SUMMARY REPORT

MetalMapper Demonstration at the Former Camp Beale, CA

March 2012

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAR 2012**	2. REPORT TYPE	3. DATES COVERED **00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE
MetalMapper Demonstration at the Former Camp Beale, CA

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and Development Program (SERDP),Environmental Security Technology Certification Program (ESTCP),4800 Mark Center Drive, Suite 17D08,Alexandria,VA,22350-3605

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**18**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

1. Introduction

Classification using the MetalMapper advanced electromagnetic sensor was demonstrated at the former Camp Beale, CA in 2011. Camp Beale was also the site of the first demonstrations of handheld versions of advanced sensors, described in a separate report. (Ref. 1) This report summarizes the results of the only the MetalMapper demonstration. The document *Implementing Classification on Munitions Response Sites* (Ref. 2) provides practical information for deciding whether classification is appropriate to a particular site and how it is best implemented.

> *Former Camp Beale, CA – complex historical usage, overlapping network of ranges throughout, relatively flat and open, moderate geologic interference*
>
> *Munitions – 37-mm projectiles, 60-mm mortars, 81-mm mortars, 105-mm projectiles*
>
> *Results – MetalMapper was used to successfully classify all of the targets of interest and eliminate about 75% of the clutter. Production contractor field crews from two different vendors collected high quality cued MetalMapper data. Both production contractor geophysicists and the developers of classification methods were successful in using these data to achieve substantial classification. Among the production geophysicists, there was considerable variation in performance. Some had difficulty with identifying about 5-10% of the TOI.*

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. 3) 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 technology 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 purpose-built 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 done at the former Camp Sibert, AL, the former Camp San Luis Obispo, CA, and the former Camp Butner, NC. 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 the former Camp Beale is the first test in which production geophysics contractors both collected and analyzed advanced sensor data using the MetalMapper. As such, one purpose of the demonstration was to train production contractors using the MetalMapper for the first time. This is an important consideration in evaluating and applying the results, which varied widely. We discourage potential customers from using the demonstration results to rank performers and make contracting selections. Particularly, poor performance by a contractor in a single demonstration should not be considered disqualifying for performing classification, as 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 MetalMapper demonstration.

Table 1. Participants in the MetalMapper Demonstration at the former Camp Beale

Task	Performer(s)	Task	Performer(s)
Site Preparation	Parsons	MetalMapper Data Analysis	Parsons CH2M HILL SAIC Sky Research NAEVA Geophysics Dartmouth College Army Corps of Engineers
EM61-Mk2 Data Collection and Target Selection	Parsons (with input from ESTCP)		
MetalMapper Data Collection	Parsons/Geometrics CH2M HILL/Geometrics		
Intrusive Investigation	Parsons	Scoring	Institute for Defense Analyses

