatt (kW) generator. Figure 24, Figure 25, and Figure 26 show the Range Master and the Remote Control Platform ready for the Phase II demonstration.

**Table 1: Remote Control Radio Specifications**

Free Band	Transceiver
Manufacturer	FreeWave Technologies
Model	FGR-09SE
FCC rules	Part 15 compliant
Emission Designator	230KF1D
Frequency Range	902 - 928 MHz
Frequency selection	Spread Spectrum, 15 per band, 105 total, user selectable
Occupied Bandwidth	230 kHz
Signal Type	Digital RS-232
Power output	100 milliwatts (mW) to 1 Watt (+30 decibels referenced to 1 milliwatt (dBm)) adjustable
Range	60 miles line of site
Power consumption	500 mA at 12 Volts (V) for 1W
Operating environment	-40 °C to +75 °C
Antenna decibel (dB) gain, Platform	3 dB Omni directional
Platform Antenna part no.	EAN0900WB
Antenna dB gain, Tripod	5 dB Omni directional
Tripod Antenna part no.	EAN0905WB

Control and Monitor Side Component Diagram

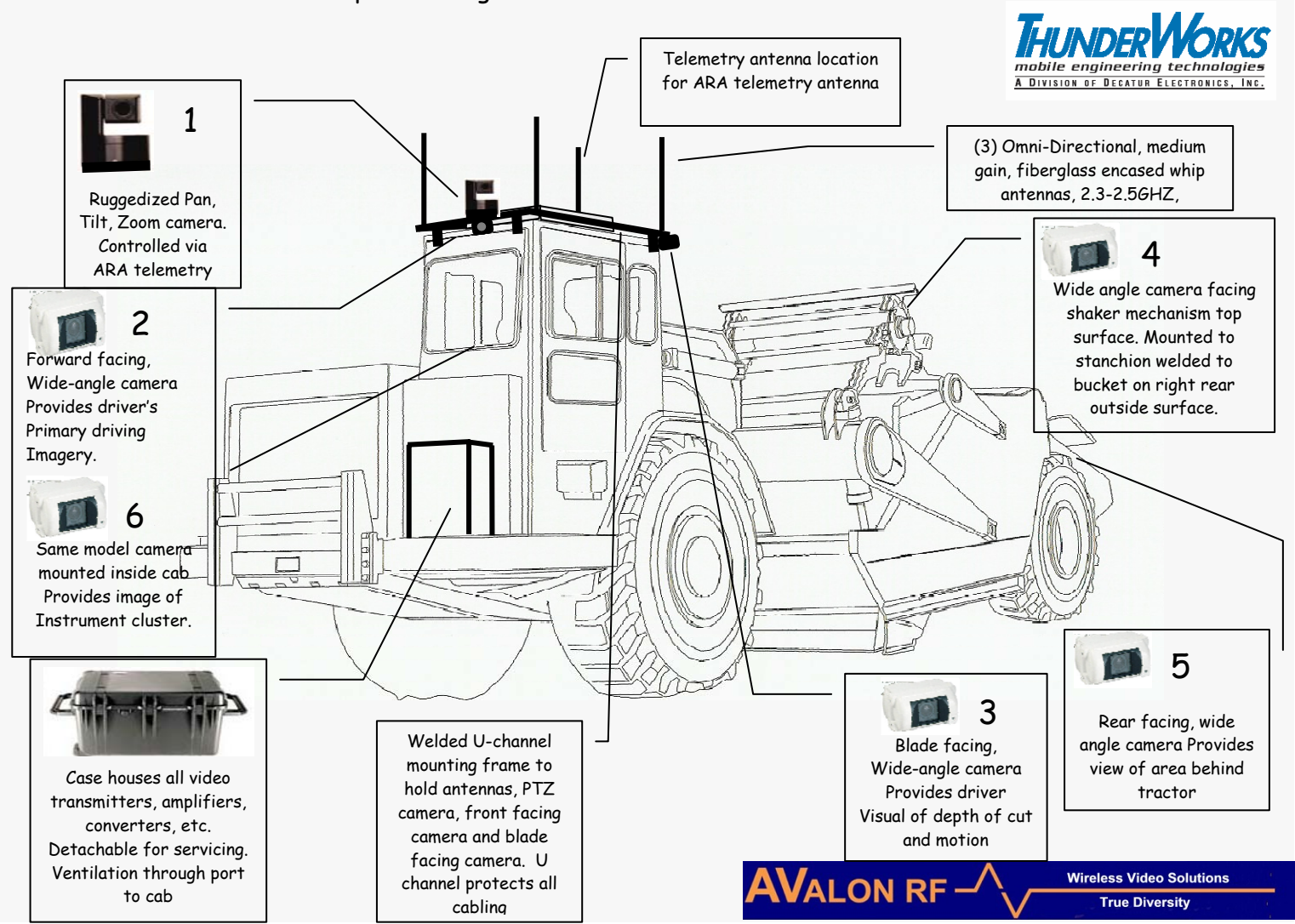


Figure 16: Remote Control Camera Placements

# Range Master Wireless Video System



Control and Monitor Side Component Diagram

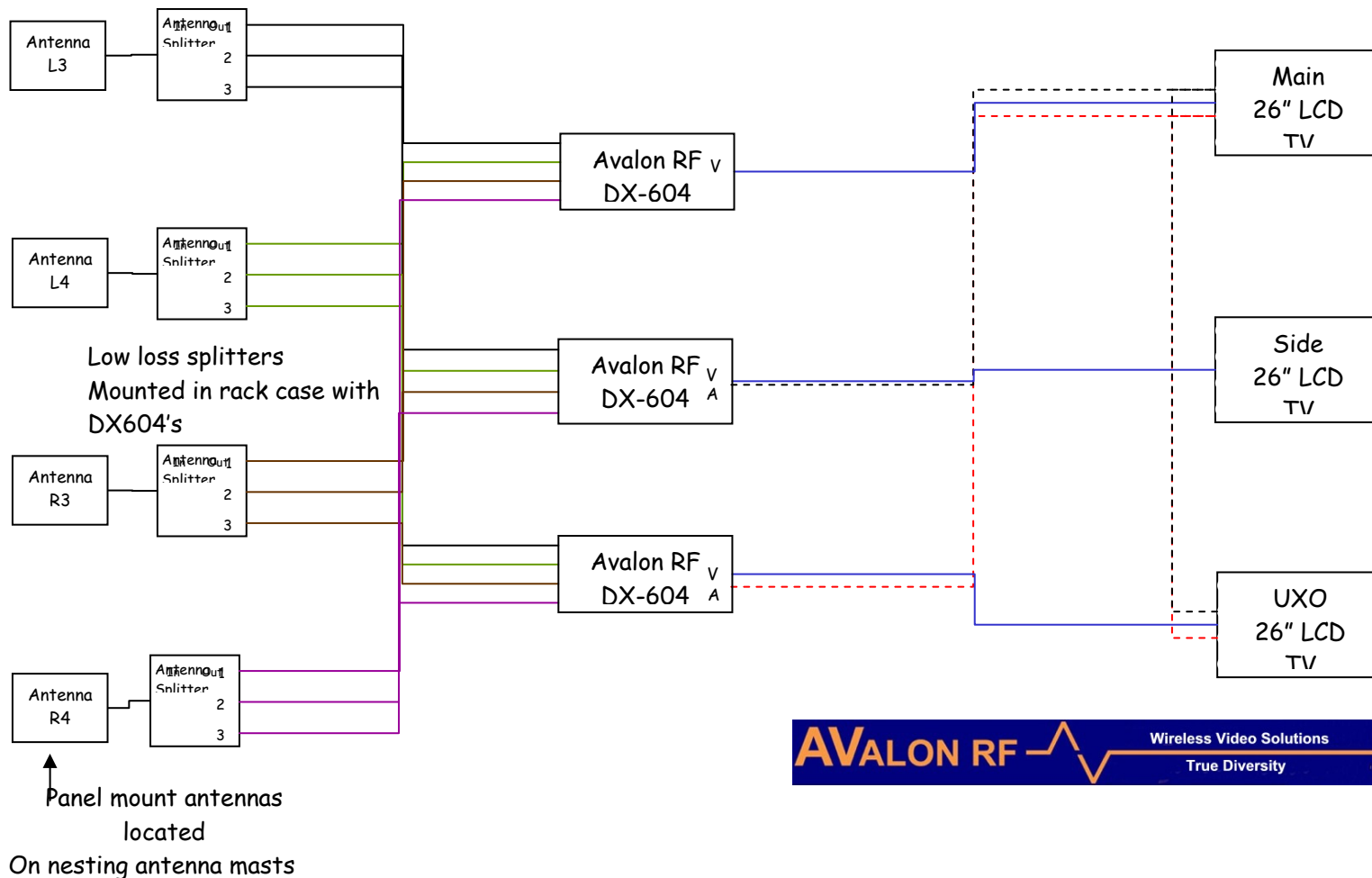


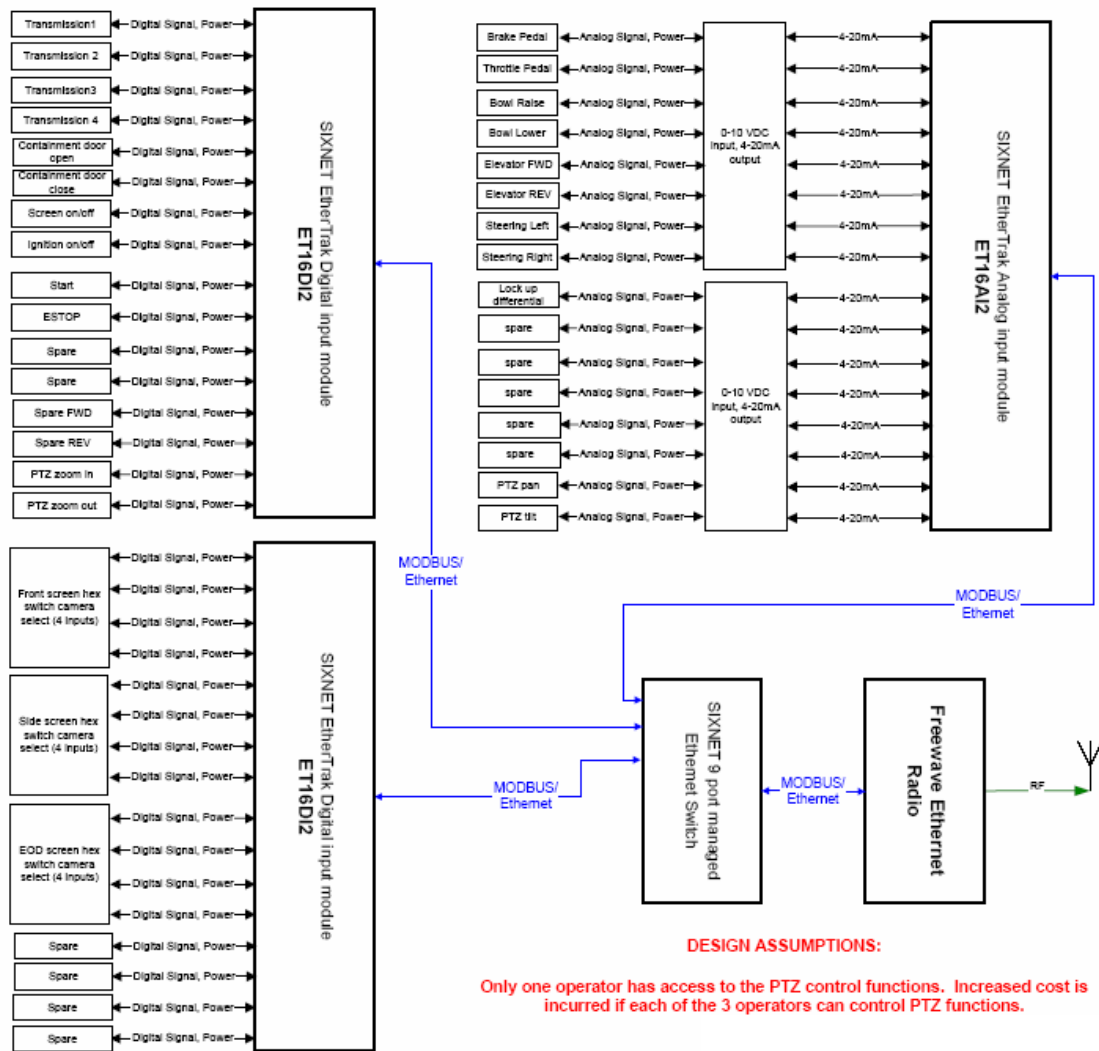
Figure 17: Range Master Video - Control Side





**Figure 18: Video Monitors inside Remote Control Platform**

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)



**Figure 19: Telemetry Schematic - Vehicle**

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

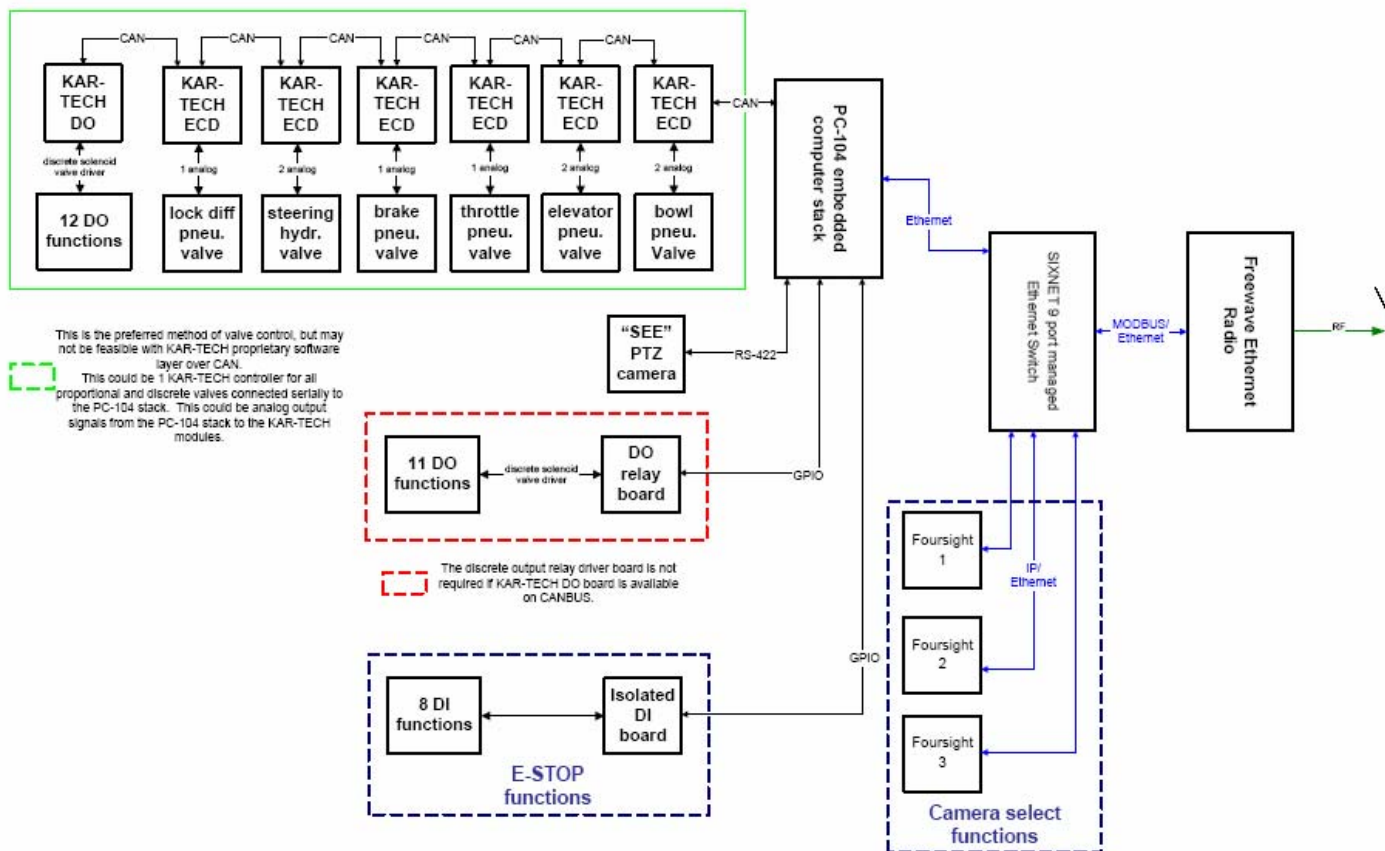


Figure 20: Telemetry Schematic - Remote Control Platform



**Figure 21: Remote Control Platform Video Monitors and Control Station**





Figure 22: Telemetry Electronics - Vehicle



Figure 23: Telemetry Electronics - Remote Platform



**Figure 24: Phase II Range Master**

**Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**



**Figure 25: Remote Control Platform and Tow/Support Vehicle at the Phase II Demonstration**



**Figure 26: Remote Control Platform with Range Master in the Distance**

### 2.1.6 Target Types of UXO and Environmental Conditions

Depending on the selected screen mesh (e.g., 1-in. secondary screen mesh for Phase I and a combination of 0.75-in. over 1-in., and then just 1-in. secondary screen mesh for Phase II); objects with a minimum dimension greater than the screen mesh will be separated from the site soil for inspection and disposal. MEC items in the first 12 in. of soil that are 30 mm and larger can be excavated by the Range Master. Reducing the secondary screen mesh to 0.75 in. allows the capture of MEC that are 20 mm and larger. The Phase II Range Master was designed to survive an unintentional detonation from UXO up to and including a 105mm projectile. The system is specially designed for use in Open Burning/Open Detonation (OBOD) areas, 40mm ranges, and high density target areas.

