MetalMapper Demonstration at the Ft. Sill, OK

April 2013

1. Introduction

Classification using the MetalMapper advanced electromagnetic sensor was demonstrated in conjunction with a Remedial Investigation/Feasibility Study (RI/FS) at the Rocket Pond Range, Ft. Sill, OK in late 2011. This report summarizes the results of that demonstration. The document *Implementing Classification on Munitions Response Sites* (Ref. 1) provides practical information for deciding whether classification is appropriate to a particular site and how it is best implemented.

Rocket Pond Range, Ft. Sill, OK – ongoing RI/FS, relatively flat and open, moderate geologic interference

Munitions – wide variety of munitions from 40-mm grenades through medium caliber projectiles and a variety of rockets

Results – MetalMapper was used to successfully classify greater than 99% of the targets of interest and eliminate about 75% of the clutter. A production contractor field crew collected high quality cued MetalMapper data. Both geophysicists from the production contractor and the developers of classification methods were successful in using these data to achieve substantial classification.

Classification is motivated by the need to perform munitions response more cost-effectively so that limited clean up dollars can be used to reduce real risk on munitions-contaminated sites sooner. The estimated liability in the FY10 Defense Environmental Programs Report to Congress for Munitions Response is $15.2B. (Ref. 2) The bulk of this liability is $10.0B for the 1703 sites identified in the Formerly Used Defense Sites (FUDS) program and $4.4B for the 2433 sites identified on Active Installations. The remaining $0.8B is in Base Realignment and Closure (BRAC). The estimated completion dates for many sites, particularly in the FUDS program, are decades out if they are to be cleaned up at planned funding levels using current practice.

When a munitions response site is cleaned up, in most cases, it is mapped with a geophysical sensor and the locations of all detectable signals are excavated. Geophysical sensors detect metal and, therefore, many of the detections do not correspond to munitions, but rather to harmless metallic objects. Field experience indicates that 95-99% or more of objects are found to be nonhazardous. Current standard practice does not provide a means to discriminate between munitions and other items, termed "clutter." As a result, most of the costs to remediate a munitions-contaminated site using current methods are spent on excavating targets that pose no threat.

Classification is a process used to make a decision about the likely origin of a signal. In the case of munitions response, high-quality geophysical data can be interpreted with physics-based models to estimate parameters that are related to the physical attributes of the object that resulted in the signal, such as its physical size and aspect ratio. The values of these parameters may then be used to determine whether the signal arose from a munition or harmless clutter. With reliable classification, only the munitions need to be removed from the site.

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) have supported the development of purposebuilt advanced electromagnetic sensors and associated analysis methods for classification. Following the successful demonstration of classification methods in controlled test environments, ESTCP initiated a Classification Pilot Program to validate the application in real-world conditions. The goal of the program is to demonstrate that classification decisions can be made using an explicit approach, based on principled analysis that is transparent and reproducible. The demonstrations are planned and conducted in cooperation with regulators and program managers in the Services.

The physics governing the electromagnetic response of a metal object is well understood and predictable. Data collected with these sensors contain the same information content on any site and demonstrations to date have confirmed that classification works predictably. Nevertheless, demonstrations will be required at a number of sites to represent the wide variability in munitions types, target densities, terrain, vegetation, geology, land use history, future land use, and other site characteristics that will affect the applicability of classification and to establish cost effectiveness and implementability. The demonstrations also present an opportunity to work out standard operating procedures and establish quality control (QC) measures. Prior demonstrations have been conducted at a number of sites across the country. Details about past and ongoing demonstrations can be found on the SERDP-ESTCP web site at http://serdp-estcp.org/Featured-Initiatives/Munitions-Response-Initiatives/Classification-Applied-to-Munitions-Response.

The demonstration at Ft. Sill continues the practice of production geophysics contractors collecting and analyzing advanced sensor data using the MetalMapper. One purpose of the demonstration was to train production contractors in the analysis of data from these advanced sensors. This is an important consideration in evaluating and applying the results. We discourage potential customers from using the results of any single demonstration to rank performers and make contracting selections; analysts will gain experience and improve. Data were also analyzed by experienced teams from the developers of the classification methods. Table 1 shows the participants and their roles in the demonstration.

Table 1. Participants in the MetalMapper Demonstration at Ft Sill

<table>
<tr><th>Task</th><th>Performer(s)</th><th>Task</th><th>Performer(s)</th></tr>
<tr><td>Site Preparation</td><td>Parsons</td><td rowspan="3">MetalMapper Data Analysis</td><td rowspan="3">Dartmouth College
Parsons
SAIC
US Army Corps of Engineers</td></tr>
<tr><td>EM61-Mk2 Data Collection and Target Selection</td><td>Parsons as part of the ongoing RI/FS</td></tr>
<tr><td>MetalMapper Data Collection</td><td>Parsons</td></tr>
<tr><td>Intrusive Investigation</td><td>Parsons</td><td>Scoring</td><td>Institute for Defense Analyses</td></tr>
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2. Ft. Sill Demonstration Flow

The sequence of the demonstration is outlined in the flow chart in Figure 2-1.