2. Camp Beale Demonstration Flow

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

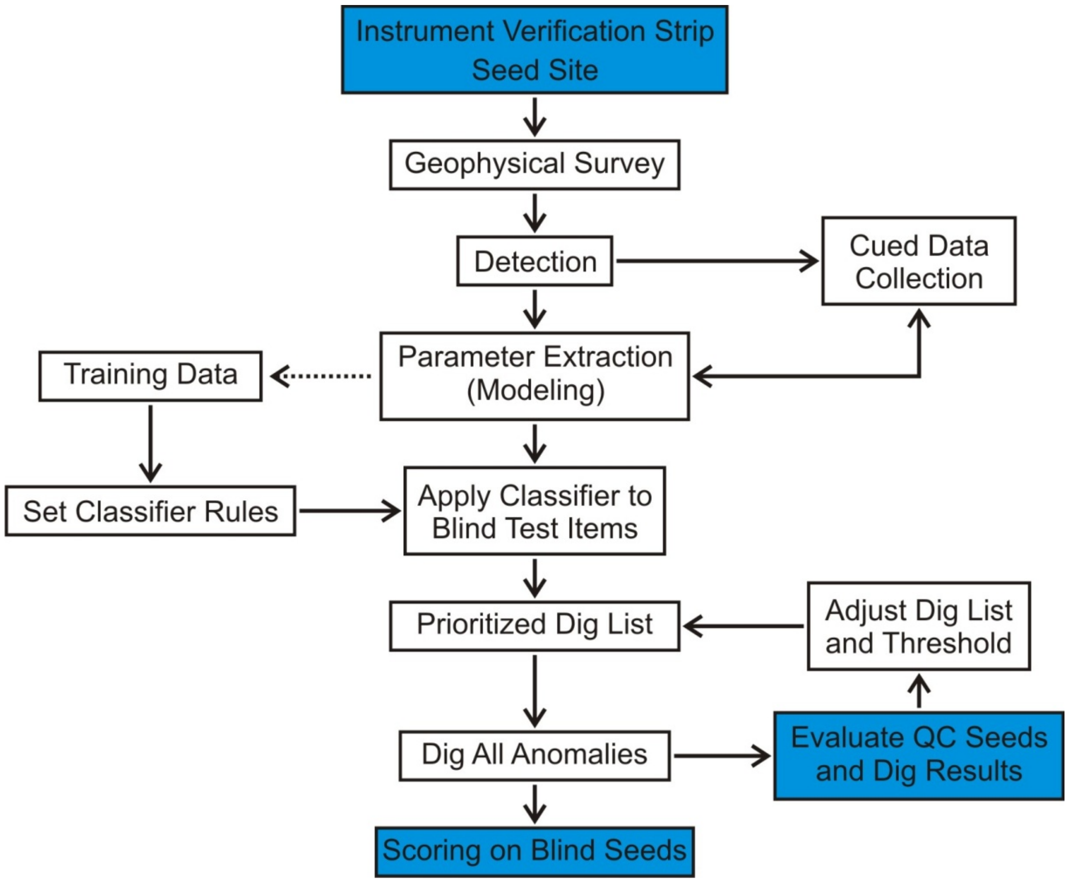

Figure 2-1. Flow chart outlining steps in the demonstration at Camp Beale. Blue boxes are tasks performed by ESTCP. Others are tasks performed by contractors.

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. 4) 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.

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.

The site was surveyed with an EM61 to provide an initial list of detected anomalies. The MetalMapper was used to collect cued data over each anomaly. 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 2. 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. 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
1	2498	-9999	Y	Can't extract reliable parameters
2	247	.97	Y	
3	1114	.96	Y	High likelihood TOI
4	69	···	Y	
5	811	···	Y	
···	313	···	N	Unable to classify
···	883	···	N	
···	···	···	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
1	2498	-9999	Y
2	247	.97	Y
3	1114	.96	Y
4	69	···	Y
5	811	···	Y
···	313	···	Y
···	883	···	N
···	···	···	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

The former Camp Beale is an approximately 60,000-acre site located in Yuba and Nevada Counties, CA. Camp Beale was subject to complex historical usage over many years and there is an overlapping network of historical ranges throughout. The demonstration was conducted in an area that is located within the historical bombing Target 4 and the Proposed Toss Bomb target area. An aerial photo of the demonstration area is shown in Figure 3-1. The area includes sections that are relatively flat and open, where the MetalMapper demonstrations took place, outlined in red and blue in Figure 3-1. The total area for the MetalMapper demonstration was 6 acres. Other sections with trees and steeper slopes where MetalMapper could not survey were used in a parallel demonstration of smaller more portable systems. During the demonstration, it was discovered that sensor data showed moderate geologic interference.