Environmental conditions will limit the Range Master performance. Heavy and wet soils will not sift properly. This tends to clog or “blind” the screen and fill the hopper with excess site soil. There are some heavy, wet, clay soils that will “blind” any screening system. For the Phase II demonstration, the site soils were sampled and run through a sieve test (see Appendix B) that documented that this soil could be sifted with moisture content up to 20%. Site terrain also complicates the Range Master’s ability to excavate in a single pass. The base carrier was designed for road construction and tends to level the site as it excavates. Dips in site terrain tend to be filled in vs. excavated and can leave potential UXO, even within the expected depth of cut (e.g., down to 12 in. below ground). Depending on the expected target depth, the operator can “over excavate” protruding soils and change the direction of travel of the Range Master to excavate below grade levels. Essentially, multiple passes can be used to alleviate variable terrain conditions.

Site vegetation also complicates the Range Master performance in a single pass. The 40mm simulant grid #2 used for the Phase I Demonstration was covered with grass, ice plant, and small Manzanita brush. The Range Master successfully removed and processed this vegetation on the first pass. Primary soil excavation occurred on subsequent passes. The prairie grass encountered during the Phase II demonstration also blinded the screens and had to be cleared from the screens frequently. In the case of heavy vegetation, it is best to cut or reduce it to as close to ground level as possible before Range Master operation. The cutting edge of the Range Master will sever roots below ground surface. The material will be processed through the Range Master. Blinding of the screens or premature filling of the hopper by dislodged roots may occur. However, the “Grizzly” bars on top on the screens will keep bulk debris off the screens. Depending on the most probable munition (MPM), it may be possible to increase the screen mesh size to allow root material to fall back on the site. In terms of site topography, the Range Master is capable of operating on vertical slopes of less than 35%. The Phase II Range Master Demonstration did explore some aspects of these limitations. However, the focus of the Phase II Demonstration was to document performance metrics under normal conditions. Once these metrics have been established, more extreme conditions can be addressed.



### **2.1.7 Theory of Operation**

Once a site is identified and the expected range of UXO is anticipated to be equal to or less than a 105mm projectile, and the site environmental sensitivities and conditions are not severe, the Range Master could be considered as a tool to help remediate the site.

In theory, the Range Master excavates a 12-ft-wide swath. The depth of excavation (typically 12 in. below ground) is controlled by two hydraulic rams that lower or lift the scraper blade. Site terrain also affects the depth of excavation. A set of chain-driven paddles lift soil from the blade, up the backing plate to the integrated power screening unit. Excavated soils and debris fall onto the tilted screening unit. The two-stage screen mesh (i.e., coarse and fine) are selected to best meet project object recovery requirements. The screen system is hydraulically shaken to facilitate shifting soils from debris. Sifted soil and debris smaller than the fine screen mesh fall directly back onto the site. Objects larger than the fine screen mesh work their way down the screen surfaces and fall into a wire mesh hopper. At the end of an excavation line, or set of lines, the operator positions the Range Master at an identified dump location and opens the hopper to dump its contents directly under the Range Master. This operation can be performed with the Range Master stationary or while it is moving if it is necessary to spread the dump over a larger area.

The Range Master's preferred direction of travel is downhill, to maximize forward momentum. It was expected that parallel lines of excavation would work best. However, the Range Master tends to tilt when it straddles excavated and unexcavated portions of the site. The Phase I and Phase II Demonstrations used parallel sets of excavation lines separated by a small distance. Subsequent passes were used to excavate the "Mohawk" portions left between passes.

Qualified UXO Technicians examine the dump piles to identify potential MEC. Identified UXO can be blown in place (BIP) or if it is considered acceptable to move, excavated UXO can be moved to a consolidated location for disposal. At regular intervals, the UXO Technicians also inspect the Range Master for any objects that may have become lodged. If an MEC item becomes lodged (e.g., in the screens) and cannot be moved, it would be blown in place and any damage to Range Master repaired.

This process is continued until the entire site has been successfully excavated to the desired depth.

## **2.2 Previous Testing of the Technology**

### **2.2.1 Pre-Proposal Testing**

The original, pre-proposal Range Master tests were conducted to ensure that the prime carrier had the ability to go intrusive at a range of depths and in different soil types. The soil types tested combined sand and loam, and at times contained up to 20% moisture, but for the most part were optimally dry. While going down an approximate 20% slope, the prime carrier demonstrated the ability to go intrusive to a depth of about 30 in. While climbing up the same slope, the prime carrier was able to go intrusive to a depth of 18 in. to 20 in. Traction effort,

## **Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**

while climbing hills, causes a decrease in the depth of intrusion. Average depth of excavation in the sand and loam soil was 18 in. Production rate of the prime carrier has been measured at approximately 900 tons per hour. This is done in order to accurately measure and gauge the prime carrier's ability along with the screening unit which was later integrated into the machine.

The screening unit was tested independently at the same time. The screening unit used a PowerScreen, which is manufactured in Ireland specifically for screening this type of material.

The throughput capability of this particular screen is approximately 800 tons per hour. This puts the production rate about 100 tons less than the prime carrier, but by slowing the rate of the prime carrier, we should be able to match the excavation and screening production rates. Throughput is determined or adjusted depending upon soil types, moisture content, rock, and other materials which transit through the double screen. Initially we began screening for 37mm projectiles, which was the target ordnance item of concern. The first test conducted used a 2-in. primary screen mesh and a 0.5-in. secondary screen mesh. In the pre-proposal test area, the soil was contaminated with machine gun links and other small items. It was determined that the 0.5-in. secondary screen mesh was too small and was being blinded. Blinding of the screen occurs when the items block the screen and do not let the soil pass through. The soil then just sloughs off the top of the screen. A change was made to a 1-in. secondary screen mesh. This allowed the capture of the 37mm items and let the machine gun links and smaller material pass through the screen and redeposit on the screened soil. Increasing the secondary screen mesh also helped to match the production rates of the screen to the prime carrier. Once these two mechanical subsystems had been tested and proven, the integration of the components began.

### **2.2.2 Phase I Integration Testing**

The inner workings of the can on the carrier were removed and a backing plate was installed. Testing has been done at Timberline Environmental Services, Inc.'s (TES's) facility to ensure the movement of the elevator paddles can be achieved in any position with the stationary backing plate in place. Full range of motion has been achieved. The next test conducted was to ensure that all materials go through the screening process. Custom-made components had to be fabricated outside the TES facility. TES cannot roll and shape 1-in. steel plate. Once the custom-made components were installed, tests were performed to ensure complete movement of the elevator paddles. The rear ejector circuit has been tested and is proving to be more than adequate to dump the screened items retained in the hopper (basket unit) after going through the screens. Screened items are retained in the hopper so that they do not re-enter the soil. A proprietary valve was installed to ensure adequate flow and pressure to the screen system.

### **2.2.3 Phase I Demonstration**

The Phase I system demonstration was conducted at the former Fort Ord, Monterey, California, Range 18. This site was selected for the following reasons:

- Proximity to Timberline's facilities to minimize mobilization costs.
- Known site history, including potential UXO and clean-up efforts.

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- Known terrain and soil conditions acceptable for the Phase I Demonstration.
- Facility interest in potential Range Master use.

Range 18 has been used as a small arms range during the entire history of this range.

The Former Fort Ord continues the MEC remediation of all training areas. Under these operations, Range 18 has previously been cleared. In 2001, the site was cleared of potential lead hazards. In 2003, the site was cleared of potential UXO hazards to a depth of 4 ft. This was a controlled test site that was constructed with known seed targets (e.g., pipe sections to simulate 40mm grenades, 60mm and 81mm mortars, and 105mm projectiles) and machine shop clutter objects, with more realistic terrain and vegetation conditions. USA mobilized the Senior UXO Supervisor, UXO Safety Officer, and Principal Investigator, and all DGM equipment on 16 February 2004. Timberline mobilized the System Operator, Maintenance Mechanic, and Project Manager and the Range Master on 17 February 2004. The Phase I Range Master required a 7-axle trailer for mobilization from Timberline's assembly facility in Cold Springs, CA, to the Former Fort Ord in Monterey, CA.

Two 100- x 100-ft grids were selected on Range 18. Parsons provided existing background EM61 data for the range and for these two grids. USA performed a 100% background check using handheld Schonstedt magnetic gradiometers. Both sites were completely clear and no surface or subsurface ferrous metals were detected.

Grid 1 was seeded with 50 each 60mm mortar simulants and 60 each 81mm mortar simulants and 196 pieces of metal clutter buried flush with the surface (0 in.), 3 in., 6 in., and 12 in. below ground.

Grid 2 was seeded with 110 each 40mm grenade simulants and 196 pieces of metal clutter buried flush (0 in.), 3 in., 6 in., and 12 in. below ground. In general, seed items along the south edge are flush with the surface and are buried deeper as each line moves north. Table 2 summarizes all Phase I Demonstration activities.

**Table 2: Phase I Demonstration Activities**

<b>Date</b>	<b>Demonstration Event</b>
16 February 2004	USA mobilized 3 personnel and equipment  Met COE site personnel and visited Range 18. Selected two demonstration grids; obtained prior DGM grid data from Parsons.
17 February 2004	USA performed a 100% surface clearance of Grid #1 and seeded the 60mm & 81mm Grid. Timberline mobilized Range Master to Range 18.

### Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

Date	Demonstration Event
18 February 2004	USA performed a 100% surface clearance of Grid #2 and seeded the 40mm Grid. Timberline set up and checked out Range Master.
19 February 2004	USA acquired seeded EM61 survey of the 60mm & 81mm Grid and the 40mm Grid. Timberline mobilized Range Master to demonstration area. Began pre-demonstration trials at Range 18.
23 February 2004	USA and Timberline performed pre-demonstration trials at Range 18.
24 February 2004	Phase I Range Master Demonstration
25 February 2004	USA acquired post-Range Master EM61 survey of the 60mm & 81mm Grid. Inventoried excavated items and sanitized unexcavated items. Timberline repaired Range Master.
26 February 2004	USA acquired post-Range Master EM61 survey of the 40mm Grid. Inventoried excavated items and sanitized unexcavated items. Timberline repaired Range Master.
27 February 2004	Completed Range Cleanup. Timberline demonstrated Range Master repaired.
28 February 2004	USA and Timberline demobilized.

A 1-day demonstration was performed on 24 February 2004. Table 3 summarizes the Phase I performance against the expected performance.

**Table 3: Phase I Expected and Actual Performance**

Type of Performance Objective	Primary Performance Criteria	Expected Performance	Actual Performance
Qualitative	1. Safety	Operator safety, No Equipment damage, No unintentional detonations	No injuries No equipment damage No unintentional detonations
	2. Ease of Use	Operator acceptance	Operator use accepted and improving. Excavation experience needed.



## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

Type of Performance Objective	Primary Performance Criteria	Expected Performance	Actual Performance
	3. Improved Geophysical site Conditions	Reduced clutter, improved detection of deeper objects.	Both grids demonstrated significantly reduced clutter and the improved ability to detect deeper objects.
Quantitative	1. Excavation Rate	2 to 5 acres per day	1 to 2 acres per day*  2 hours and 12 minutes to complete grid 1, 1 Hour 7 Minutes for 3/4 Grid 2
	2. Seed Item Recovery Rate	90 to 100 %	82.7 % for Grid 1**  65.0 % for Grid 2**
	3. Down Time	< 20% Down Time	29% Down Time - Actual  15% Down Time – Realistic***
* Excavation rates based on individual 100- x 100-ft grids with identified hydraulic limitation and turn-around times twice as long as excavation times. Excavation rate should meet the expected rates with larger areas and functional hydraulics.			
** These calculations account for unexcavated areas due to early lift and breakdown.			
*** The realistic down time excludes delivery of the wrong valve and the extra 24 hours that the error introduced to the total repair time.			

The Phase I demonstration resulted in a recommendation to transition into Phase II.

### 2.2.4 Phase II Integration Testing

On 13 and 14 October 2005, the Phase II Range Master went through integration testing at a quarry in Livermore, CA (see Figure 27). Range Master was remotely operated up to a range of 1.4 miles. When the telemetry link was lost, the system shut down as designed. Raising the antennas at the remote control platform would increase the operating range.

All emergency stop (E-Stops) were exercised successfully. These include the rear and both side E-Stop buttons mounted to Range Master's exterior, the Key "off" master switch in the cab, the circuit breakers providing power, the remote control consol E-Stop button, and two software E-Stops.

Two 13-ft-wide by 800-ft-long test runs were established and seeded with a total of 20 40mm and 81mm simulants. Two simulants were placed on the surface, and the rest were buried 8 in. deep. Three passes were made over the test lane, each averaging 7.75 minutes. The hopper was

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

dumped approximately every 125 ft (see Figure 28). Nineteen simulants were recovered. Three of the recovered simulants were crushed because of the hard, rocky nature of the quarry.

All video cameras were adjusted to provide optimum feedback. The split screen monitors all worked well. The air nozzles mounted to each camera kept the lenses clear even under very dusty conditions.

The remote control platform design was well accepted by all designers and operator. Telemetry functions all worked. The steering control was adjusted to reduce sensitivity and improve performance.

Air conditioning needs to be working to keep electronics cool. Otherwise the system shuts down. Overall Phase II Integration testing was successful.