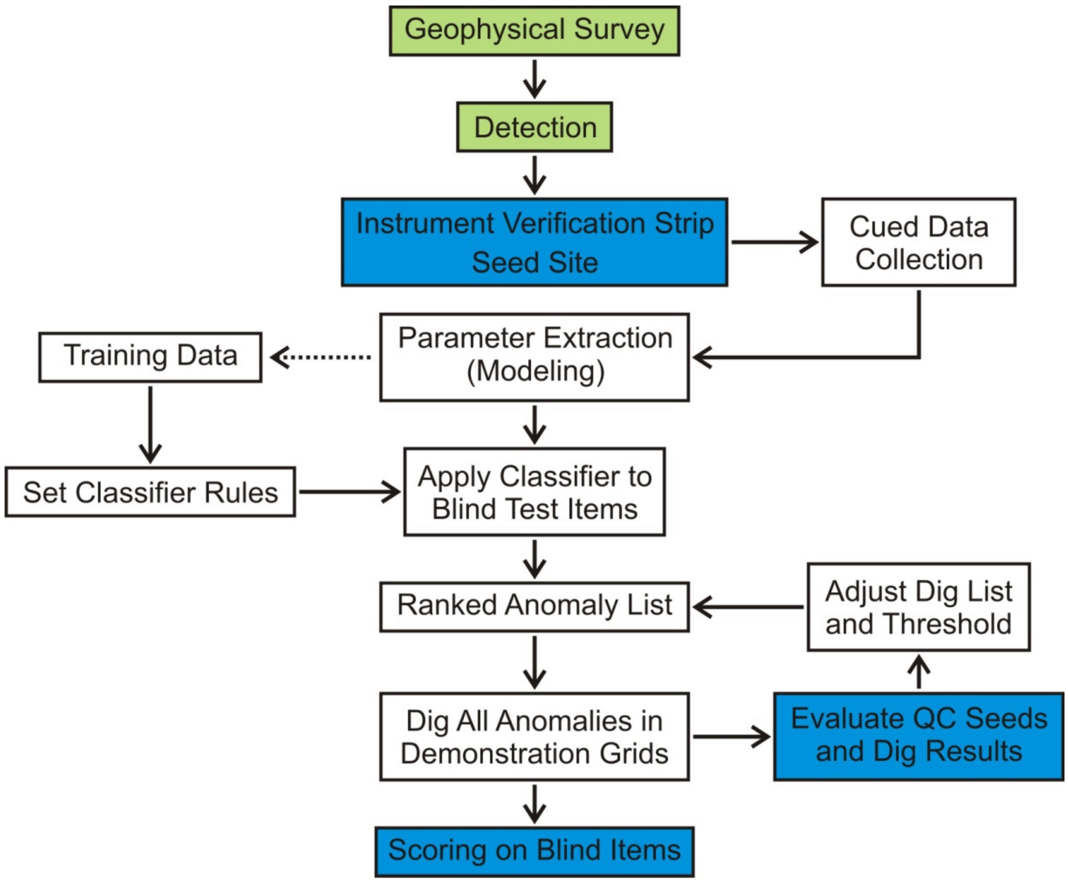

Figure 2-1. Flow chart outlining steps in the demonstration at Ft Sill. Green boxes are tasks performed as part of the RI/FS, blue boxes are tasks performed by ESTCP. Others are tasks performed by contractors.

Targets of Interest (TOI) are all objects that must be removed from the site. Typically the TOI will include all known or suspected munitions types, any other unexpected munitions, munitions parts such as fuzes that present an explosive hazard, and all seeded items. When classification is applied to a site, the local project team will decide what items constitute TOI.

Prior to the beginning of data collection, an instrument verification strip (IVS) was installed and the site was seeded with inert munitions and small industry standard objects (ISOs), 1-in nominal X 4-in pipe nipples. (Ref. 3) Data collectors visited the IVS twice daily to verify equipment function at the start and end of each day. Since there are few native unexploded ordnance (UXO) on any munitions response site, the seeds provided sufficient targets of interest (TOI) to allow a statistically defensible determination of the correct classification of TOI.

As part of the RI/FS, the site was surveyed with an EM61 array to provide an initial list of detected anomalies. The MetalMapper was used to collect cued data over each anomaly in the grids selected for this demonstration. All detected targets were dug up to provide complete ground truth for the purposes of determining performance. The UXO technicians photographed each item that was dug and recorded its location, depth, and description.

The geophysical data were passed to the data analysis teams. A complete overview of the analysis procedures can be found in Ref 1. Briefly, the analysts used methods based on the dipole model to estimate target parameters. Analysts were offered training data from test pit measurements and the opportunity to request additional training data from the recovered targets, as though they were doing a limited number of sample digs. These data were used to set classifier rules – the decisions that separate the anomalies into TOI and non-TOI. The classifiers were then applied to all of the targets that remained blind for each demonstrator. Since training data was by request, the blind target set was different for each demonstration.

The product required from each analyst was a ranked anomaly list as shown in Figure 2-2. One and only one judgment was required for each entry on the anomaly list. Following any classifier training data, the first items on each anomaly list are those targets for which reliable parameters cannot be extracted and therefore must be dug. Next are those items which the analyst is the most confident are TOI. The items are ranked according to decreasing likelihood that the item is a TOI. Any items which the analyst was able to analyze but was not able to make a classification decision on at this time were placed next on the anomaly list. Last are all those items that the analyst was confident are not TOI ranked by their likelihood. This initial list is shown in the left panel of Figure 2-2.