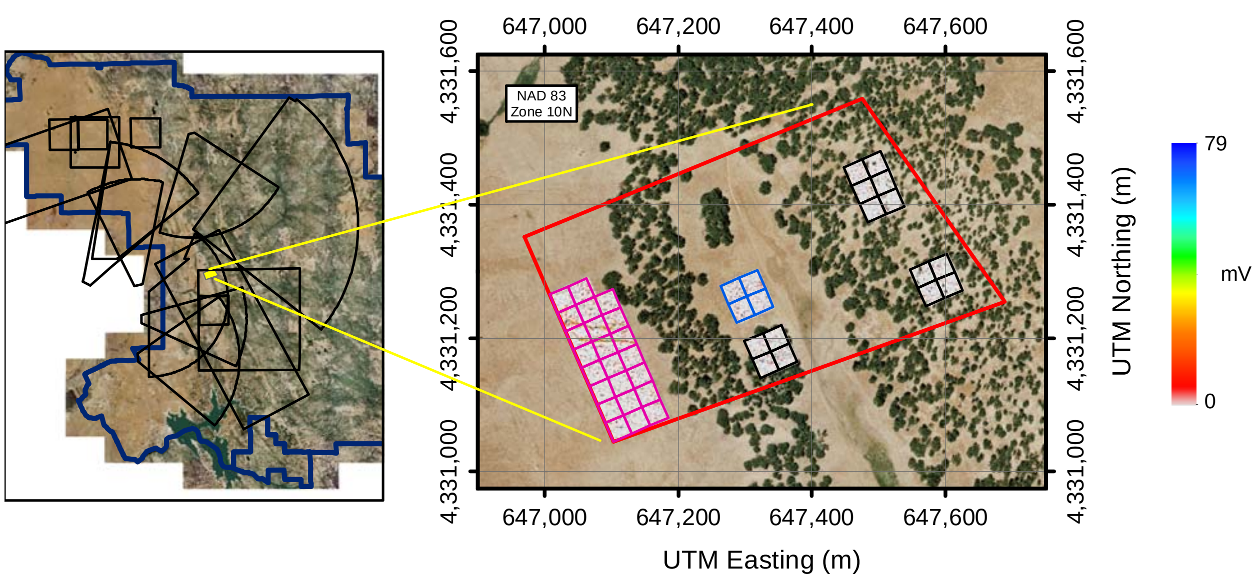

Figure 3-1. Aerial photograph showing demonstration area at Camp Beale. The MetalMapper was demonstrated in the grid sections marked in red and blue.

All visible metal objects were removed from the surface at the site. First order reference points were installed by a registered surveyor for geolocation reference. A quiet area was located near the demonstration area to establish an instrument verification strip (IVS) used for daily verification of proper sensor operation and a training pit to collect sensor data for algorithm training.

Prior to the demonstration, the suspected munitions in this area included:

- 37-mm projectiles,
- 60-mm mortars,
- 81-mm mortars, and
- 105-mm projectiles.

At the particular site of this demonstration, evidence of 81-mm mortars and 105-mm projectiles was found during the Site Inspection intrusive investigation in 2005. (Ref. 5) It is also suspected that 60-mm mortars may be present. In addition, 37-mm projectiles have been found scattered throughout the former Camp Beale and are included as another suspected munition in this area. Due to the complex usage of this site over many years and the overlapping network of historical ranges, it is also possible that other munitions types beyond those listed above are present.

The objective of the demonstration was to detect and correctly classify all TOI on the site. 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. During the intrusive investigation, the only munitions-related items found, other than those expected, were expended fuzes. These were determined to be nonhazardous by virtue of their having functioned and they were not included in the TOI.

At a live site, the number of UXO is small, far from enough to determine any demonstrator's classification performance with acceptable statistical confidence bounds. In fact, on the Camp Beale demonstration site, only four munitions were recovered in the intrusive investigation. Therefore, the site was seeded with enough TOI to ensure statistical validity on measures of classification of TOI. The seeds are listed in Table 3-1. For the first time, the seeds included not only inert munitions, but also industry standard objects. (Ref. 4) The ISOs are also considered TOI and expected to be both detected and correctly classified.

Table 3-1. Seeds Emplaced for the Camp Beale demonstration (includes the handheld demonstration area)

Item	Number	Depth range (cm)*
Industry Standard Object - Small	65	10-25
37-mm projectile	59	10-32
60-mm mortar	34	15-40
81-mm mortar	33	15-50
105-mm projectile	9	15-60

*Depths are to the center of the object.

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. All seed depths were specified at 15 cm in the site seeding plan, with direction for crews to bury them deeper where soil conditions allowed. In some cases, the items were buried at shallower depths due to ground conditions.

4. EM61 Detection Survey

An initial survey was performed with an EM61-MK2 in its standard cart configuration with cm-level global-positioning-system (GPS) navigation. These data were used both to provide a common anomaly list for the two MetalMapper data collections that were to follow and to attempt classification using only the EM61 data as a point of comparison.

The data quality objectives for the detection survey were based on the 37-mm projectile, which was expected to be the most difficult to detect TOI at the site. The EM61 survey was performed on half-meter line spacing. The anomaly selection criteria were set to detect a 37-mm projectile at a depth of one foot (30 cm). This depth was chosen as the deepest depth to which a 37-mm could be reliably detected. The EM61 signal strength in channel 2 versus depth for the 37-mm is shown in Figure 4-1. (Ref. 6) The signal at 30-cm depth for the least favorable orientation is 5.2 mV, which was used as the amplitude threshold for identifying anomalies.