**Figure 27 Range Master at Phase II Integration Testing**



**Figure 28 Phase II Integration Test Depth of Cut and Example Dump Pile**

### **2.3 Factors Affecting Cost and Performance**

From the Phase I demonstration, the factors affecting cost and performance included:

- Mobilization costs are a significant consideration. The Phase II Range Master requires a 9-axle trailer to handle the weight of the armored system vs. the 7-axle trailer used for the Phase I system. The short-haul mobilization costs for just the Phase II Range Master are estimated at \$10.00 per mile. For long hauls, a combination of rail and trailer mobilization might prove to be more cost effective, but must provide adequate loading and unloading facilities that are not normally available.
- Wet and saturated soils reduce performance. These conditions require slower forward speeds to adequately process soils with greater density and reduce the Range Master's excavation rate. In addition to operational techniques, tailored to the soil conditions, work schedule techniques can be employed to deploy Range Master during dry soil seasons to minimize this limitation. There are some heavy wet clay soils that will blind any screening system.

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

- The identified system hydraulic limitation affected performance during the Phase I demonstration. This limitation was corrected after the demonstration and is not expected to affect future performance. For the Phase I demonstration, this limitation required the operator to stop either the hydraulically driven excavation paddles or the hydraulically driven screen shaker motor to adjust the hydraulically driven excavation depth. Stopping to adjust the depth of the cut extended the time in most excavation lanes. A higher-than-normal engine rpm was used to compensate for this limitation. This resulted in faster-than-normal forward speeds that tended to overload the screening system and scrape excessive amounts of soil off the grid. With the hydraulic limitation corrected, it is expected that the Range Master's forward speed and depth of excavation will be continuously adjustable and tailored to match the screening unit's capacity for optimum performance.
- Individual 100- x 100-ft grids were used for the Phase I demonstration. This resulted in turnaround times that were longer than the actual excavation and dump times for each pass through the grid. Excavating larger, contiguous areas should provide greater production, as productivity is directly related to excavation line length, with turnaround times becoming a smaller percentage of the overall operating time.

### 2.4 Advantages and Limitations of the Technology

The Range Master Technology was brought into being for the purpose of greatly reducing the human element involved with the clean-up of heavily contaminated UXO sites. The technology is sound and does work; however, the test on 24 February 2004 was conducted under difficult conditions. The site had received and continued to receive almost 4 in. of rain. The soils were saturated. This caused problems screening the material. Wet conditions were addressed as being undesirable early on in the program; however, because of the logistics involved and scheduling considerations, it was decided to proceed with the demonstration.

The hydraulic problem that surfaced during the demonstration was the direct result of a control valve failure. This valve was installed by Caterpillar Corporation. The proprietary flow control valve was robbing too much oil from the control circuit. Re-routing the hydraulic circuitry alleviated the control problem. It is expected with normal operations the two test grids could have been excavated in less than 1 hour each.

### 3.0 Phase II Demonstration Design

The Phase II Range Master Demonstration was performed over a 2-week period from 18 June through 29 June 2006 at Bomb Target #2 at the former Lowry Bombing and Gunnery Range, Colorado.

#### 3.1 Performance Objectives

The objectives of the Phase II Range Master Demonstration were to:

- Demonstrate remote/safe excavation of an actual heavily contaminated UXO site.
- Excavate and successfully screen from the site objects (UXO) of the size and depth advertised (e.g., 20mm projectiles and larger in the first 12 in.).
- Improve site geophysical conditions.
- Track costs to better establish production rates/costs.

The specific metrics to be demonstrated, the expected performance criteria, and the actual performance demonstrated are included in Table 4 (see Appendix C for details). The downtime was calculated. Acceptable system reliability during the Phase II demonstration (e.g., less than 20% down time expected) was demonstrated, including the replacement of the screen shaker coupler, all inspections, and final wash down.



## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

**Table 4: Phase II Performance Objectives**

<b>Type of Performance Objective</b>	<b>Primary Performance Criteria</b>	<b>Expected Performance</b>	<b>Actual Performance</b>
Qualitative	1. Safety	Safe remote operation, No Equipment damage	Successful. No personnel or equipment damage.
	2. Ease of Use	Operator acceptance	Better than manual operation. Need better track guidance and scraper experience.
	3. Improved Geophysical site Conditions	Reduced clutter, improved detection of deeper objects.	Unsuccessful. Operator's inexperience in scraper operation resulted in uneven depth of excavation.
Quantitative	1. Excavation Rate	1 to 2 acres per day	2 days per acre
	2. Item Recovery Effectiveness	90 %	Unknown, as site has not been fully cleared. 2,133 items were excavated (508 pounds)
	3. Effective depth of excavation	At least 12" were consistently excavated.	Not achieved. Excavations ranged from 18" to 0".
	4. Down Time	< 20% Down Time	Successful. Down time was 9.7%
	5. Reduced number of DGM Anomalies	Before and after dig lists show reduced anomaly density.	Not calculated
	6. Excavation costs are reduced	Per acre costs are below manual excavate and sift costs (e.g., \$51.1K/acre from Phase I).	Successful. Demonstrated \$46.235K/acre, a \$4.093K savings over conventional excavate and sift at \$50.328K/acre.

Ease of use was assessed and documented during post-excavation interviews with the Phase II Range Master operator and UXO Technicians. This include ease of excavation, soil screening, hopper dumping, and screened item inventorying by UXO personnel. The operator reported that the Range Master was easy to use remotely. They expressed difficulty in seeing excavation boundary markers and maintaining straight line excavations when dust conditions became extreme. All controls (e.g., screen shaker and hopper dump) were accessible and easy to operate. The Range Master base carrier drove and handled normally. The screened item recovery by UXO personnel was satisfactory, but complicated by excess soil in the hopper.

Improvement to DGM site conditions did not result in a significantly reduced background and clutter anomalies (e.g., the ability to reduce the effects of near-surface clutter and to enhance the ability to detect deeper objects). A comparison of the pre excavation EM61 surveys and the post-Range Master excavation EM61 surveys documents that there was little improvement for each

excavated grid (see section 4.2.4). This was due to a combination of the operator's inexperience in scraper operation, resulting in uneven excavation depth, and the high density of metal below the excavation depth.

### 3.2 Selecting Test Site(s)

The Phase II system technology demonstration was performed at the former Lowry Bombing and Gunnery Range, in Colorado. During the site visit to FLBGR, Bomb Target #2 (BT#2) was selected as the most appropriate site for the Phase II demonstration. The reasons for selecting this site included the following.

- This site is actively being cleared and may benefit from this technology demonstration.
- The terrain and vegetation appear to be suitable.
- The site is close to major access roads for optimum logistics.
- There are sufficient cleared areas outside the MSD to:
  - Stage the Remote Control Platform
  - Set up and practice.
- There are ample areas that require remediation. A set of five adjacent 50- x 50-m grids (Grids D4-4, C4-3, C4-4, B4-3, and B4-4), forming a North/South area 50 m (164 ft) wide x 250 m (820 ft) long just east and north of the old target center, have been identified for the actual demonstration/remote excavation (see Figure 29).

#### 3.2.1 Anticipated UXO

The most probable MEC item to be recovered during this demonstration in BT #2 are the 20mm High Explosive Incendiary (HEI) projectile, MK23 practice bomb, and MK15 practice bomb. This assumption is in keeping with the site's ESS Addendum 1 and is based on the information obtained during the EE/CA dated January 1998. A background DGM survey of each demonstration grid was acquired to document "as is" conditions prior to demonstration and to ensure there are no background anomalies (e.g., undocumented utilities or very shallow bedrock) that could pose a safety hazard to this technology demonstration. There was also a concern that incendiary MEC/UXO items were present at BT#2. Therefore, a water truck (Shaw) was made available to minimize the risk of fire to the site. The possibility of 20mm projectiles required a 0.75-in. secondary screen mesh to capture objects with this diameter and larger. Since there were no 0.75-in. screens specifically designed for Range Master, a set of commercial off-the-shelf 0.75-in. screens were purchased and bolted over the 1-in. secondary screens.

#### 3.2.2 Soil Types/Stratigraphy Soil Moisture

There are no known soils or geologic conditions at BT#2 that would preclude a successful test/demonstration of the Range Master. A soil sieve test was performed by Sky Research prior to mobilization to document the suitability of sifting site soil, as a function of soil moisture.

### **3.2.3 Land Use**

BT#2, also designated Sector 7, was used as a bombing target during World War II. This area is currently used for cattle grazing. It is anticipated that the State Land Board property (e.g., BT#2) will convert from cattle grazing to residential use in the future.

### **3.3 Testing and Evaluation Plan**

A Phase II Demonstration Plan was developed and submitted to ESTCP, the Corps of Engineers, Huntsville and Omaha, to Shaw, and Sky; the plan was reviewed and finalized. In concert with the demonstration plan, an ESS Addendum was submitted and approved to allow the use of the Range Master on the live site. Other demonstration preparatory activities included the development of the Site Safety and Health Plan, a site soil sieve analysis, an initial surface sweep, and a DGM of the grids to be excavated. Post-demonstration activities included a second surface sweep and a final DGM survey.

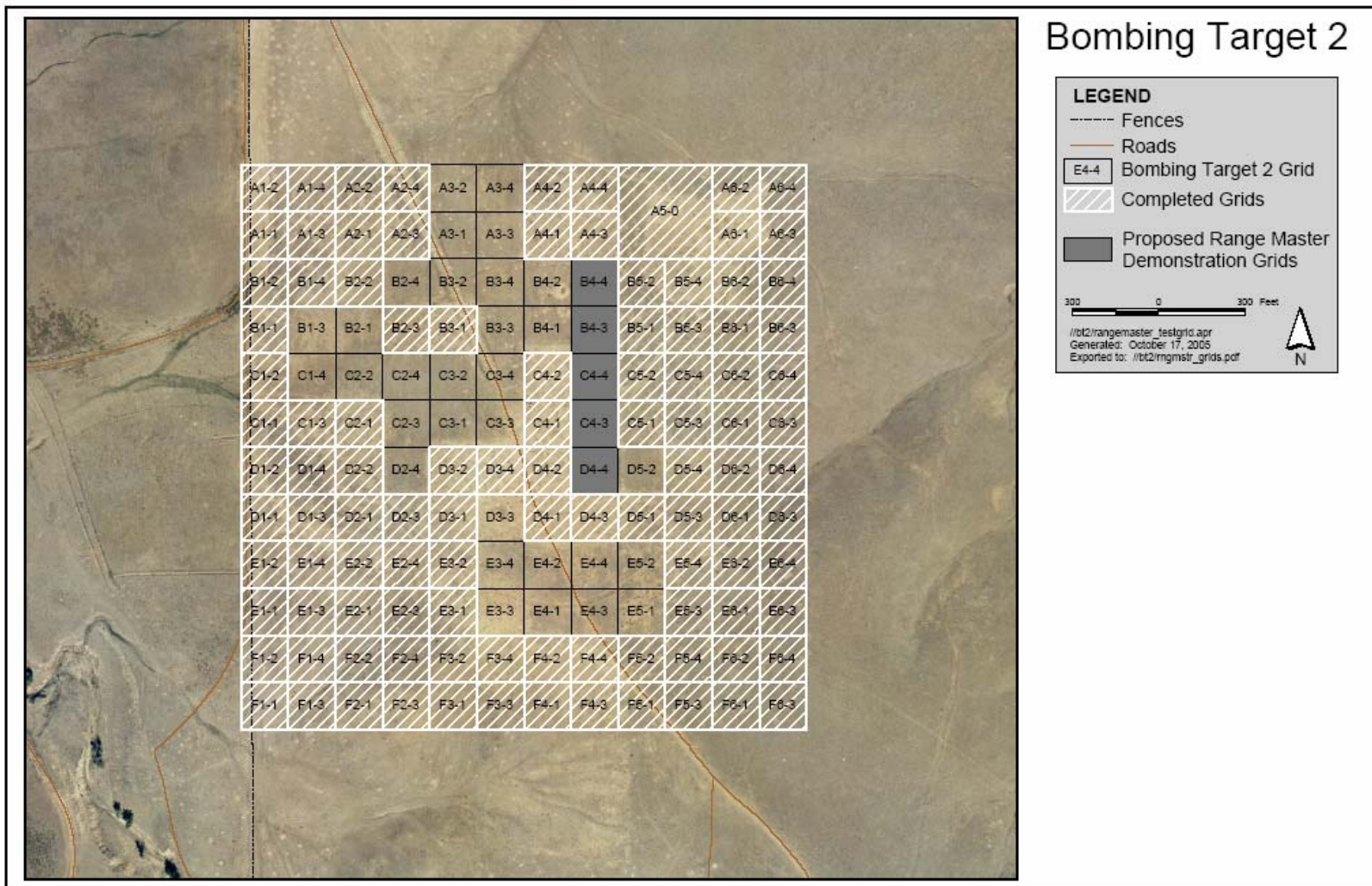


Figure 29: Range Master Phase II Demonstration Grids at FLBGR BT#2

### **3.3.1 Soil Sieve Tests**

A soil sieve test was performed to document that the site soils were suitable for screening by Range Master prior to mobilizing the system to FLBGR. A total of ten 5-gallon buckets of soil were collected from the first 12 in. at BT#2 and provided to Advanced Terra Testing, Inc. The soils were air dried to a baseline moisture content of 4.7% from their native moisture content of 9.3%. The soil was dry, dusty, and friable. Two screen combinations were tested. One was a 2-in. primary screen with a 1-in. secondary screen. The other was a 2-in. primary screen with a 0.75-in. secondary screen. Both were combinations used by Range Master. Test results for both screen combinations indicated that the site soils were able to be screened up to a moisture content of 18% to 20%. At these moisture contents, the soil lost its dry characteristics and began to clump and retain soil on the screens (see Appendix B, Soil Sieve Test Report).

### **3.3.2 Pre-Demonstration DGM**

Following the initial surface sweep of the five consecutive 50- x 50-m demonstration grids by Shaw, Sky Research (Sky) performed the pre-excavation DGM of the selected grids. USA processed and analyzed all of the time gates from the EM61-MK2 array deployed by Sky. The DGM data from time gate 3 showed the best overall response and documented that the grids were heavily contaminated with subsurface metal, typical of areas adjacent to a bombing target. This data was acquired with an array of EM61-MK2 all metals detectors. The data shown in Figure 30 is for Time Gate 3 and documents that the selected demonstration area is a high density site.



Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

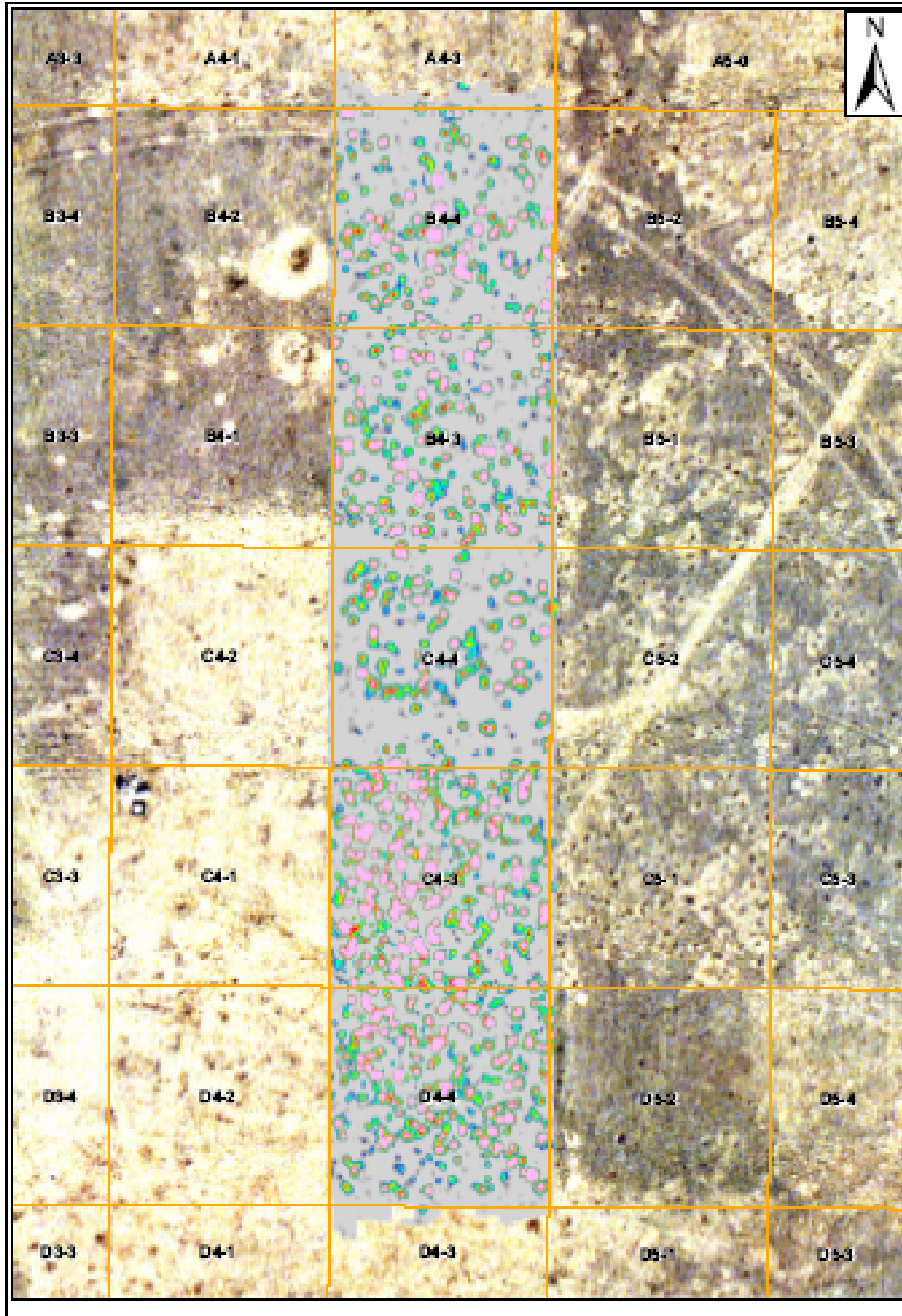


Figure 30: Pre-Excavation DGM of Demonstration Grids at FLBGR BT#2

### 3.3.3 Period of Operation

The Phase II Range Master Demonstration was performed over a 2-week period from 18 June through 29 June 2006 at Bomb Target #2 at the former Lowry Bombing and Gunnery Range, Colorado. Armed with an approved ESS Addendum, the soil sieve tests indicating that the local soils are able to be screened during dry seasons, and the pre-excitation DGM, the team mobilized for the Phase II Range Master Demonstration, scheduled for the week of 18 June 2006.

### 3.4 Mobilization

Timberline Environmental Services, Inc. mobilized the Range Master on a 9-axle trailer from Elkton Farms, Maryland, to FLBGR, Colorado (see Figure 31). The system arrived and was staged in the Shaw compound on 18 June 2006. The rest of the demonstration team mobilized on 18 June.



Figure 31: Range Master Transported on 9-Axle Trailer

### 3.5 Set Up

*Monday and Tuesday, 19 – 20 June 2006* – Met at the Shaw compound at 0740 and received Site Health and Safety briefing. Shaw had contacted Utility Notification Center of Colorado and received clearance for the Phase II excavation activities at FLBGR BT#2.

Range Master preparation activities included putting air in the system's tires, driving it off the transportation trailer, installing the 0.75-in. screen bolted over the 1.0-in.-secondary screen, pulling a hydraulic pump, rebuilding it to proper specifications and reinstalling it, installing the video cameras and antennas, and getting the cab air conditioning repaired. At the end of the

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

second preparation day, Range Master was mobilized to BT#2. Both the Remote Control Platform and the Range Master were staged next to a cleared and marked practice area (see Figure 32). The practice area was adjacent to the Demonstration grids at BT#2, but outside the Minimum Safe Distance established in the approved ESS Addendum.



**Figure 32: Range Master and the Remote Control Platform at the Cleared Practice Area**

### 3.5.1 Area Excavated

During this demonstration, Range Master excavated grids B4-4, B4-3, C4-4, and C4-3. Grid D4-4 was not excavated.

*Wednesday, 21 June 2006* – The morning was spent installing the Remote Control Platform antennas and running through the system checkout, including all emergency stops. The system was exercised over the practice area, first in manual mode, and then in remote mode (see Figure 33). With the video-enhanced field of view, the Range Master was easier to operate in the remote mode. The procedure to inspect the Range Master for lodged MEC was rehearsed.

By the end of the afternoon, Range Master was positioned at the demonstration grids. Shaw walked the team around the five consecutive 50-m grids. The edges of the demonstration grids were marked with orange marking paint to help guide the Range Master operator. Demonstration excavations began at 1421 hours (2:21 PM) and continued until 1611 hours (4:11 PM), completing a net of seven west-to-east 50-m excavation runs (see Excavation Times by Line in Appendix C). The dump hopper was left open on two runs and one run was a very shallow excavation. All three runs were repeated. Prior to the team accessing Range Master or inspecting the excavation results, the system was shut down, and the Remote Control key was handed to the UXO Safety Officer. The Safety Officer then drove to the Range Master and thoroughly inspected it for lodged MEC before issuing an “all clear” call.



**Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**



**Figure 33: Range Master at FLBGR BT#2**

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

**Thursday, 22 June 2006** – The Phase II demonstration was continued all day, completing 31 excavation runs. The demonstration began using overlapping runs along the west/east 50-m lines. It was hoped that the Range Master could excavate along the 250-m north/south lines; however, the hopper was filling even along the 50-m lines. As the demonstration continued, the operation shifted from excavating overlapping lines to leaving an unexcavated Mohawk between runs, and then coming back to excavate each Mohawk.

It was noted that the 0.75-in. screen bolted to the 1.0-in. secondary screen created an effective screen mesh finer than the desired 0.75 in. This had the effect of loading the hopper with unprocessed soil prior to reaching the end of each excavation run. At the end of the day, together with the State Regulator, and ESTCP, it was decided to remove the 0.75-in. screen and continue with the 2.0-in. primary screen and the 1.0-in. secondary screen.

**Friday, 23 June 2006** – The morning was spent removing the 0.75-in. screen. The demonstration continued at 1232 hours, completing a total of 23 runs. The first seven runs were shorter than 50 m because the grid end marks had become hard to see. The average excavation times for the 1.0-in. secondary screen improved slightly, but the larger improvement was in smaller piles dumped at the end of each run, meaning the Range Master was processing the site soil more effectively. The 0.75-in. screen bolted to the 1.0-in. screen left large dump piles 3 to 4 ft high. This was a result of unprocessed soil passing over the power screen and into the hopper before it could be sifted. These dump piles included objects that were successfully screened and captured along with objects that were simply captured with the excess unprocessed soil. After the 0.75-in. screens were removed, leaving the original 1.0-in. screens, Range Master was better able to process the site soils, resulting in “smaller” dump piles of 1 to 2 ft high.

Scott Millhouse observed the demonstration on Friday and with only two of the five grids completed, encouraged the team to extend the demonstration to complete the five demonstration grids. ESTCP agreed and arrangements were made to extend the demonstration.

**Monday, 26 June 2006** – After 17 runs, working through the third grid and into the fourth grid, the Range Master experienced a hydraulic leak. The system was shut down immediately. The source of the leak was a blown oil filter seal. Part of the team began recovering the contaminated soil into 55-gallon drums while the filter was replaced, and the hydraulic oil reserve was refilled. When the Range Master was restarted, it was discovered that the screen shaker motor was not operating. Operations were concluded for the day.

**Tuesday, 27 June 2006** – The team disassembled the shaker motor coupling from the screen and discovered that the coupling teeth had been destroyed and needed replacement. A replacement coupler was located in North Denver, purchased, the keyway milled to fit and reinstalled. The demonstration continued by 1145 hours, reaching the south end of the fourth grid boundary by 1338 hours.

Shaw expressed concern about the amount of soil in each dump pile, and the need to restore the site prior to demobilizing for the Fourth of July break. The demonstration operations then shifted from excavating grids to reprocessing the dump piles along the four completed grids' east boundary (200 m) in order to reduce the amount of soil in each pile. By the end of the day ten



## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

runs were made south to north through the dump piles, creating a new pile in the site's northeast corner.

*Wednesday, 28 June 2006* – Completed reprocessing the dump piles with additional runs south to north. The new pile, in the site's northeast corner, was processed again, with runs east to west, creating a final pile in the site's northwest corner.

The Range Master was then used to restore the condition of the four excavated grids. For this effort, the hopper was left open and the Range Master traversed the grids north to south and south to north in a rototiller mode to smooth the site. A total of 21 runs were made to level the site. The UXO Safety Office conducted an MEC inspection before the Range Master was moved to the Practice Area.

*Thursday, 29 June 2006* – Range Master was used to restore the practice area, using the same rototiller technique. The system was hosed clean and received a final MEC inspection prior to leaving BT#2 and returning to the Shaw compound.

### 3.5.2 Residuals Handling

Shaw processed and handled all of the residual materials excavated by Range Master during the Phase II Demonstration. This included examination of the final dump pile and a second surface sweep to recover any objects exposed by Range Master.

### 3.5.3 Operating Parameters for the Technology

The key design criteria for the Range Master is matching the selected screen mesh with site soil and vegetation conditions and selecting sites where the expected MEC does not exceed the design limitation of a 105mm projectile. The Range Master was initially fitted with a 0.75-in. screen bolted over the 1.0-in. secondary screen for this demonstration, in order to capture potential 20mm projectiles. During the Phase II demonstration, this fine screen mesh proved to be a challenge to process. This slowed the excavation rate and tended to fill the hopper with excess soil, resulting in larger (3 to 4 ft high) dump piles. Once the 0.75-in. screens were removed, leaving the 1.0-in. secondary screens, the system was better able to process the site soils. Timberline supported the demonstration with a qualified remote control operator, but without experience in scraper operation. This proved to be the limiting factor in the overall Phase II demonstration performance. USA supported the demonstration with the UXO Safety Officer and the Principal Investigator. Records of time were kept in elapsed time format for the start of each excavation line, each excavated item dump, and the turn time for each line.

### 3.5.4 Experimental Design

All excavation lines were run from west to east. An average of 20 lines was used to excavate each 50-m grid.

Range Master removed and exposed 2,133 metal pieces, totaling approximately 508 pounds from the four grids excavated. From the post-excavation DGM, it is clear that this represents only a portion of the objects that should have been removed. Displaying the DGM results at lower scales only highlights the fact that Range Master's first operational demonstration did not accomplish all that it could have. As explained in Subsection 4.3, the Range Master operator was

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

very skillful at safe remote operation, but not sufficiently experienced in scraper operation. Instead of stopping to process excess soil on the screens, the operator raised the cutting blade to reduce soil throughput. These shallower-than-planned excavations failed to capture many of the near-surface objects. Timberline Environmental Services, Inc. has reevaluated this approach and has decided that the best path forward will be to train experienced scraper operators in remote control operation.

### 3.5.5 Sampling Plan

N/A

### 3.5.6 Demobilization

Following the Phase II demonstration, Range Master was used to restore the practice area, using the same rototiller technique. The system was hosed clean and received a final MEC inspection prior to leaving BT#2 and returning to the Shaw compound. The demonstration personnel demobilized. Shaw then performed a second surface clearance of the four grids excavated and inspected the final dump pile. All excavated material was cataloged and processed by Shaw personnel. Sky then surveyed each excavated grid with their EM61-MK2 towed array to document post-Range Master geophysical site conditions.

## 3.6 Selection of Analytical/Testing Methods (for Remedial Technologies)

The following analytical methods were used to monitor and evaluate the Phase I Range Master performance.

### 3.6.1 Excavation and Production Rates

Table 5 shows the average excavation times achieved during this Phase II Demonstration. There was no effect of the finer 0.75-in. plus 1.0-in. secondary screen vs. just the 1.0-in. secondary screen on the average excavation times to complete a 50-m run. However, the Range Master was able to process the site soils more effectively with just the 1-in. secondary screen. This resulted in smaller dump piles at the end of each run. Appendix C includes Table 11 of each run time. Range Master reprocessed the dump piles to reduce the amount of site soils in the piles. This moved the piles, deposited on the east boundary of each west-to-east run, to the northeast corner of the demonstration area. Range Master was then used to level the site, in preparation for the Post-Excavation DGM. It was then decided to process the dump pile again to reduce the amount of soil one more time. This effort moved the dump pile from the site's northeast corner to the northwest corner.

**Table 5: Average Excavation Rates per 50-m Grid**

Average 50-m Excavation	0:07	minutes
Average Runs/50-m Grid (0.62 acres)	20	runs
Average 200m Reprocess	0:08	minutes
Average 200m Leveling Run	0:03	minutes
Average Re-Reprocess	0:02	minutes

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

The demonstrated excavation rate per 50-m grid is calculated by multiplying the average time per 50-m line (7 minutes) by the average number of lines per grid (20 each) = 2:31 hours:minutes. This equates to just over 4 hours per acre (0.62 acres per 50-m grid).

Practically, the excavations took longer, accounting for routine MEC inspections and maintenance. Adding all of the excavation times and maintenance times and dividing that by four grids resulted in a practical excavation rate of 6:49 hours:minutes per 50-m grid or approximately 11 hours per acre.

Taking the entire Phase II demonstration days into account, including setup and storage, the actual excavation rate was 1.5 days per 50-m grid or 2.4 days per acre.

This still compares favorably to conventional excavate and sift operations, where the production rate is 40 hours per acre or 4 10-hour days per acre (see Table 6).

**Table 6: Range Master Phase II Production Rates**

Demonstrated Excavation Rate/50-m Grid	2:31	hours:minutes	4.1	Hours/acre
Practical Excavation Rate/50-m Grid, including inspections and maintenance	6:49	hours:minutes	11.0	Hours/acre
Actual Excavation Rate/50-m Grid	1.5	days	2.4	days/acre
Conventional Excavate & Sift			40	Hours/acre

### 3.7 Excavated Items

Following the excavation, Shaw inspected the dump areas and the final dump pile. They also performed a second surface clearance to recover items newly exposed by Range Master and to prepare the site for post-excavation DGM by Sky. Table 7 summarizes the items excavated by Range Master and recovered by Shaw (see Figure 34):

**Table 7: Items Excavated by Range Master from BT#2**

Item Excavated	From Dump Piles		From Grids	
	Count	Unit	Count	Unit
Mk 23 Bomb	35	each	15	each
Booster Cup	3	each		
Booster (M152 Fuze)	2	each		
HE Bomb Frag	1	each		
HE Frag	3	each		
OE Scrap	2,059	each		
2.25" Rocket	1	each		
Small Arms	11	each		
Non OE Scrap	3	each		
Subtotals	2,118	each	15	each
Estimated Weight of Items Excavated	443	lbs	65	lb

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)



**Figure 34: Photographs of Items Excavated by Range Master from FLBGR BT#2**

### **3.7.1 Improved Geophysical Site Conditions**

Following the second surface clearance, Sky performed the post-excavation DGM of the four grids excavated by Range Master. USA Environmental analyzed the data from all four EM61-MK2 time gates. Of all of the times gates, time gate 3 showed the best before and after

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

response. All of the post-excavation DGM time gates are more active than the pre-excavation DGM. The reasons that explain this are:

1. The soil was loosened by Range Master so the towed array sensor support sank in, moving the sensors closer to the ground.
2. Range Master moved and brought objects closer to the surface, but failed to capture and remove them.