Initial Ranked Anomaly List

Rank	Anomaly ID	Decision Statisitic	Dig	Comment
	2498	-	Y	Classifier training data
1	247	-	Y	Can't extract reliable parameters
2	1114	.97	Y	
3	69	.96	Y	High likelihood TOI
4	811	···	Y	
5	313	···	Y	
···	704	···	N	Unable to classify
···	883	···	N	
···	···	···	N	
···	···	···	N	High likelihood not TOI
···	···	···	N	
···	···	···	N	
···	···	···	N	
···	···	.02	N	
···	···	.02	N	
N	···	.01	N	

First Pass Threshold

Final Ranked Anomaly List

Rank	Anomaly ID	Decision Statisitic	Dig
	2498	-	Y
1	247	-	Y
2	1114	.97	Y
3	69	.96	Y
4	811	···	Y
5	313	···	Y
···	704	···	Y
···	883	···	N
···	···	···	N
···	···	···	N
···	···	···	N
···	···	···	N
···	···	···	N
···	···	.02	N
···	···	.02	N
N	···	.01	N

Final Threshold

Figure 2-2. Initial and Final Ranked Anomaly Lists. A detailed description is in the text.

The seeds were divided into QC seeds and blind seeds. When analysts submitted their initial prioritized lists, the QC seeds were used to provide feedback if seed targets were missed. Analysts were also provided with the ground truth information on all anomalies in the red part of their lists and any requested anomalies in the yellow part. This is signified by the threshold on the left side of Figure 2-2. Based on this information, the analysts were then allowed to revisit their rankings and assignments for all items that were still blind until they were satisfied that the best possible classification had been achieved.

In the final list, shown in the right panel of Figure 2-2, the analyst was required to provide a threshold that corresponds to the division between those items recommend for digging and those that can safely remain in the ground. That is, the list is all red and green with a threshold separating the two categories. The final prioritized anomaly lists were scored against the emplaced blind seeds and recovered targets by IDA.

3. Site Description and Preparation

Fort Sill is located in Comanche County in southwestern Oklahoma, adjacent to the City of Lawton, Oklahoma, and occupies approximately 94,000 acres. (Ref. 4) The Wichita Mountains National Wildlife Refuge is located along the northwest boundary of the installation. Oklahoma City is located about 90 miles northeast of Fort Sill and Dallas-Fort Worth is approximately 180 miles south.

Fort Sill was originally called Camp Wichita and was created in 1869 by Major General Philip H. Sheridan who led a campaign into Indian Territory to stop hostile tribes from raiding border settlements in Texas and Kansas. MG Sheridan later renamed it in honor of Brigadier General Joshua W. Sill, killed during the Civil War. In 1901, the City of Lawton was established along the southern boundary of Fort Sill. The Fort Sill mission has changed from cavalry to field artillery and air defense artillery. The Rocket Pond Area (Figure 3-1) was used for weapons systems training involving 40mm grenades, 66-mm light anti-tank weapon (LAW) rockets, and 2.36-in and 3.5-in rockets.

A UXO clearance was conducted on the area in 1994. (Ref. 5) The range was surface cleared over all grids (approximately 400 acres). The pond basin, dam, and other areas (approximately 194 acres) were subsurface cleared to a depth of one foot. During the clearance, 287 UXO items were destroyed out of 115,500 anomalies excavated (0.25%), 133,000 items related to UXO were removed and 190,980 pounds of scrap were removed.

Fort Sill is scheduled for mission growth due to BRAC which has resulted in the need for infrastructure upgrades. An RI/FS is being conducted on the Rocket Pond Area (~555 acres) to facilitate anticipated construction at this site. At the same time, a MEC clearance project (156.91 acres) is being conducted along the 52nd Street right of way adjacent to the RI/FS area to support base upgrades. The munitions discovered during this clearance project served as the source of QC seeds for this demonstration as well as valuable guides for the data analysts.

Figure 3-1. Aerial photograph showing Rocket Pond RI/FS area outlined in blue. The 52nd Street clearance project was conducted along the road running along the western and northern boundaries.

The suspected munitions in this demonstration area include, but are not limited to:

- 40-mm HE and practice grenades,
- MKII hand grenades,
- M9 anti-tank (AT) rifle grenades,
- M11A2 practice AT rifle grenades,
- 2.36-in and 3.5-in high explosive anti-tank (HEAT) rockets,
- 66-mm LAW rockets,
- Signal/Illumination flares,
- fuzes (grenade, projectile, and rocket), and
- limited evidence of 20-mm and 37-mm projectiles.

The objective of the demonstration was to detect and correctly classify all TOI 37mm and larger. The analysts were provided information about the historical use and known munitions types. But, the direction specified that, in addition to these munitions, any unexpected munitions would also be considered TOI.

At a live site, the number of UXO is usually small, far from enough to provide adequate opportunities to demonstrate that classification can reliably identify the TOI. This may not be true on a heavily-used training range but we have no way of knowing this in advance. To be safe, the site was seeded with inert TOI to serve as process QC checks; because of this, the seeds are emplaced at depths which should lead to good signal-to-noise ratios. The seeds are listed in Table 3-1. The seeds included inert munitions from other sites, industry standard objects, (Ref. 3) and a small number of items recovered from the clearance project adjacent to the demonstration site. The ISOs are also considered TOI and expected to be both detected and correctly classified.