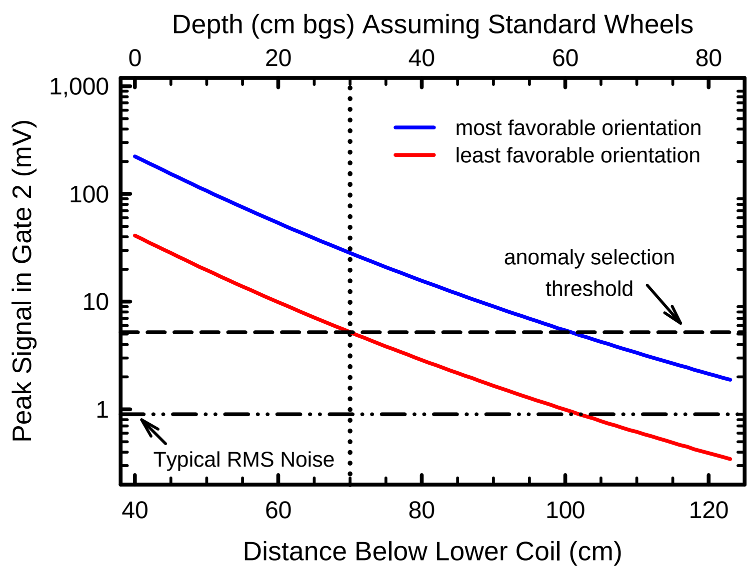

Figure 4-1. EM61 response in Gate 2 versus depth for a 37-mm projectile

The EM61 survey resulted in a total of 1490 anomalies in the MetalMapper area, including the seeds. This translates to approximately 250 anomalies per acre. Details can be found in the vendor's report. (Ref. 7) All seeds were detected in the EM61 survey.

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. 8.

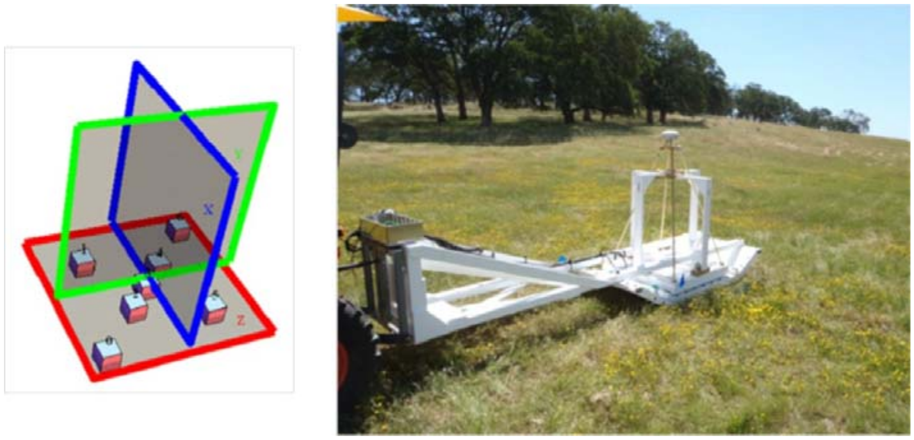

Figure 5-1. Schematic and photo of the MetalMapper as used at former Camp Beale

In this demonstration MetalMapper was used only in cued mode. It was used in a sled configuration mounted to a front loader tractor. Two commercial geophysics vendors, CH2M HILL and Parsons, collected MetalMapper data at Camp Beale for the first time. Operators were trained in the field operations and QC procedures and data were QCed by personnel with prior experience with MetalMapper initially.

Details on the data collection and QC procedures followed by each vendor can be found in the respective reports. (Ref. 9, 10) The most common QC failure was that the MetalMapper was positioned too far from the anomaly to obtain reliable parameter estimates. For both vendors, 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 methods used by the two contractors to collect background data differed and likely affected the analysis of some targets. The background is subtracted from the data taken over an anomaly to remove any ground response. Parsons collected background data in the morning and evening in the area of the IVS. CH2M HILL collected background data several times per day at areas throughout the site near where they were collecting cued data. Due to moderate geologic response of the soils and variability in this response across the site, particularly in the central area shown in Figure 5-2, the more frequent background data collection sampling throughout the site by CH2M HILL resulted in better background subtraction for some targets.