The site is close to target center and is truly cluttered with metal at a full range of depths with much, if not most, below 12 in. Range Master was successful in removing a lot of the near surface metal, but failed to get it all within its operational design (the first 12 in.). Section 4.2.4, which describes and depicts the before excavation and after excavation DGM results, documents that a significant amount of the subsurface metal remains below the Range Master's excavation depth (typically 12 in.). In hindsight, this is to be expected for a bombing target.

No analytical analysis was performed on the DGM maps (e.g., target analysis). However, a comparison of the pre-excavation DGM maps from the post-excavation DGM maps (before and after) demonstrates that there was little to no significant improvement in site geophysical conditions. For the first live site demonstration of the Range Master, USA is pleased with these results. Most of the near-surface clutter and MEC simulants were removed from the grids, creating much improved geophysical site conditions. The simulated 105mm buried 3 ft in the center of each grid are easily detectable in the post-excavation data. The seed items left behind are also easily detectable.

### 3.7.2 Down-Time

Down time was calculated from the time the Range Master was on-site through the Phase II demonstration. The Range Master was available for operations a total of nine days, or 216 hours (9\*24). The Range Master does require regular maintenance. Table 8 summarizes the maintenance performed during this demonstration. The first 2 days on site were spent preparing the system for demonstration. Regular MEC inspections, system restarts, and clearing camera lenses were routine. Removing the 0.75-in. screen over the 1.0-in. secondary screen (see Figure 35) was extra maintenance time, as was the repair of the screen shaker coupler (see Figure 36). It proved advantageous that the demonstration was performed near the city of Denver, Colorado, where a spare coupler was found, purchased, modified, and installed in half a day.



**Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**

**Table 8: Range Master Maintenance Times during the Phase II Demonstration**

Day 1 - Pre-Demonstration	8	Hours	Install 0.75-in. Screens & Hydraulic Pump Repair
Day 2 - Pre-Demonstration	8	Hours	AC Repair
Day 3 - Practice & Demonstration	0	Hours	
Day 4 - Demonstration	0.5	Hours	Clean Rear Camera Lens
Day 5 - Demonstration	4.5	Hours	Pulled out 0.75-in. screens
Day 5 - Demonstration	2.5	Hours	Shifting Repair - Remote Computer Reset
Day 6 - Demonstration	6	Hours	Hydraulic Leak from Blown Filter Gasket
Day 7 - Demonstration	3	Hours	Shaker Coupler Replacement
Day 7 - Demonstration	1	Hours	Tighten Top Port Screen
Day 8 - Demonstration	1	Hours	Reset Remote Computer Twice
Day 8 - Demonstration	1	Hours	Final MEC Decontamination
Day 9 - Demonstration	1.5	Hours	Final Wash Down
Total Maintenance Time	37	Hours	Total Maintenance Time
Demonstration Maintenance Time	21	Hours	Demonstration Maintenance Time



**Figure 35: 0.75-in. Over 1.0-in. Secondary Screen**



**Figure 36: Broken (left) and Replacement Shaker Coupler (right)**

The Range Master's availability was calculated as a percentage of demonstration down time (1-(21/216)) = 90.3%. The total Phase II maintenance and down time was 9.7%. This includes set up time to mount the 0.75-in. screens, hydraulic pump repair, and air conditioning repair.

### **3.8 Selection of Analytical/Testing Laboratory**

N/A

## 4.0 Performance Assessment

### 4.1 Performance Criteria

Performance for the Phase II Range Master Demonstration was documented in the areas of (1) Safety, (2) Excavation Rate, (3) Item Recovery, (4) Improved geophysical site conditions, (5) Ease of Use, and (6) Down Time (refer to Table 8 for details).

### 4.2 Performance Confirmation Methods

The following sections document the Phase II results.

#### 4.2.1 Range Master OE Safety Assessment

The safety assessment for the Phase II Range Master was good. USA's UXO Safety Office observed all aspects of this demonstration, from setup to cleanup. Personnel working in close proximity to the Range Master were required to wear a hard hat. Throughout the demonstration, there were no personnel injuries. The remote Range Master operation was considered safe. There was no design-inherent damage to the Range Master. The UXO Safety Officer's report follows:

Phase two testing on Range Master was conducted at former Lowery Bombing and Gunnery Range, Denver, Colorado, on 19-29 June 2006. The continued development of safety standards are a part of the Range Master testing. New safety measures were identified while in the remote configuration and will be written into future safety plans for the Range Master.

All team members on the first day of operation were given a full and comprehensive briefing to include the Shaw site safety brief and a site specific ordnance brief of all known MEC expected at Bomb Target # 2. The Range Master demonstration UXO Safety Officer then gave a series of briefings for PPE, specific heavy machinery safety associated with Range Master, and Minimum safe distances while in all operating modes, Contingency plans for all emergency situations evacuation routes and communication procedures. A walk around familiarity with Range Master was conducted by Timberline Environmental Services, Inc.

Safety measures were put into place for the remote operation of Range Master that were effective throughout the testing phases and provided personnel a safe environment at all times. In addition to normal heavy equipment safety procedures, specific remote operations safety was incorporated, to include positive shutoff key control and downrange access entry limitations.

The inspection process for possible lodged ordnance was conducted on as-needed intervals and prior to all maintenance issues. Ordnance found on or near Range Master was evaluated by the UXOSO and either removed or referred to Shaw Environmental for proper disposal.

In conclusion, all safety issues were addressed and some new safety identified concerns pertaining to remote operations were developed. During the Phase II demonstration, it was noted that soil built up under the arms that control the lifting paddles. The effect was to push the paddles up and away from the backing plate and potentially hiding hazardous objects. Operationally this produced a rolling "wave" of soil in front of the cutting edge and less effective soil/object lifting. In terms of safety, these pockets of soil represented sources of potential

## **Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**

hazards. The new safety measure was to add the inspection of the paddle arms and manually clear any soil built up prior to continuing operations to the standard system inspection. No hazardous objects were discovered during any of the Range Master inspections. Range Master personnel maintained a positive safety attitude throughout the testing phase. No detonations or MEC problems occurred, and no accidents, near misses or safety violations took place.

### **4.2.2 Excavation and Production Rates**

Please see Subsection 3.6.1, Excavation and Production Rates.

### **4.2.3 Excavated Items**

Please see Subsection 3.7, Excavated Items.

### **4.2.4 Improved Geophysical Site Conditions**

Following the post-demonstration surface clearance by Shaw, Sky performed the post-excavation DGM of the four grids excavated by Range Master. Figure 37 shows both the before excavation and after excavation DGM results. From this data; it is clear that a significant amount of the subsurface metal remains below the Range Masters' excavation depth (typically 12 in.). In hindsight, this is to be expected for a bombing target. The demonstration Work Plan did allow for a post-excavation depth evaluation using a probe technique. However, this task was not performed or reported. From walking each excavation lane and visually observing the cuts, it was obvious that the cutting blade was typically set too deep at the beginning of each pass, causing the Range Master to plow into the ground too deeply and quickly overloading the screens. To correct this, the blade was raised too much, resulting in uneven and ineffective excavation. The scalloping along each pass was a clear demonstration of inexperience in excavation technique.



Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

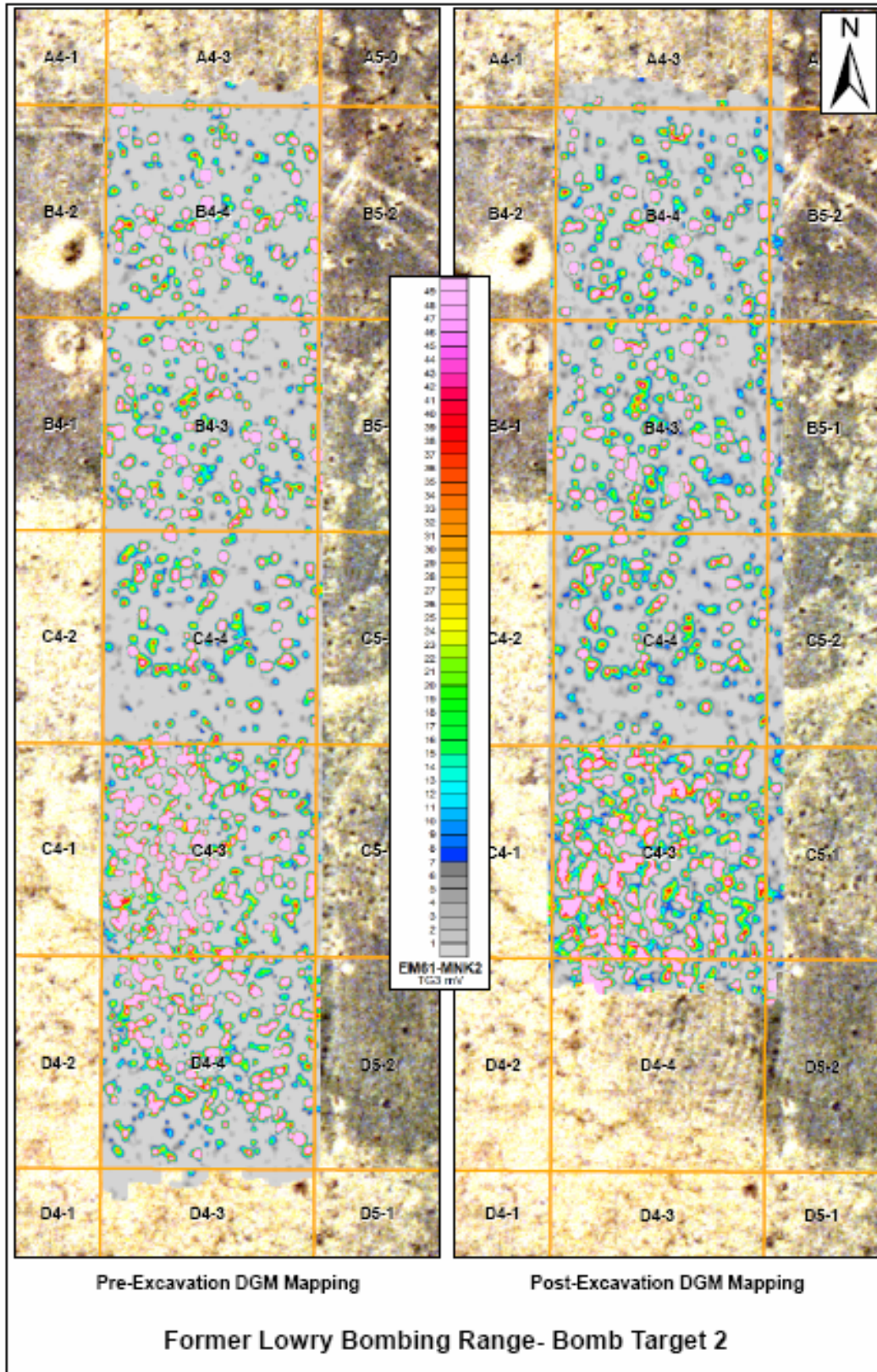


Figure 37: Pre- and Post-Excavation DGM



#### **4.2.5 Ease of Use**

The Phase II Range Master (Armored and Remote Controlled) proved easier to use than manual operation. This is attributed to the video provided to the operator, providing an all-around view. The display of the instrument cluster and the audio from the Range Master cab proved to be invaluable in monitoring and operating the system.

The single remote control key in the control platform provided the necessary safety assurance during all required maintenance and inspections (this key was given to the UXO Safety Officer to prevent any accidental remote operation). Although used only during setup, the emergency stop switches provided an extra level of safety. The flashing strobe on top of Range Master provided a clear indication that the system was in remote operation.

There were limits on visibility caused by the dust created during excavation. This most affected the visibility of the start and end marks (orange marking paint) for the excavation area. A GPS with the site boundary and planned tracks would help greatly. Limited visibility also obscured the screening area, making it difficult to judge the soil processing rate at times.

#### **4.2.6 Down-Time**

Please see Subsection 3.7.2.

### **4.3 Data Analysis, Interpretation, and Evaluation**

In terms of performance, the Phase II Range Master demonstrated safe and effective remote control operation. The inexperience of the operator in scraper operation proved to be a limiting factor in maintaining a 12-in. excavation depth. The design concept is solid and with the deployment of operators experienced in scraper use and trained in remote operation, Range Master is ready for additional demonstrations or production use.

#### **4.3.1 Excavation Experience**

At one of the In Progress Reviews, ESTCP asked if the Range Master operator needed excavation experience. Our answer at the time was that we thought someone with greater remote control skills would make a better operator. However, this demonstration highlighted that there needs to be a balance of both skills. The Phase II operator demonstrated great skill in safely and effectively maneuvering the Range Master throughout the demonstration. However, their inexperience in excavation resulted in a scalloped excavation depth ranging from just barely scraping the surface to more than 18 in. below surface. An operator with excavation experience would have used the depth of cut more effectively to control forward speed and provided a more uniform excavation.

#### **4.3.2 Site Expectations**

It was originally expected that Range Master would excavate the grids in the long 250-m (north/south) direction vs. the shorter 50-m (east/west) direction to minimize turnaround times and maximize production. However, the system hopper was filled, mostly with unprocessed soil,

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

prior to completing a 50-m run. With the desire to keep the dump piles off the demonstration grids, the shorter 50-m run was used throughout the demonstration.

The prairie grass was not expected to present an issue for Range Master. However, this species of vegetation has long runners that would often blind even the primary 2.0-in. screen. Range Master either needs to clear the vegetation in one pass, or a means of clearing vegetation from the screens needs to be developed.

Although BT#2 provided a good opportunity for the Phase II demonstration, the fact that it was a former bombing target, with significant amounts of metal below the Range Master's excavation depth (typically 12 in.), was unfortunate. Range Master is better suited to live sites where the majority of metal is within the first 12 in. of the surface (e.g., artillery, mortar, grenade, or strafing ranges).

## 5.0 Cost Assessment

### 5.1 Cost Reporting

USA tracked the demonstration costs for the Phase II Range Master demonstration (Table 9). Costs are broken out for USA and Timberline, and for the original demonstration schedule (first 5 days) and the extended demonstration (additional 4 days). Please note that Timberline did not charge for the original Phase II demonstration, nor did they include the mobilization or demobilization costs for Range Master.

**Table 9: Cost Tracking**

Cost Category	Sub Category	Details
Original Phase II Demonstration		
Start-up Cost	Mobilization	\$ 3,873.90
	Demonstration Set-up	\$ 1,503.45
	Demonstration	\$ 9,626.10
Capital Costs	Range Master – Sunk Cost	\$ 0.00
Demonstration Operating Cost	Timberline	\$ 0.00
Original Demonstration Cost		\$15,003.45
Extended Phase II Demonstration		
	USA Costs	\$ 6,013.80
	Timberline Costs	\$21,493.60
Extended Demonstration Cost		\$27,507.40
<b>Total Phase II Demonstration Cost</b>		<b>\$42,510.85</b>

### 5.2 Cost Analysis

This section is designed to assess the demonstration costs and extrapolate a more realistic cost estimate for fielding the Range Master.