Table 3-1. Seeds emplaced for the Ft Sill demonstration

Item	Number	Depth (cm)	Item	Number	Depth (cm)
Small Industry Standard Object	34	15 - 28	Practice hand grenade	2	12 - 15
37-mm projectile	62	10 – 29	2.36-in rocket	3	15 - 20
40-mm projectile	22	10 – 25	LAW rocket motor	1	15
MkII hand grenade	20	10 – 20	flare canister	2	15
rifle grenade	5	10 - 19	signal flare	1	12

No attempt was made to separate the seeds from the surrounding clutter. For safety, seeds were emplaced using standard anomaly avoidance procedures. For realism, the emplacement teams were instructed to replace any metal dug up during emplacement back in the hole with the seeded object.

4. EM61 Detection Survey

The EM61-MK2 data used for anomaly identification was collected as part of the RI/FS. Before the start of digital geophysical mapping, vegetation was removed as needed and surface debris removal was conducted over ~250 acres of the site guided by the results of the 1994 UXO clearance. The site was then divided into grids to facilitate data collection.

Either a towed array of three EM61-MK2 instruments arranged side-by-side or a single sensor mounted on its standard wheels was used for the detection survey depending on local conditions. As expected, most of the site was surveyed with the towed array. A response threshold of 10 mV for the sum of EM61-MK2 gates 1 through 3 was used for anomaly selection. (Ref. 4)

An example of the implications of this threshold choice is shown in Figure 4-1. The response of a single EM61-MK2 (the worst case) to a small ISO in its least and most favorable orientations is plotted as a function of depth. The 10 mV threshold in the sum channel corresponds to signal amplitude expected for a small ISO in it least favorable orientation at 30 cm below the ground. Under the center sensor of the three sensor array, the same item at the same depth would produce a sum channel signal of 12.4 mV.

The EM61 survey of the Rocket Pond area resulted in far more anomalies than could be could be investigated further in a demonstration of this scale. Accordingly, five of the original grids were selected for the MetalMapper data collection and analysis, Figure 4-2.

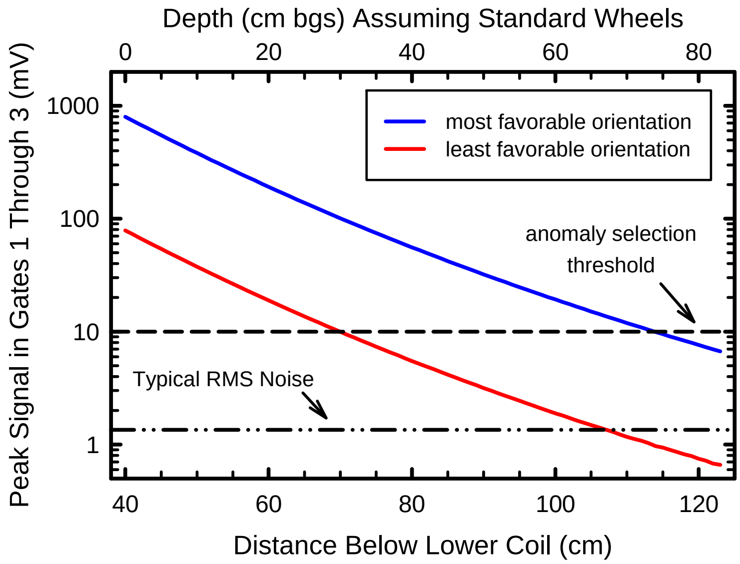

Figure 4-1. Sum of EM61-MK2 response in Gates 1 through 3 versus depth for a small ISO