Both data sets were analyzed by multiple analysts. Although there were small differences in various measures of data quality, in addition to the background subtraction issue, both data sets were of high overall quality and acceptable to perform classification. Detailed comparisons of the analyses of the two data sets can be found in the individual analysts' reports available on the SERDP-ESTCP web site (http://serdp-estcp.org/Featured-Initiatives/Munitions-Response-Initiatives/Classification-Applied-to-Munitions-Response/Former-Camp-Beale).

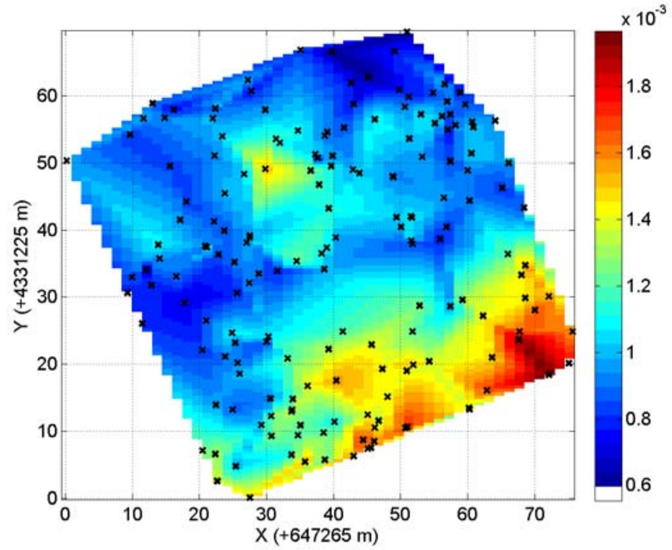

Figure 5-2. Measured background variability in the center four grids of the site

The production rates for the two data collectors were 115 and 186 targets per day for CH2M HILL and Parsons respectively. CH2M HILL reported recollecting data on about 7% of the total anomalies due to QC failures, while Parsons reported an overall rate of 10%, with about 20% at the beginning of the field work falling off to only about 2% near the end. Both contractors noted that these rates reflect inefficiency inherent in learning to operate a new system and are not likely predictive of future productivity.

6. Classification Results

All data sets were analyzed by multiple analysts, including both the developers of the analysis methods and production geophysics vendors. Figure 6-1 shows an overview of the results achieved by all analysts working with the MetalMapper data. The panel on the left shows the percent of TOI correctly classified versus the number of clutter at each analyst's operating threshold. The inset expands the upper left of the graph for clarity. Desired performance is to correctly classify 100% of the TOI and eliminate all of the clutter. The panel on the right shows the number of clutter that the analyst needed to dig to get to 100% correct classification of the TOI, regardless of where the analyst put the threshold. This can be thought of as the best the analyst could have done by putting the threshold in exactly the optimum place where the last TOI is found in the ranked list. The symbols above the bars correspond to the symbols in the left panel.

At their specified thresholds, most analysts achieved good results, correctly classifying 95% or more of the TOI and eliminating 70-85% of the clutter. This includes both the classification algorithm developers and the production contractors and is quite remarkable, especially considering that this was the attempt at analyzing MetalMapper data by many of these analysts. However, there was a range in performance, with one analyst correctly classifying less the 95% of the TOI at his threshold and another achieving only about a 30% reduction in clutter.

This range is even more evident in the right panel. The best performer could have eliminated all but 100 of the clutter (a 93% reduction) with 100% correct classification of TOI, where as the poorest performer at best could have eliminated about only 7% of the clutter.