#### 5.2.1 Cost Comparison

Previous testing of the technology was described in the pre-proposal testing of the Range Master Excavator and an independent screening unit (Phase I Final Report). This closely represents the current state of use for sifting operations at MEC sites where soils are excavated, hauled to a sifting unit, and fed through the screens. Screened items are inspected for MEC and are disposed of. Sifted soils are returned to the site. During this pre-proposal test, the unmodified Range Master excavated an area equivalent to nine (9) 100- x 100-ft grids, about 2.1 acres. The dry excavated soils were fed to the original screening system that is now scaled down in Range Master. Screened items were identified, sorted, and disposed of. The sifted soils were returned to the site. The cost for this conventional operation was \$105,690.00 or  $(\$105,690.00/9)$  \$11,743.33 per 100- x 100-ft grid or  $(\$105,690.00/2.1 \text{ acres})$  \$50,328.57 per acre. The soil conditions for this test were optimal (dry).

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

The Phase II demonstration integrated this process on a common platform and performed the operation remotely on-site. The same, but modified (now armored and controlled remotely), base carrier was used. The integrated screening unit was a scaled-down version of the same unit used for the pre-proposal test. The sifted soil was returned to the site in real time while the screened items were dumped for inspection. The soil conditions for the Phase II Demonstration were optimally dry.

Table 10 extracts the costs associated with the practical demonstration. It includes mobilization for the Range Master, Operator, Mechanic, UXO Safety Officer, and Project Engineer, labor for the actual demonstration time (50 hours), Range Master cost, consumed fuel and hardware, site restoration, and demobilization. USA would like to note that on a real job, an additional UXO team would be required to handle disposal of any recovered UXO. The minimum team would consist of three (3) personnel; a UXO Technician III (team leader), a UXO Safety Officer, and a UXO Technician II or III. For this part of the report, USA used the actual rates for the UXO Safety Officer.

A significant savings in time and cost was demonstrated, although these costs must be tempered. The demonstration time per grid averaged (50 hr/4 grids) 12.5 hours per 50-m grid or 20.25 hours per acre. The pre-proposal test demonstrated an average 20 hours per 100-ft grid or 87.12 hours per acre. Although the Phase II excavation proved to be inconsistent due to inexperience in excavator operation, it can be expected that Range Master will significantly reduce the time needed to excavate and sift high density UXO sites. The average cost per acre detailed in Table 10 was \$46,235.77. The pre-proposal test sifted a total of nine (9) 100- x 100-ft grids, or 2.1 acres at a cost of \$50,328.57 per acre.

**This represents a potential savings of \$4,092.80 per acre.**

**Table 10: Practical Demonstration Costs**

Cost Element	Unit Cost	Cost for 5 days
Mobilization		
USA Mobilization	UXO Safety Officer	\$ 3,873.90
Timberline Mobilization	Subtotal	\$41,910.00
	Range Master \$38,000.00	
	Support Vehicle \$2,437.00	
	Air Fares \$450.00	
	Labor \$1,023.00	
Mobilization Subtotal		\$45,783.90
Demonstration		
USA Demonstration Costs	\$ 751.73 per day * 5 days	\$ 3,758.63

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

Cost Element	Unit Cost	Cost for 5 days
Timberline Labor and Per Diem	\$2,109.00 per day * 5 days	\$10,545.00
Range Master	\$4,000.00 * 5 days	\$20,000.00
Support Vehicle	\$93.60 * 5 days	\$ 468.00
Fuel and Consumables	\$450.00 * 5 days	\$ 2,250.00
Demonstration Total		\$37,021.63
Demobilization		
USA Demobilization		\$ 3,873.90
Timberline Demobilization	Subtotal	\$28,910.00
	Range Master \$25,000.00	
	Support Vehicle \$2,437.00	
	Air Fare \$450.00	
	Labor \$1,023.00	
Demobilization Total		\$32,783.90
Practical Demonstration Total		\$115,589.43
Total per 50- x 50-m Grid	\$115,589.43/4 50-m grids	\$28,897.36 per 50-m Grid
Total per Acre	\$115,589.43/2.5 Acres	\$46,235.77 per Acre
Total per 10 Hour Day	\$115,589.43/50 Hours	\$23,117.89 per Day

### 5.2.2 Cost Basis

The proposed cost for the Phase II demonstration was \$13,500.00. This did not include any costs from Timberline, including all mobilization, labor, and per diem costs. The practical demonstration costs were \$115,589.43. The basis for determining more realistic real world work costs were based on the actual mobilization/demobilization and the demonstration costs prorated to the 50 hours of actual work time. From the prorated cost, the costs per 50-m grid, the cost per acre, and the cost per 10-hour day were calculated.

These prorated costs are based solely on the limited demonstration data of mobilizing equipment and personnel to excavate four 50-m grids. A more likely scenario would cover a larger area. This would allow the high mobilization/demobilization costs to be spread over a larger area.

### 5.2.3 Cost Drivers

Mobilization/demobilization, contiguous excavation area, soil and terrain conditions, and on-site maintenance are considered the major cost drivers. The Range Master's weight requires a heavy-duty 9-axle trailer, with special permits and escorts required, to move it from place to place. The best estimate for Range Master transportation costs are \$18/mile. Maintenance costs need to be considered in terms of time and materials costs and availability. Most parts are available off-the-shelf, either new or used, world-wide. Maintenance of these items will be minimal. However,



## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

should the Range Master require depot level maintenance, either bringing the depot on-site or returning the Range Master to the depot, will add significant cost and time.

### 5.2.4 Life Cycle Costs

The life cycle costs for Range Master #1 include the purchase price (\$100,000.00) plus the project start up task funded by USAESCH (\$25,000.00) plus the Phase I and Phase II development costs, including non-recurring engineering and design (\$804,470.00). The expected life of the scraper is estimated at 5,000 hours, or 500 10-hour work days. Operation and maintenance costs are included in the Range Master rental rate of \$4,000.00 per day (\$2,000,000.00). This brings the expected life cycle cost of Range Master #1 to a total of \$2,929,470.00.

The current Range Master rental rate of \$4,000.00 per day is expected to maintain the system throughout its expected life. The estimated transportation cost of \$18.00 per mile can be used as a guide for planning (this does not include personnel mobilization/demobilization costs).

## **6.0 Implementation Issues**

### **6.1 Environmental Checklist**

The use of the Range Master will require permission to excavate. At some sites, this may require that a digging permit be obtained. Limiting the excavation to 18 in. or less may negate this requirement.

### **6.2 Other Regulatory Issues**

For the Phase II demonstration, an ESS Addendum was written and approved to bring the Range Master technology onto the demonstration site. Timberline will continue to seek DDESB approval of the Range Master technology for live site use.

Some active range installations may require frequency allocation for the Range Master video and telemetry radio links. Local air fields and emergency response organizations should each be informed of these frequencies and power specifications.

### **6.3 End-User Issues**

End-user issues and concerns are detailed in Subsection 1.4 above. From the Phase II Demonstration, a method to measure and assess Range Master excavation depth needs to be established and a track guidance feature needs to be implemented.

## 7.0 References

### 7.1 Phase II Demonstration Plan

Phase II Demonstration Plan for Test, Evaluation, and Demonstration of the Range Master, a Tool for Excavation of Heavily Contaminated UXO Sites, dated March 2006.

## APPENDIX A. POINTS OF CONTACT

Personnel responsible for the management and operation of this project demonstration are as follows.

### **Project Manager**

Mr. Al Crandall was responsible for overall project accomplishment.

Phone: (813) 343-6362, Cell: (813) 997-3325  
Email: [acrandall@usatampa.com](mailto:acrandall@usatampa.com)  
Address: 720 Brooker Creek Blvd., Suite 204, Oldsmar, FL 34677

### **Range Master Operator**

Mr. Terry Northcutt was responsible for Range Master mobilization, operation and maintenance, reports to Project Manager. Mr. Northcutt is the primary point of contact for TES on this project.

Phone: (209) 965-3118  
Email: [terry@timberlineenvsv.com](mailto:terry@timberlineenvsv.com)  
Address: 29925 Highway 108, Cold Springs, CA 95335

### **UXO Safety (USAE)**

Mr. Larry Mash was responsible for the Range Master safety assessment during all phases of demonstration, real time observation of the screened material during excavations, and all routine inspections of Range Master for potential lodged UXO.

Phone: (813) 343-6364  
Email: [lmash@usatampa.com](mailto:lmash@usatampa.com)  
Address: 720 Brooker Creek Blvd., Suite 204, Oldsmar, FL 34677

### **COE Project Manager**

Mr. Jerry Hodgson was the primary point of contact with the Corps of Engineers; Omaha District for the work going on at the former Lowry Bombing and Gunnery Range.

Phone: (402) 221-7709  
Email: [jerry.l.hodgson@nwo02.usace.army.mil](mailto:jerry.l.hodgson@nwo02.usace.army.mil)  
Address: U.S. Army Corps of Engineers, Omaha District  
215 North 17<sup>th</sup> Street, Omaha, NE 68102

### **FLBGR OE Specialist**

Mr. Jim Anelle was the primary point of contact for the Phase II Range Master operation at BT#2 of the former Lowry Bombing and Gunnery Range for the Army Corps of Engineers, Omaha District.

Phone: N/A  
Email: N/A

## **Remote Excavation of Heavily Contaminated UXO Sites (Range Master)**

Address: U.S. Army Corps of Engineers, Omaha District  
215 North 17<sup>th</sup> Street, Omaha, NE 68102

### **Shaw Project Manager**

Mr. John Mullen was the senior project manager for Shaw at FLBGR. John was responsible for all Shaw tasks relating to this demonstration including surface sweeps, MEC inspections and disposal, range scheduling and logistics, and site restoration.

Phone: (303) 741-7682, cell (303) 475-7395  
Email: john.mullen@shawgrp.com  
Address: Shaw Group  
9201 East Dry Creek Road  
Centennial, CO 80112

### **Sky Project Geophysicist**

Mr. Bart Hoekstra was responsible for pre and post excavation DGM test grid characterization, geophysical outputs, and reports. Sky is also responsible for the site soil analysis and report.

Phone: (303) 680-8109  
Email: N/A  
Address: Sky Research, Inc.  
21196 E. Euclid Drive  
Centennial, CO 80016

### **USAESCH Contracting Officer's Technical Representative**

Mr. Scott Millhouse is the contracting officer's technical representative (COTR) for this project. Scott provided valuable technical input on the Range Master design, soil sieve testing, and the Phase II demonstration.

Phone: (256) 895-1607  
Email: [scott.d.millhouse@hnd01.usace.army.mil](mailto:scott.d.millhouse@hnd01.usace.army.mil)  
Address: 4820 University Square  
Huntsville, AL 35816



**APPENDIX B. SOIL SIEVE TEST REPORT**



June 2nd, 2006

Shaw Environmental & Infrastructure, Inc.  
Centennial, Colorado 80112-2818

Attn: Morey Engle

Re: Range Master Soil Sieve Testing Program

Dear Morey,

Advanced Terra Testing, Inc. (ATT) is pleased to present Shaw Environmental & Infrastructure (SHAW), the results of the Range Master Soil Sieve Testing Program. This letter report will summarize the test procedures used, and present the results of the testing program.

There is no American Society for Testing Material (ASTM), American Association of State Highway and Transportation Officials (AASHTO), or Army Corp of Engineers (COE) testing procedure which outlines the test methods to be followed for this particular testing program. The testing procedures followed, were a combination of objectives laid out in the Range Master Soil Sieve Test Plan provided by SHAW and various ASTM test procedures. Additional direction was provided via a conference call with ATT, SHAW, Scott Millhouse, Al Crandall, and Meggan Pickner on Thursday May 18<sup>th</sup>, 2006. The laboratory was allowed to use their discretion to facilitate the testing process.


ATT received ten (10) five gallon buckets of bulk soil material from the Former Lowry Bombing and Gunnery Range (FLBGR) Bomb Target #2 (BT#2) test area. The bulk soil material weighed approximately 460 pounds at the as-received moisture content. All of the material was composited, and mixed thoroughly. A portion of the composited material was split out and used to determine the as-received moisture content. The moisture content was determined by ASTM D2216 (Moisture Content). The moisture content of the as-received material was 9.3%. Visually, the material appeared dry, and created dust during the compositing and mixing phase. The sample was spread out on a tarp in a 2-3" lift and allowed to air dry for approximately 48 hours. Fans were used to help reduce the moisture content. At the end of the drying period, the sample was remixed and a moisture content was performed using ASTM D2216. This moisture content at this point was 4.7%. The bulk soil was then split up into 30 pound samples and placed into buckets and sealed with lids to maintain the moisture content. We were able to obtain 14 samples to be used in the testing program.

At this point of the testing program, the decision was made to deviate from the original plan. Visual observations of the sample at 4.7% and 9.3% moisture (dry, dusty, friable), suggested that drying the sample to 0% moisture, which would be difficult due to the quantity of material, would not provide any sieve data that could not be extrapolated from data collected from the testing of the 4.7% sample. Data obtained from the 4.7% sample provided the baseline of the moisture conditions of the remainder of the samples. In order to optimize the range of moisture conditions vs. the quantity of material available, a sample was moisturized to 10%. Visual observations of the sample (semi-dry, slightly dusty, minimal clumping) suggested that additional moisture could be added before significant changes in the sample properties would start to take place. At 18% moisture, the sample no longer exhibited the dusty conditions, and started to create some small clumps. Based on these observations, the remaining samples were moisture conditioned in 2% increments to 26%. All of the samples were allowed to cure overnight in sealed containers. All samples were moisturized by calculating the dry weight of the sample, and adding the appropriate amount of water to achieve the target moisture content.

Soil sieve testing was accomplished using the 2" and 1", and the 2" and ¾" sieve combinations. Sample was poured from the bucket into the Gilson mechanical sieve shaker. Sample was mechanically agitated for 5 minutes. The screens were removed and any material retained on the individual sieves was weighed and recorded. The screens were cleaned in between each test. This process was followed until all samples had been tested. As expected, at the higher moisture contents, the soil balled up, stuck to the screens and clogged the sieve openings. Data obtained from the testing is presented in tabular and graphical form for your review. Please note that all calculations in the tables are based on the wet weight of the samples. Moisture contents are approximate. No moisture content tests were performed on the tested samples. Photographs of the bulk soil sample and the testing process are also included.

If you have any questions regarding the testing procedures or test results, please do not hesitate to contact me. Thank you for the opportunity to provide these testing services to Shaw Environmental & Infrastructure.

Sincerely,  
Advanced Terra Testing, Inc.



Kerry Repola  
Laboratory Manager

Moisture Content Determinations  
ASTM D 2216

CLIENT: Shaw Environmental & Infrastructure  
LOCATION: Range Master Soil Sieve Testing

JOB NO.: 2543-04

BORING

SAMPLE DEPTH

SAMPLE NO.