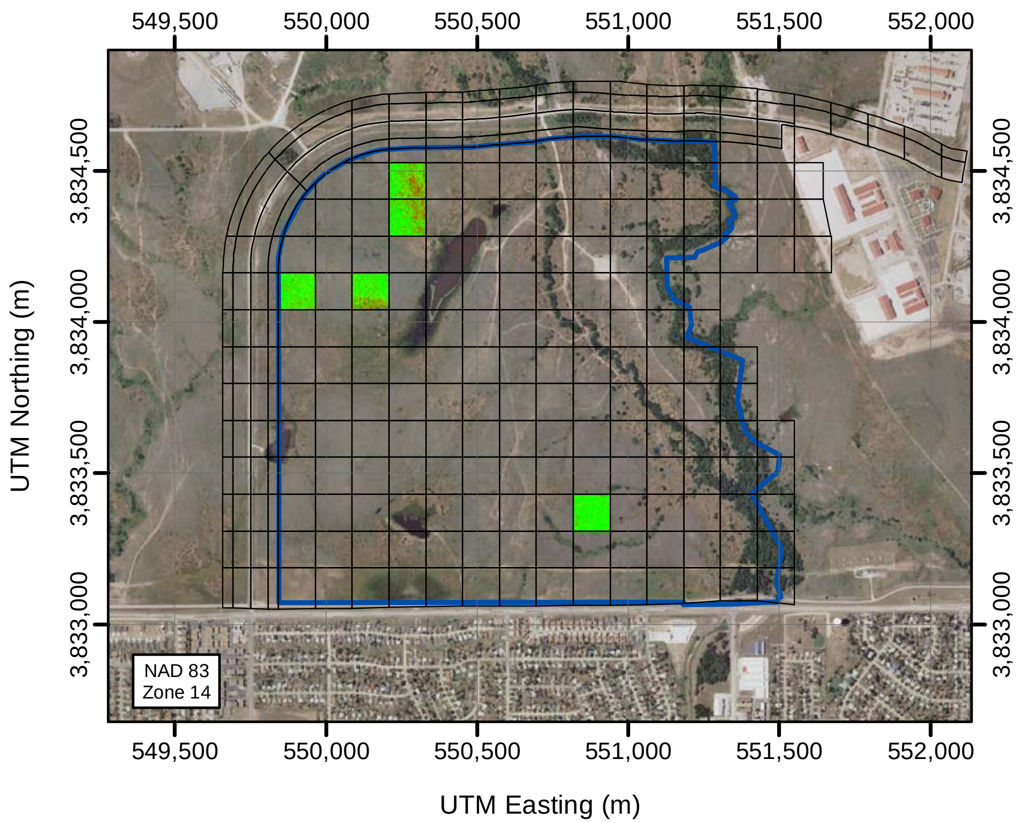

Figure 4-2. The five grids selected for the MetalMapper demonstration

The five demonstration grids are shown in more detail in Figure 4-3. They were chosen to represent the range of anomaly densities found at this site. Grid C09, in the lower right of figures 4-2 and 4-3 is far from any target area and likely represents the site background away from any target. Grids

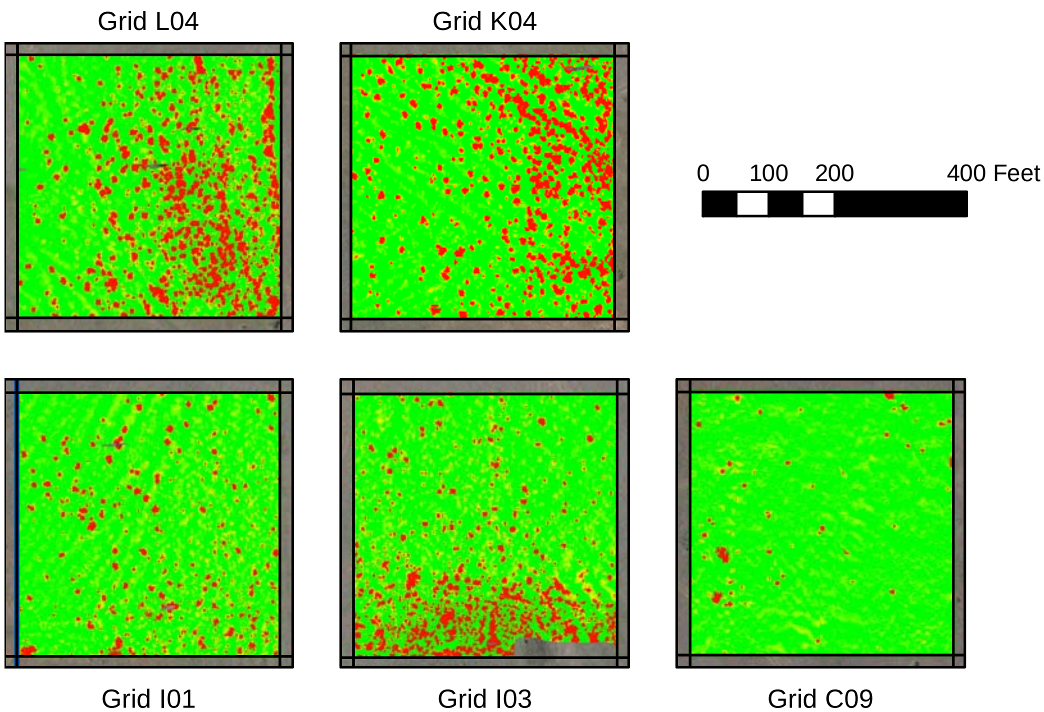

Figure 4-3. Detail of the five grids used for this demonstration

K04 and L04 are adjacent to the most densely contaminated target area and represent a test of the high-density capabilities of classification. The final two grids, I01 and I03, represent intermediate densities that should be amenable to classification.

A total of 1908 anomalies were selected for study, distributed as shown in Table 4-1. All anomalies in grid C09 were investigated and a subset of the available anomalies in the other four grids. These anomalies were chosen from both the highest density area in each grid and an area of intermediate density.

Table 4-1. Anomalies investigated in each grid

Grid	Number of Anomalies
C09	126
I01	430
I02	445
K04	408
L04	499
Total	**1908**

5. MetalMapper and Data Collection

The MetalMapper developed by Geometrics is designed to be a stand-alone survey and cued detection system. The system, shown in Figure 5-1, is composed of three orthogonal 1-m x 1-m transmitters for target illumination and 7 three-axis receivers for recording the response. Its sampling is electronically programmable and therefore flexible. It measured the decay curve up to 8 ms after the transmitters were turned off. Centimeter-level GPS is used for navigation and geolocation and an inertial measurement unit (IMU) is used to measure platform orientation. In cued mode, MetalMapper is positioned over each anomaly on its target list and collects the full suite of data while stationary. The digital data set produced by MetalMapper is fully described in Ref. 7.

Figure 5-1. Schematic and photo of the MetalMapper as used at Ft. Sill

In this demonstration MetalMapper was used only in cued mode. It was used in a sled configuration mounted to the rear three-point hitch of a tractor. A commercial geophysics vendor, Parsons, collected MetalMapper data at Ft. Sill.