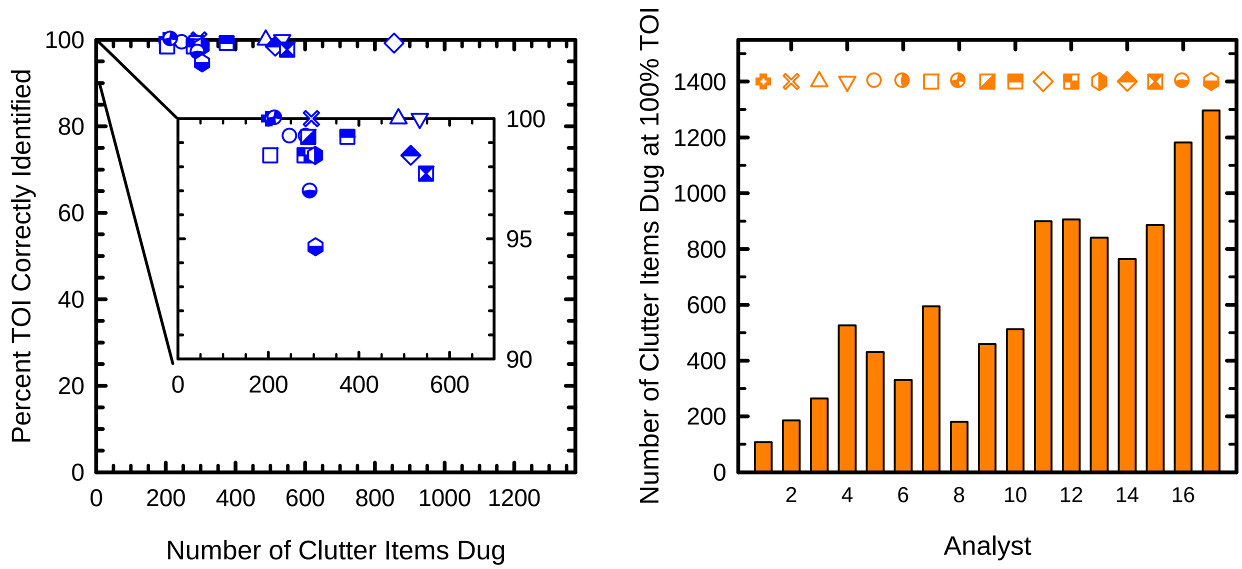

Figure 6-1. Results of all analysts in the Camp Beale demonstration. The left panel shows the percent TOI correctly identified versus number of clutter at the analysts chosen threshold. The right panel shows the number of clutter that would have to be dug to classify 100% of the TOI, regardless of where the analyst put the threshold.

6.1 Analysis by Algorithm Developers

Here we present only a few representative examples of the results from the developers. This is meant to set a baseline of what is achievable on this site by the most experienced analysts. A complete compendium of all results can be found in the report by IDA. (Ref. 11)

Figure 6-2 shows the receiver operating characteristic curve achieved by SAIC analyzing the MetalMapper data collected by Parsons. 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 called likely TOI and the green are those the analyst called high confidence not TOI. No anomalies were classified as "can't classify." 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 any training data that the analyst requested and the initial black line represents any items in the "can't analyze" category. The blue dot represents the 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.

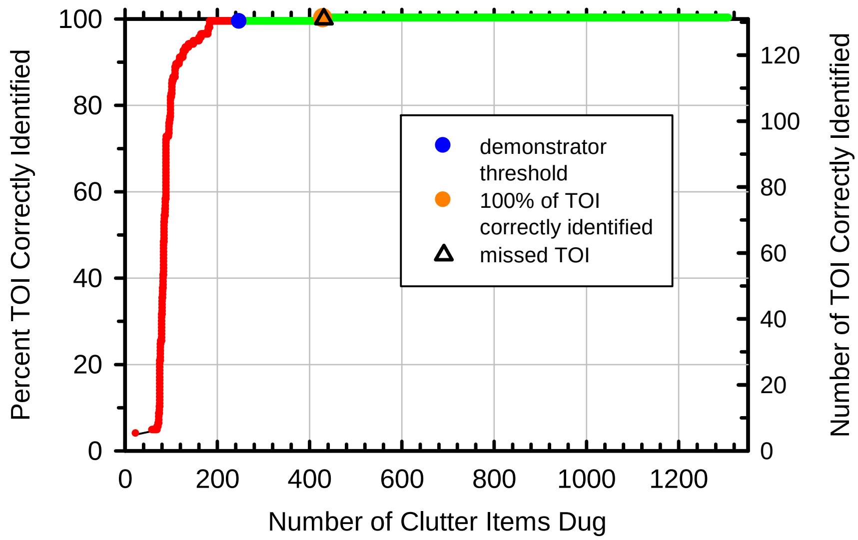

Figure 6-2. Results of SAIC analysis of MetalMapper data acquired by Parsons

In this demonstration, there were 1310 total clutter items as determined from the ground truth. This analyst was able to correctly identify all but 249 of these items, for a possible savings of more than 80% of the digs. However, one ISO seed item (Target 1965) is missed at the analyst threshold. This target was examined in detail to determine the cause of the failure.