Bulk Soil

DATE SAMPLED

DATE TESTED

05-19-06 BKL

SOIL DESCRIPTION

MOISTURE DETERMINATIONS

Wt. of Wet Soil & Dish (gms)	814.27
Wt. of Dry Soil & Dish (gms)	746.49
Net Loss of Moisture (gms)	67.78
Wt. of Dish (gms)	16.26
Wt. of Dry Soil (gms)	730.23
Moisture Content (%)	9.3

Data entered by:  
Data checked by: RS  
FileName:

SR  
Date: 5/23/06  
SWN0BULK

Date: 05/22/2006

ADVANCED TERRA TESTING, INC

Moisture Content Determinations  
ASTM D 2216

CLIENT: Shaw Environmental & Infrastructure  
LOCATION: Range Master Soil Sieve Testing

JOB NO.: 2543-04

BORING

SAMPLE DEPTH

SAMPLE NO.

Bulk Soil

DATE SAMPLED

DATE TESTED

05-22-06 BKL

SOIL DESCRIPTION

MOISTURE DETERMINATIONS

Wt. of Wet Soil & Dish (gms)	640.95
Wt. of Dry Soil & Dish (gms)	612.97
Net Loss of Moisture (gms)	27.98
Wt. of Dish (gms)	15.32
Wt. of Dry Soil (gms)	597.65
Moisture Content (%)	4.7

Data entered by:  
Data checked by: RD  
FileName:

SR  
Date: 5/23/06  
SWN0SOIL

05/23/2006

ADVANCED TERRA TESTING, INC



Wet Sieve Analysis At Specific Moisture Contents

Client: Shaw Environmental  
 Boring: Composite  
 Depth: --  
 Sample No.: Bulk Soil

Job No.: 2543-04  
 Sample Date, By: --  
 Date Tested, By: 6/01/06 RS  
 Location: Former Lowry Bombing Range  
 Project No.: Range Master Soil Sieve Testing

2" and 1" Sieve Test

% Moisture	Wt. Wet Sample (lbs)	Wt. Retained 2" Sieve (lbs)	Wt. Retained 1" Sieve (lbs)	% Retained 2" Sieve	% Retained 1" Sieve
4.7	30.00	0.00	0.41	0.00	1.37
10.0	31.52	0.00	0.49	0.00	1.55
18.0	33.81	0.00	0.58	0.00	1.72
20.0	34.38	0.00	0.66	0.00	1.92
22.0	34.96	0.00	2.04	0.00	5.84
24.0	35.53	0.00	4.78	0.00	13.45
26.0	36.10	0.00	6.90	0.00	19.11

2" and 3/4" Sieve Test

% Moisture	Wt. Wet Sample (lbs)	Wt. Retained 2" Sieve (lbs)	Wt. Retained 3/4" Sieve (lbs)	% Retained 2" Sieve	% Retained 3/4" Sieve
4.7	30.00	0.00	0.65	0.00	2.17
10.0	31.52	0.11	1.31	0.35	4.16
18.0	33.81	0.00	0.58	0.00	1.72
20.0	34.38	0.00	0.87	0.00	2.53
22.0	34.96	0.00	5.90	0.00	16.88
24.0	35.53	0.00	6.04	0.00	17.00
26.0	36.10	0.39	17.29	1.08	47.89

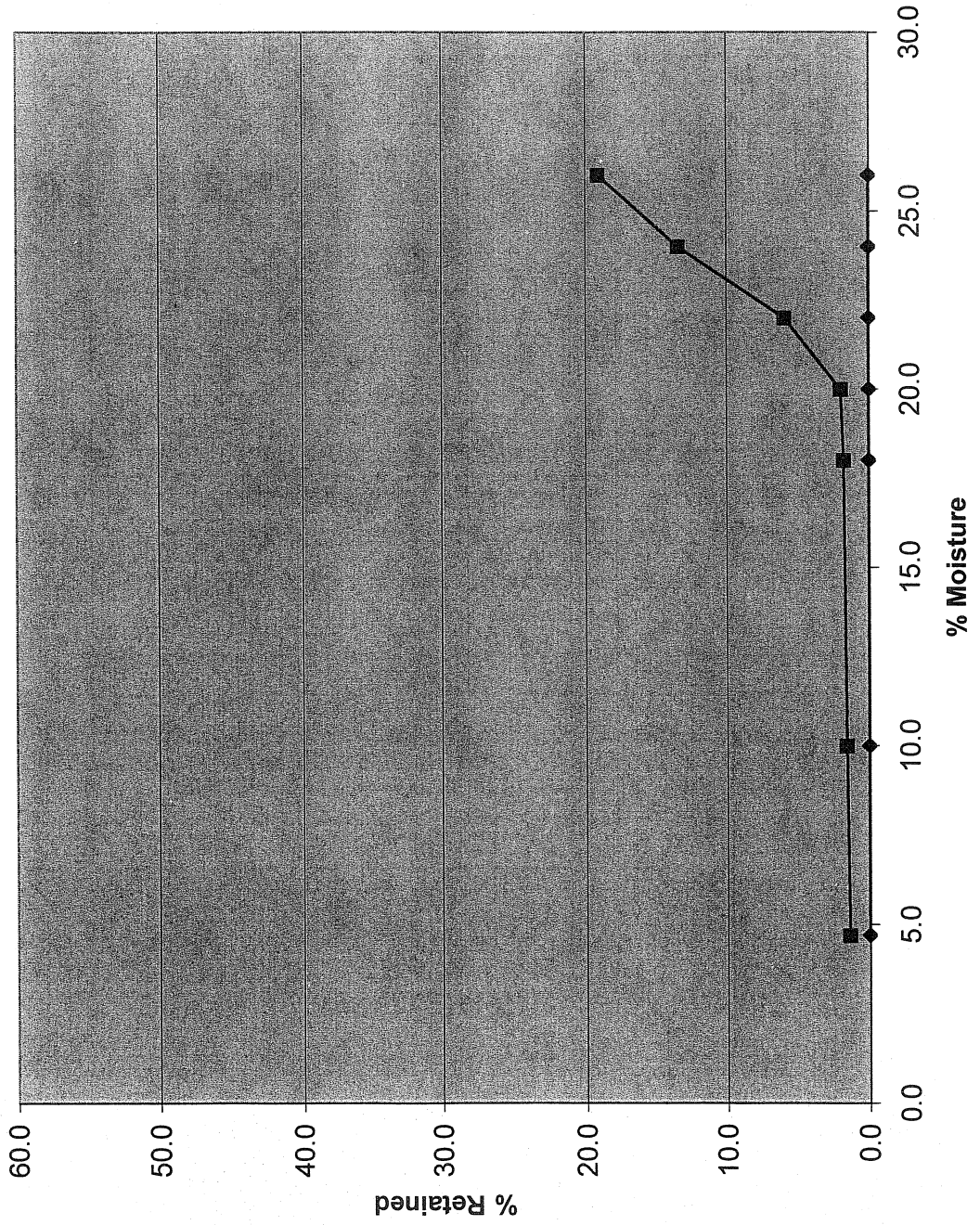
\* Note: Weight of +2" material was mostly grass clumps. The +3/4" sample also contained numerous grass clumps.



Data Entered By: RS  
 Date Entered: 06/02/06  
 File Name: SWM0BULK.xls

Data Checked By: RS  
 Date: 6/1/06

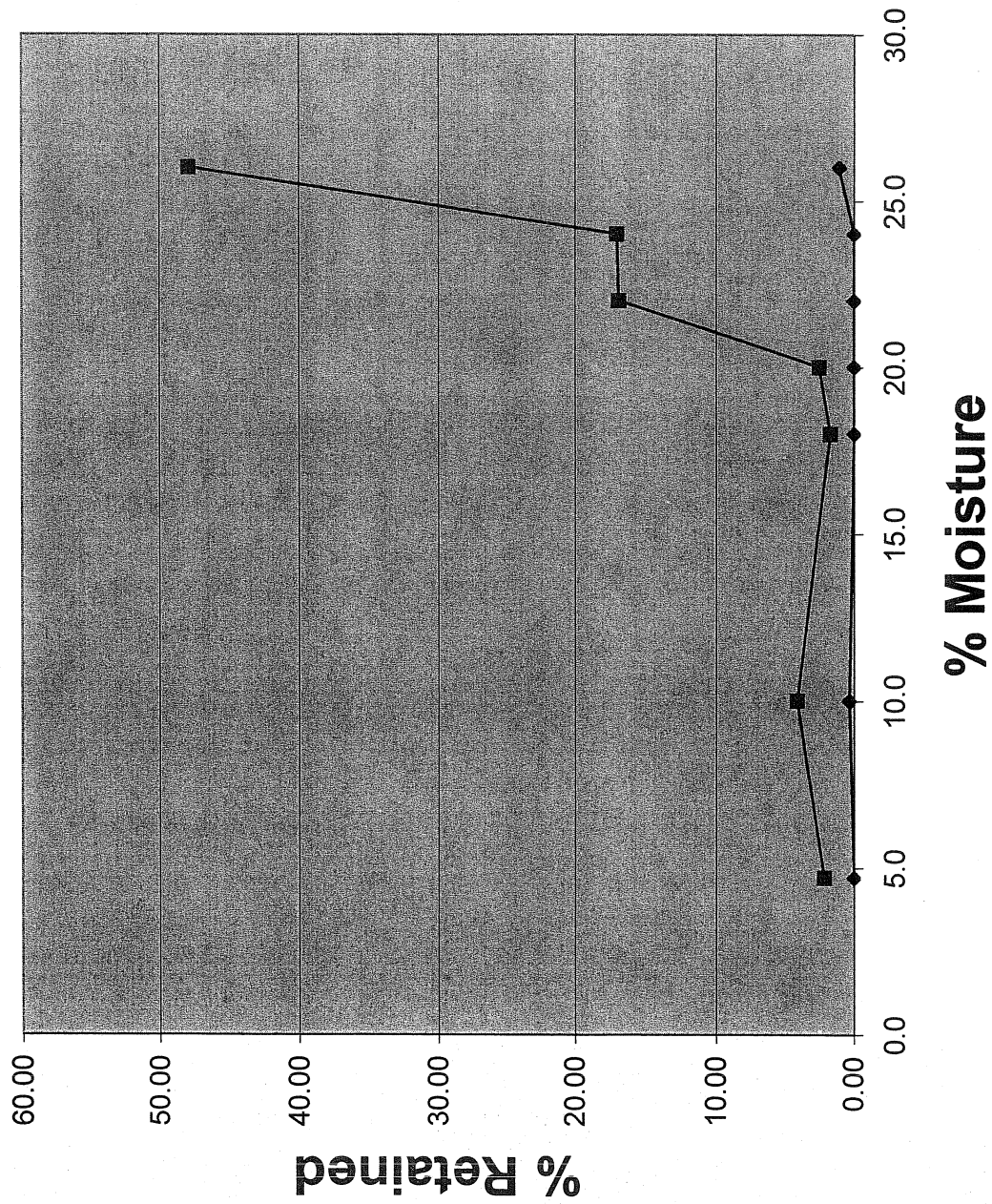
# 2" and 1" Sieve Combination



◆ % Retained 2" Sieve (2-1")  
■ % Retained 1" Sieve (2-1")



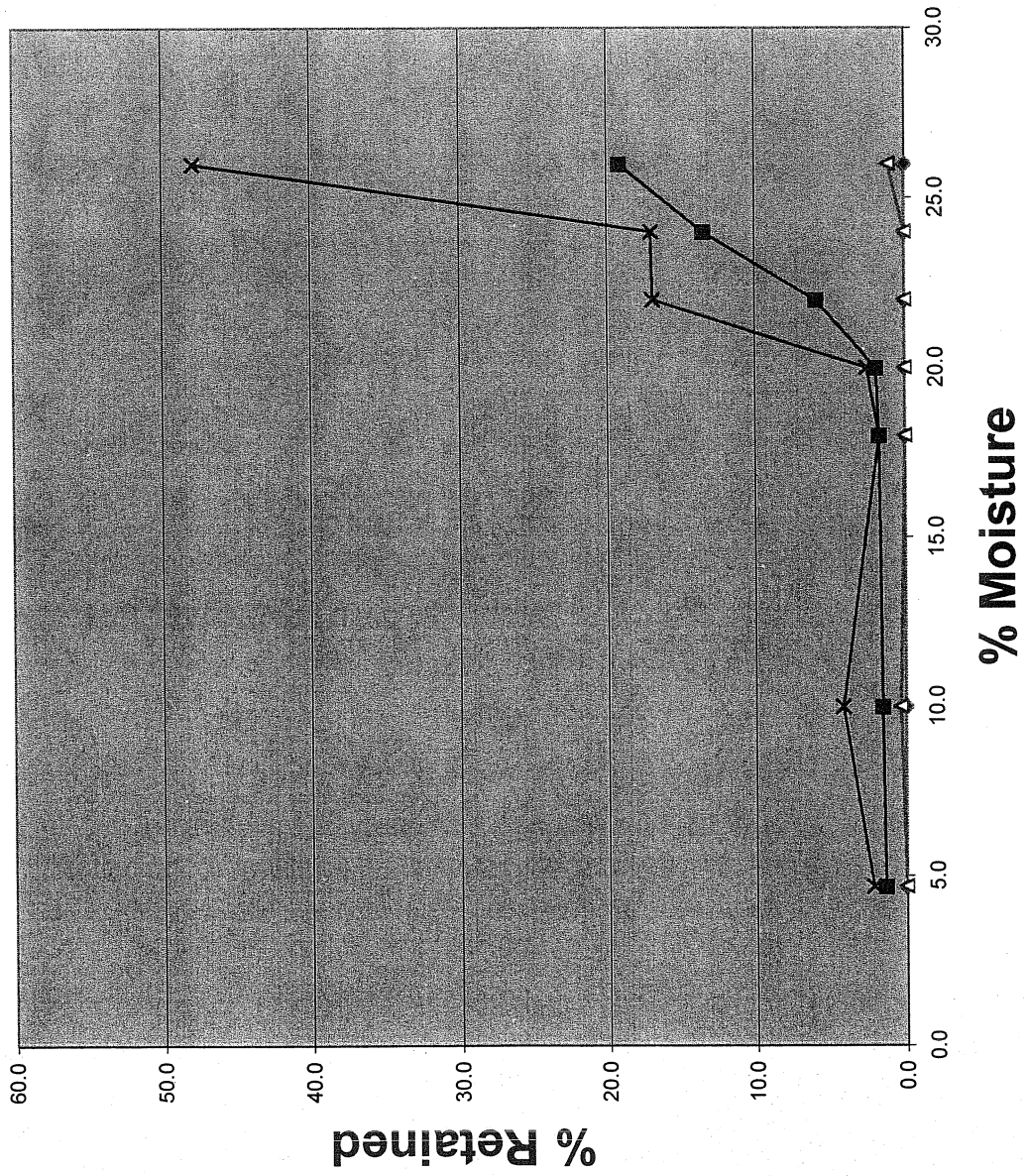
# 2" and 3/4" Sieve Combination



◆ % Retained 2" Sieve (2-3/4")  
■ % Retained 3/4" Sieve (2-3/4")



# Sieve Analysis Graph - All Combinations



## APPENDIX C. PHASE II EXCAVATION TIMES

This appendix documents the time for each operational pass of the Range Master Phase II demonstration. The operational types of passes included full width excavations (designated cut or re-cut), excavations of strips intentionally left (designated Mohawk), runs to reprocess the dump piles (designated reprocess), runs to restore site conditions (designated level), and final passes to reprocess the dump pile a last time (designated re-reprocess).



## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

**Table 11: Phase II Demonstration Excavation Time Log**

Date	Lane/pass	Direction	Type	Start	Pre-dump	End	Final Dump	Total Time	Comments
6/21/2006	1	W-E	Cut	14:21		14:28	14:34	0:13	Stopped to adjust trailer antennas, initial dump in grid. Backed up and moved it off grid. Static on main video display
6/21/2006	2	W-E	Cut	14:38		14:51	14:51	0:13	Hopper left open! Backed up and repeated lane 2. Hopper still open. Stopped to check lever in RM
6/21/2006	3	W-E	Cut	15:31		15:36	15:37	0:06	
6/21/2006	4	W-E	Cut	15:38		15:42	15:43	0:05	Shallow dig. Need to repeat
6/21/2006	4	W-E	Re-cut	15:44		15:47	15:48	0:04	
6/21/2006	5	W-E	Cut	15:49		15:54	15:55	0:06	
6/21/2006	6	W-E	Cut	15:59		16:02	16:03	0:04	
6/21/2006	7	W-E	Cut	16:07		16:11	16:12	0:05	Hopper was left open the whole run!
6/22/2006	7	W-E	Re-cut	8:59		9:02	9:04	0:05	lane 7 again
6/22/2006	8	W-E	Cut	9:07		9:12	9:13	0:06	
6/22/2006	9	W-E	Cut	9:21	9:27	9:37	9:40	0:19	
6/22/2006	10	W-E	Cut	9:43	9:51				Hopper left open!
6/22/2006	10	W-E	Cut	9:54	9:58	10:02	10:04	0:10	
6/22/2006	11	W-E	Cut	10:07	10:14	10:19	10:27	0:20	Safety stop to check source of white smoke. Water tower behind Range Master!
6/22/2006	12	W-E	Cut	11:03	11:09	11:21	11:22	0:19	Port top screen loose
6/22/2006	13	W-E	Cut	11:24	11:28	11:42	11:43	0:19	
6/22/2006	14	W-E	Cut	11:46		11:52	11:53	0:07	Shallow (5-in.) cut
6/22/2006	15	W-E	Cut	11:56	12:01	12:07	12:08	0:12	
6/22/2006	16	W-E	Cut	12:10	12:19	12:29	12:30	0:20	Two pre dumps
6/22/2006	17	W-E	Cut	13:36		13:40	13:41	0:05	SW Grid 2 To SE Grid 2
6/22/2006	18	W-E	Cut	13:44		13:48	13:50	0:06	Some overlap with lane 16 at E end
6/22/2006	19	W-E	Cut	13:50		13:51	13:52	0:02	Some overlap with lane 15 at E end
6/22/2006	20	W-E	Mohawk	13:57		14:00	14:01	0:04	
6/22/2006	21	W-E	Mohawk	14:02		14:04	14:05	0:03	
6/22/2006	22	W-E	Mohawk	14:07	14:12	14:17	14:18	0:11	Two pre dumps
6/22/2006	23	W-E	Mohawk	14:22		14:25	14:26	0:04	
6/22/2006	24	W-E	Mohawk	14:30		14:33	14:34	0:04	
6/22/2006	25	W-E	Mohawk	14:36	14:40	14:43	14:44	0:08	
6/22/2006	26	W-E	Mohawk	14:44		14:48	14:49	0:05	
6/22/2006	27	W-E	Cut	14:52		14:58	14:59	0:07	Cut around blow hole W of grid
6/22/2006	28	W-E	Cut	15:01	15:05	15:11	15:12	0:11	Hopper open after pre dump

### Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

6/22/2006	29	W-E	Mohawk	15:14		15:18	15:20	0:06	
6/22/2006	30	W-E	Mohawk	15:22	15:24	15:27	15:28	0:06	
6/22/2006	31	W-E	Cut	15:30		15:34	15:35	0:05	Shut down to clear rear camera. Air burst has condensation and wets lens.
6/22/2006	32	W-E	Cut	16:00		16:04	16:05	0:05	
6/22/2006	33	W-E	Mohawk	16:07		16:09	16:10	0:03	
6/22/2006	34	W-E	Cut	16:13	16:16	16:19	16:20	0:07	
6/22/2006	35	W-E	Mohawk	16:22		16:23	16:24	0:02	
6/22/2006	36	W-E	Mohawk	16:26		16:27	16:28	0:02	Last run with 3/4-in. screens over 1-in. screens
6/23/2006	37	W-E	Cut	12:32	12:36	12:38	12:40	0:08	First run with 1-in. screens. S of 2nd grid moving S. Short due to no grid marking
6/23/2006	38	W-E	Cut	12:41	12:45	12:49	12:51	0:10	Short line
6/23/2006	39	W-E	Cut	12:53		12:58	12:59	0:06	Short line
6/23/2006	40	W-E	Cut	13:02		13:07	13:08	0:06	Short line
6/23/2006	41	W-E	Cut	13:12		13:15	13:16	0:04	Short line
6/23/2006	42	W-E	Cut	13:18		13:20	13:23	0:05	Short line
6/23/2006	43	W-E	Cut	13:25	13:27				Short line. RM quit shifting!
6/23/2006	44	W-E	Cut	15:07		15:11	15:12	0:05	S end of grid 3 moving N. Full line, square again
6/23/2006	45	W-E	Cut	15:16	15:21	15:24	15:25	0:09	
6/23/2006	46	W-E	Re-cut	15:28	15:37	15:39	15:40	0:12	Stalled at previous short dump
6/23/2006	47	W-E	Re-cut	15:43					Hopper open
6/23/2006	47	W-E	Re-cut	15:49		15:52	15:54	0:05	
6/23/2006	48	W-E	Re-cut	15:56		16:04	16:05	0:09	
6/23/2006	49	W-E	Re-cut	16:07		16:10	16:12	0:05	
6/23/2006	50	W-E	Re-cut	16:13		16:17	16:18	0:05	
6/23/2006	51	W-E	Re-cut	16:20		16:24	16:26	0:06	Last run of the day
6/26/2006	52	W-E	Cut	8:27	8:29	8:35	8:36	0:09	N end of grid 3. Rained over the weekend. Less dust, more clods.
6/26/2006	53	W-E	Cut	8:37	8:40	8:45	8:46	0:09	
6/26/2006	54	W-E	Cut	8:47	8:52	8:55	8:56	0:09	
6/26/2006	55	W-E	Cut	8:58	9:01	9:06	9:07	0:09	
6/26/2006	56	W-E	Mohawk	9:08		9:11	9:12	0:04	
6/26/2006	57	W-E	Mohawk	9:15		9:17	9:18	0:03	
6/26/2006	58	W-E	Mohawk	9:20	9:23	9:26	9:27	0:07	
6/26/2006	59	W-E	Mohawk	9:29		9:32	9:33	0:04	S end of grid 3
6/26/2006	60	W-E	Mohawk	9:34		9:37	9:38	0:04	End of grid 3
6/26/2006	61	W-E	Cut	9:42	9:45	9:50	9:51	0:13	First cut in N end of grid 4; hopper left open after predump

## Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

6/26/2006	62	W-E	Cut	9:53	9:58	10:05	10:06	0:13	
6/26/2006	63A	W-E	Cut	10:08		10:10		0:08	Tried leaving hopper open as a deep initial cut
6/26/2006	63B	W-E	Cut	10:11		10:18	10:19	0:08	Did not work well
6/26/2006	64	W-E	Cut	10:21	10:24	10:29	10:30	0:09	
6/26/2006	65	W-E	Cut	10:32	10:37	10:41	10:42	0:10	
6/26/2006	66	W-E	Cut	10:44		10:49	10:50	0:06	
6/26/2006	67	W-E	Cut	10:52	10:55	11:00	11:01	0:09	
6/26/2006	68A	W-E	Cut	11:07	11:11				Hydraulic oil leaking on Range Master. Immediate shut down.
6/26/2006	68B	W-E	Re-cut	15:32					Shaker not working. Debugged until 1630. Not fixed yet.
6/27/2006	68B	W-E	Re-cut	11:45		11:49	11:50	0:05	
6/27/2006	69	W-E	Cut	11:52	11:55	11:59	12:00	0:08	
6/27/2006	70	W-E	Cut	12:02	12:06	12:09	12:10	0:08	
6/27/2006	71	W-E	Cut	12:13		12:16	12:17	0:04	S end of grid 4
6/27/2006	72	W-E	Mohawk	12:18		12:22	12:23	0:05	Mohawks working north thru grid 4
6/27/2006	73	W-E	Mohawk	12:24	12:27	12:29	12:30	0:06	
6/27/2006	74	W-E	Mohawk	12:31	12:36	12:41	12:42	0:11	
6/27/2006	75	W-E	Mohawk	12:44	12:49	12:53	12:54	0:10	
6/27/2006	76	W-E	Mohawk	12:56	13:02	13:06	13:07	0:11	
6/27/2006	77	W-E	Mohawk	13:09	13:13	13:18	13:19	0:10	
6/27/2006	78	W-E	Mohawk	13:21		13:27	13:28	0:07	
6/27/2006	79	W-E	Mohawk	13:30		13:37	13:38	0:08	End of grid 4
6/27/2006	80	S-N	Reprocess	13:40		13:45	13:46	0:06	S of grid 4 to N of grid 1
6/27/2006	81	S-N	Reprocess	13:51		13:56	13:59	0:08	S of grid 4 to N of grid 1. Port top screen loose. Stopped to repair
6/27/2006	82	N-S	Reprocess	15:20		15:23	15:24	0:04	N of grid 1 to S of grid 4
6/27/2006	83	S-N	Reprocess	15:26		15:33	15:34	0:05	S of grid 4 to N of grid 1
6/27/2006	84	N-S	Reprocess	15:36		15:40	15:41	0:05	N of grid 1 to S of grid 4
6/27/2006	85	S-N	Reprocess	15:42		15:49	15:51	0:09	S of grid 4 to N of grid 1
6/27/2006	86	N-S	Reprocess	15:52		15:56	15:56	0:04	N of grid 1 to S of grid 4
6/27/2006	87	S-N	Reprocess	15:57		16:05	16:07	0:10	S of grid 4 to N of grid 1
6/27/2006	88	N-S	Reprocess	16:09		16:11	16:12	0:03	N of grid 1 to S of grid 4
6/27/2006	89	S-N	Reprocess	16:14			16:24	0:10	S of grid 4 to N of grid 1
6/28/2006	90	N-S	Reprocess	8:28		8:33	8:34	0:06	N of Grid 1 to S of Grid 4
6/28/2006	91	S-N	Reprocess	8:39		8:49	8:50	0:11	S of grid 4 to N of grid 1
6/28/2006	92	N-S	Reprocess	8:52		8:59	9:00	0:08	N of Grid 1 to S of Grid 4
6/28/2006	93	S-N	Reprocess	9:02	9:13	9:13	9:14	0:12	S of grid 4 to N of grid 1

### Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

6/28/2006	94	N-S	Reprocess	9:16		9:27	9:28	0:12	N of Grid 1 to S of Grid 4
6/28/2006	95	S-N	Reprocess	9:29			9:50	0:21	S of grid 4 to N of grid 1 - Shaker Quit! Safety Sweep 9:53 to 9:58 - Reset Remote Computer.
6/28/2006	96	N-S	Reprocess	10:16		10:32	10:34	0:18	N of Grid 1 to S of Grid 4
6/28/2006	97	S-N	Reprocess	10:35		10:53	10:54	0:19	S of grid 4 to N of grid 1
6/28/2006	98	N-S	Reprocess	10:57		11:05	11:06	0:09	N of Grid 1 to S of Grid 4
6/28/2006	99	S-N	Reprocess	11:08		11:09	11:10	0:02	S of grid 4 to N of grid 1
6/28/2006	100	S-N	Reprocess	11:13		11:24	11:25	0:12	S of grid 4 to N of grid 1 - Backed down
6/28/2006	101	S-N	Reprocess	11:30		11:39	11:40	0:10	S of grid 4 to N of grid 1 - Backed down with blade down
6/28/2006	102	S-N	Reprocess	11:43		11:50	11:51	0:08	S of grid 4 to N of grid 1 - Backed down with blade down
6/28/2006	103	S-N	Reprocess	11:54		11:56	11:57	0:03	S of grid 4 to N of grid 1 - Half run. Backed down with blade down
6/28/2006	104	S-N	Reprocess	12:02		12:13	12:14	0:12	S of grid 4 to N of grid 1 - Backed down with blade down
6/28/2006	105	S-N	Reprocess	12:18		12:24	12:25	0:07	S of grid 4 to N of grid 1 - Backed down with blade down
6/28/2006	106	S-N	Reprocess	12:30		12:42	12:43	0:13	S of grid 4 to N of grid 1 - Shut down for break - Shaker wouldn't restart. Performed safety sweep and reset remote computer.
6/28/2006	107	S-N	Reprocess	13:02		13:08	13:09	0:07	S of grid 4 to N of grid 1 - Partial run
6/28/2006	108	S-N	Reprocess	13:11		13:14	13:15	0:04	S of grid 4 to N of grid 1 - Partial run
6/28/2006	109	N-S	Level	13:17			13:21	0:04	
6/28/2006	110	S-N	Level	13:22			13:25	0:03	
6/28/2006	111	N-S	Level	13:26			13:29	0:03	
6/28/2006	112	S-N	Level	13:30			13:33	0:03	
6/28/2006	113	N-S	Level	13:35			13:39	0:04	
6/28/2006	114	S-N	Level	13:41			13:44	0:03	
6/28/2006	115	N-S	Level	13:45			13:49	0:04	
6/28/2006	116	S-N	Level	13:50			13:53	0:03	
6/28/2006	117	N-S	Level	13:54			13:58	0:04	
6/28/2006	118	S-N	Level	13:59			14:03	0:04	
6/28/2006	119	N-S	Level	14:04			14:07	0:03	
6/28/2006	120	S-N	Level	14:08			14:10	0:02	
6/28/2006	121	N-S	Level	14:11			14:14	0:03	
6/28/2006	122	S-N	Level	14:15			14:16	0:01	
6/28/2006	123	N-S	Level	14:17			14:19	0:02	
6/28/2006	124	S-N	Level	14:22			14:24	0:02	
6/28/2006	125	N-S	Level	14:25			14:28	0:03	
6/28/2006	126	S-N	Level	14:31			14:35	0:04	Backed Down
6/28/2006	127	S-N	Level	14:36			14:39	0:03	

### Remote Excavation of Heavily Contaminated UXO Sites (Range Master)

6/28/2006	128	S-N	Level	14:41			14:43	0:02	
6/28/2006	129	E-W	Re- Reprocess	14:45		14:46	14:47	0:02	NE of grid 1 to NW of grid 1
6/28/2006	130	E-W	Re- Reprocess	14:49		14:51	14:52	0:03	NE of grid 1 to NW of grid 1
6/28/2006	131	E-W	Re- Reprocess	14:53		14:54	14:55	0:02	NE of grid 1 to NW of grid 1
6/28/2006	132	E-W	Re- Reprocess	14:56		14:57	14:58	0:02	NE of grid 1 to NW of grid 1
6/28/2006	133	E-W	Re- Reprocess	14:59		15:01	15:02	0:03	NE of grid 1 to NW of grid 1
6/28/2006	134	E-W	Re- Reprocess	15:05		15:06	15:07	0:02	NE of grid 1 to NW of grid 1
6/28/2006	135	E-W	Re- Reprocess	15:09		15:10	15:11	0:02	NE of grid 1 to NW of grid 1
6/28/2006	136	E-W	Re- Reprocess	15:14		15:15	15:16	0:02	NE of grid 1 to NW of grid 1 - End of Excavation
6/28/2006				15:20		15:52		0:32	MEC Decontamination