Details on the data collection and QC procedures followed by Parsons can be found in their demonstration report. (Ref. 8) The most common QC failure was that the MetalMapper was positioned too far from the anomaly to obtain reliable parameter estimates because of inaccurate cueing from the EM61 detection survey. If the separation between the center of the MetalMapper and the anomaly location was more than 40 cm, the anomaly was revisited and additional data collected within the 40-cm specification.

The production rate for the cued data collection was 117 targets per day. This is lower than the rate achieved at most sites and was primarily due to intermittent computer failures in the MetalMapper system. Parsons reported an overall recollection rate of 5.8%.

6. Intrusive Results

The intrusive investigation at this site was not ideal from the standpoint of a classification demonstration. The intrusive crew, who were working in support of the RI/FS, was directed to the location of the EM61-MK2 anomalies rather than where the MetalMapper collected cued data. The MetalMapper was initially positioned at the exact location of the EM61 anomaly but in many cases the MetalMapper detected no item directly below this initial position and so was moved to be centered over the nearest item before collecting data. Seventy nine anomalies were removed from the anomaly list because the item recovered was more than 0.6 m from the position of the MetalMapper. A summary of the items recovered at the remaining 1908 anomaly locations is given in Table 6-1.

Table 6-1. Intrusive Results at Ft. Sill

Recovered Item	Number
TOI	290 (150 seeds)
Munitions Debris	1172
Range-related Debris	95
Cultural Debris	282
No Recovered Item	69
Total	**1908**

A further breakdown of the identities of the TOI recovered is given in Table 6-2. The ISOs and 37-mm projectiles were inert seeds as were all but one of the 40-mm and most of the miscellaneous items. Most of the native TOI recovered were 3.5-in rockets and rocket motors.

Table 6-2. TOI Recovered at Ft. Sill

Description	Number	Description	Number
small ISO	38	40-mm grenade	23
37-mm projectile	62	40-mm frag ball	6
3.5-in rocket motor	122	rifle grenade	5
3.5-in rocket	7	MkII grenade	18
2.36-in rocket	3	Miscellaneous seeds	4

7. Classification Results

The MetalMapper data were analyzed by multiple analysts, including both the developers of the analysis methods and the production geophysics crew. Highlights of these analyses are presented in this section.

Figure 7-1 shows the receiver operating characteristic curve achieved by an analyst from Parsons. (Ref. 8) The colors on the plot correspond to the red and green colors in the final ranked anomaly list as shown in Figure 2-2. The red are the items the analyst classified as "high likelihood TOI" and the green are those the analyst called "high likelihood not TOI." The graph plots the percent of the targets of interest correctly classified on the vertical axis and the number of clutter items on the horizontal axis. The offset from zero in the starting point reflects the small amount of training data that the analyst requested and an initial black line would represent any items in the "unable to extract reliable parameters" category; this analyst was able to analyze all data. The blue dot represents the

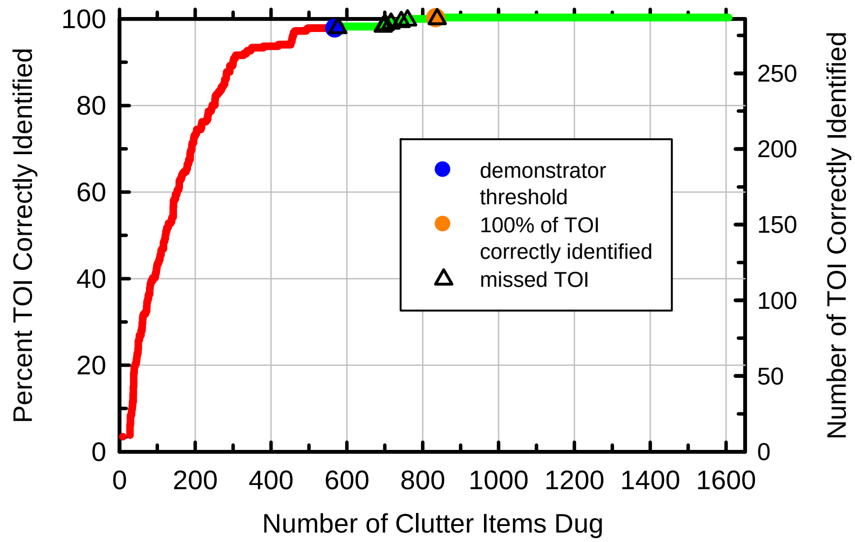

Figure 7-1. Results of Parsons analysis of the MetalMapper data

threshold selected by the analyst and the orange dot shows the point on the ranked anomaly list where 100% of the target of interest are captured. Ideally, a classifier would correctly identify all targets of interest in the red with zero clutter and all of the clutter would be in the green. In this case, the red part of the curve would go straight up to 100% and the green part of the curve would run straight across the top axis. Success in these demonstrations was defined by eliminating the maximum amount of clutter while correctly identifying all of the TOI. Finally, black triangles mark the position of TOI that were not classified correctly by the analyst.

In this demonstration, there were 1610 total clutter items as determined from the ground truth. This analyst was able to correctly identify more than 60% of them at his threshold. However, seven TOI were incorrectly classified at the analyst threshold. It would have required over 200 more digs for this analyst to have correctly identified all the TOI.

Figure 7-2 shows the results of the SAIC analysis of the MetalMapper data. (Ref. 9) This analyst was able to correctly classify over 80% of the clutter at threshold but again, seven TOI were missed. This analyst would have had to dig almost the entire site to capture these TOI.

The TOI incorrectly classified by these two analysts are compared in Table 7-1. The two lists comprise the same seven anomalies with the order being very similar between the two analysts. The difference between the two ROC curves results from the Parsons analyst placing these items in the middle of the ranked anomaly list and the SAIC analysts placing them near the bottom of the list.

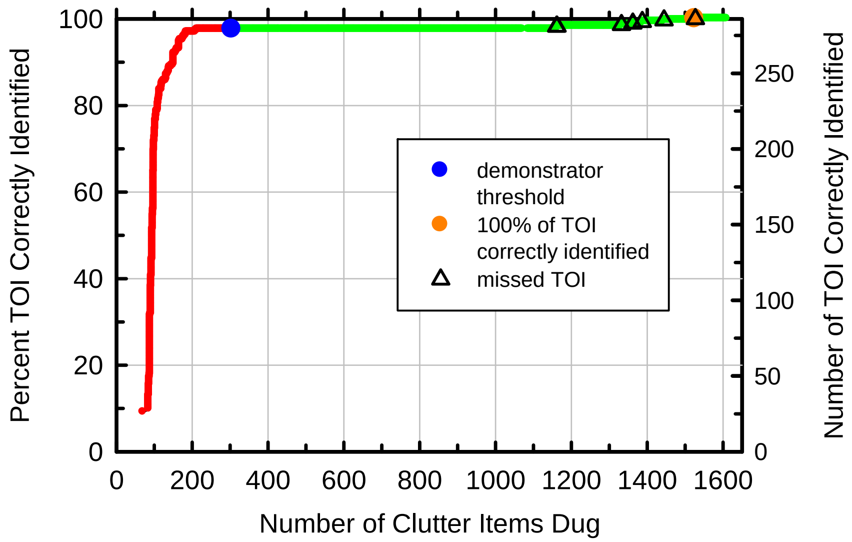

Figure 7-2. Results of the SAIC analysis

Table 7-1. TOI incorrectly classified by two analysts

Parsons	SAIC
FS-1658	FS-1658
FS-1656	FS-1656
FS-1895	FS-1488
FS-1488	FS-1895
FS-1378	FS-1378
FS-1974	FS-1579
FS-1579	FS-1974

Six of these common misclassified TOI are pictured in Figure 7-3. Each of these items was identified as a "40mm Frag Ball Cups Containing HE" by the intrusive team. All six of these items were recovered from Grid I-03, adjacent to one of the heavily-used targets. Neither of the analysts had ever encountered this item before nor did they know to expect it. This illustrates that even experienced analysts may miss TOI they do not expect to encounter.

Finally, Figure 7-4 shows the results of the analysis by researchers at Dartmouth College of these data. This analysis was able to correctly identify 75% of clutter items at threshold. Although this ROC curve looks substantially better than the two above, it is not as simple as that. The first ranked anomaly list submitted by this analyst classified two of the items pictured in Figure 7-3 as TOI but had the other four classified as not-TOI with one of them late in the ranked anomaly list. Examination of the dig results from this initial list alerted the analyst to the presence of these items and led him to correctly classify these items on subsequent lists.

Figure 7-3. Six of the common missed TOI at Ft. Sill

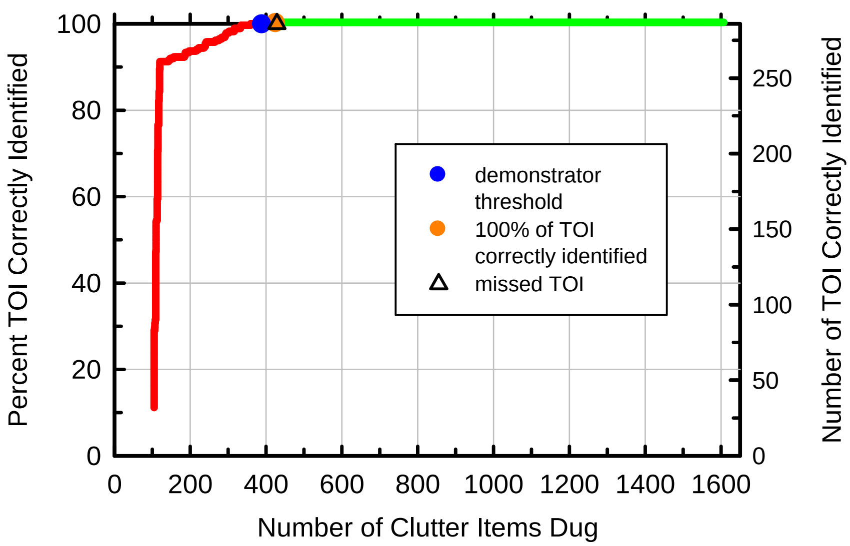

Figure 7-4. Results of the Dartmouth analysis

After the initial round of analyses, both the SAIC and Parsons analysts were asked to re-run their classifier with the knowledge that there were 40-mm frag balls on the site. Both had similar results; the second analysis identified all the 40-mm frag balls and added very few extra clutter digs. An example is shown in Figure 7-5. The SAIC analysts found the six missing 40-mm frag balls with only 18 extra clutter digs leaving only one missed TOI, an expended 3.5-in rocket motor with significant damage shown in Figure 7-6. This highlights the importance of performing a thorough site characterization accounting for both intact munitions and their expected hazardous components and communicating this information to the analysts.

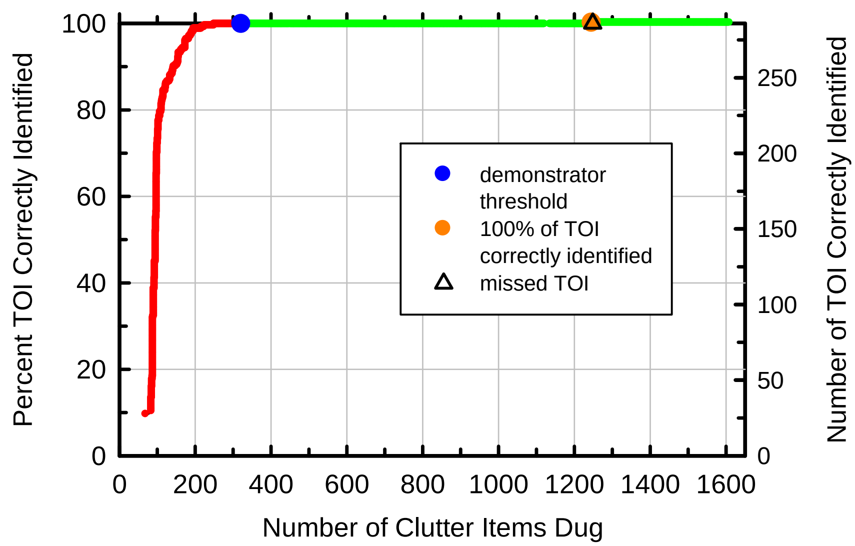

Figure 7-5. Results of the SAIC re-analysis of the MetalMapper data using knowledge of the presence of 40-mm frag balls

Figure 7-6. The remaining misclassified item in the SAIC analysis shown in Figure 7-5

8. Conclusions

Classification was used at Ft. Sill to successfully eliminate about 75% of the clutter. A production contractor field crew collected high quality cued MetalMapper data. Both geophysicists from the production contractor and the developers of classification methods were successful in using these data to achieve substantial classification.

Ft. Sill is a challenging site for two reasons. First, the grids in, and adjacent to, the heavily used targets had a high anomaly density that necessitated the use of multi-source models which were just being perfected at the time of this demonstration. Second, the wide variety of munitions that were encountered for the first time at this site was a challenge for the library-based classification methods.

This last difficulty can be overcome through effective communication throughout the project. This demonstration was carried out at the same time as the RI/FS so detailed site characterization data was not available to the analysts; this would not be the case for a normal project. Even in the absence of site characterization data, the class of TOI missed by two of the analysts could have been correctly classified with better communication. All of the UXO technicians on site knew to expect

40-mm balls on a 40-mm range but this knowledge was never transmitted to the analysts. The results of every classification project will be enhanced by transfer of all available site characterization information to the analyst.

Finally, significant experimental difficulties could have been avoided if there had been closer coordination between the RI/FS and this demonstration. Using anomaly locations that result from an EM61 survey with wide lane spacing results in relatively inaccurate initial locations which sometimes require significant relocation of the MetalMapper to achieve high-quality cued data. This offset from the initial anomaly location, if not accounted for in the intrusive investigation, can lead to recovery of items that do not correspond to those that were interrogated by the MetalMapper.

9. Acronyms

BRAC	Base Realignment and Closure
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Site
GPS	Global Positioning System
HE	High Explosive
IDA	Institute for Defense Analyses
IMU	Inertial Measurement Unit
ISO	Industry Standard Object
IVS	Instrument Verification Strip
LAW	Light Anti-tank Weapon
mV	millivolt
QC	Quality Control
RI/FS	Remedial Investigation/Feasibility Study
ROC	Receiver Operating Characteristic
SERDP	Strategic Environmental Research and Development Program
TOI	Target of Interest
UXO	Unexploded Ordnance

10. References

1. "Implementing Classification on Munitions Response Sites, ESTCP," Dec. 2011, http://serdp-estcp.org/content/download/12780/151578/version/1/file/Implementing_Classification_on_Munitions_Response_Sites_FR.pdf.
2. "Defense Environmental Programs Annual Report to Congress – Fiscal Year 2010," http://www.denix.osd.mil/arc/ARCFY2010.cfm.

3. "Geophysical System Verification: A Physics-Based Alternative to Geophysical Proveouts for Munitions Response, ESTCP," July 2009, http://serdp-estcp.org/content/download/7426/94837/version/1/file/GeoSysVerif-July-09-FINAL.pdf.
4. "Final Work Plan, Rocket Pond Remedial Investigation / Feasibility Study," Parsons, May 2011.
5. "Ordnance Removal Project Rocket Pond Range Fort Sill Final Report," Human Factors Applications, Inc., Ordnance Disposal Division, 1994
6. "EM61-MK2 Response of Standard Munitions Items," NRL/MR/6110--08-9155, October 2008, http://serdp-estcp.org/content/download/8454/103959/version/1/file/Munitions+Report-MR_9155.pdf.
7. MetalMapper: A Multi-Sensor TEM System for UXO Detection and Classification, ESTCP Project 200603 Final Report, February 2011, http://serdp-estcp.org/content/download/9593/122667/file/MR-200603-FR.pdf.
8. Parsons Ft. Sill Report, in preparation.
9. SAIC Ft. Sill Report, in preparation.
10. Dartmouth Ft. Sill Report, in preparation.