This analysis relied on matching the measured signature of each target to candidate targets of interest in a library. Figure 6-3 shows the response of the missed target (its three principle polarizabilities versus time) as calculated from the data collected by Parsons and by CH2M HILL. The measured data are shown in colors and the library signatures are shown in gray. In the Parsons data, the largest response in red follows the library response - although not exactly - for the entire time window, the second response in blue follows the library curve only to about 1 ms and then wanders off, and the third response appears poorly defined throughout and wanders around. The best match of the measured data was to the ISO, but the fit was poor and below the threshold selected by the analyst to declare a match. With closer visual QC, the poor data in the green line would be discounted, which would have prevented the miss.

The responses calculated from the CH2M HILL data are shown for comparison. In this case, both the largest and second responses follow the library curves throughout the time window. Again, the weakest response is poorly defined and wanders. However, the overall match to the library item is much better in this case and the target is correctly identified as an ISO. There is nothing about this ISO that makes it impossible to classify. However, the miss in the analysis of one of the data sets highlights the difficulties in properly classifying low signal targets.

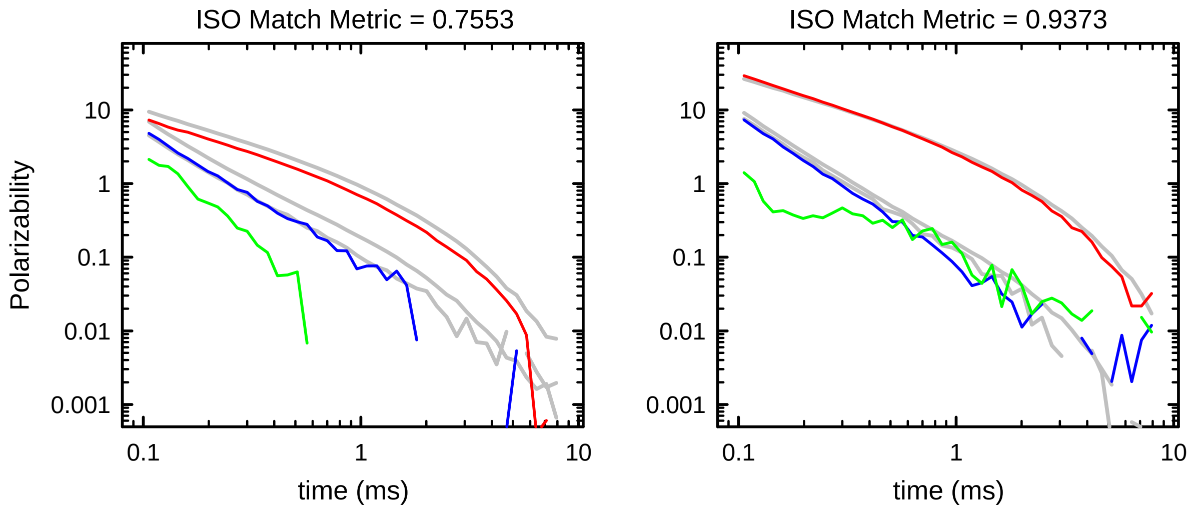

Figure 6-3. Polarizabilities of Target 1965 derived from the data collected by Parsons(left) and CH2M HILL (right). The colored lines are the modeled polarizabilities and the gray lines are ISO polarizabilities from the library

Figure 6-4 shows the results of the Sky attempt at analysis of the EM61 survey data only, which support very limited classification. Only about 114 of the total 1310 total clutter items could be correctly classified as such. Furthermore, the shape of the red part of the curve is far from ideal. It rises steeply until only about 90% of the TOI are identified. Then it continues to slowly drift upward, suggesting that many of the clutter and the targets of interest look alike to an EM61. These results are typical of all analysts who attempted to analyze the EM61 data at Camp Beale. This is not surprising on a site with small targets of interest, ISOs and 37-mm projectiles, that are of similar size to much of the clutter. The information available from the EM61 is much more limited than that available from the MetalMapper: estimates of object size are poorer and the decay rate is measured at only 4 coarse time intervals over a much shorter time window. This performance is the best result that could be achieved by an experienced analyst using these data.

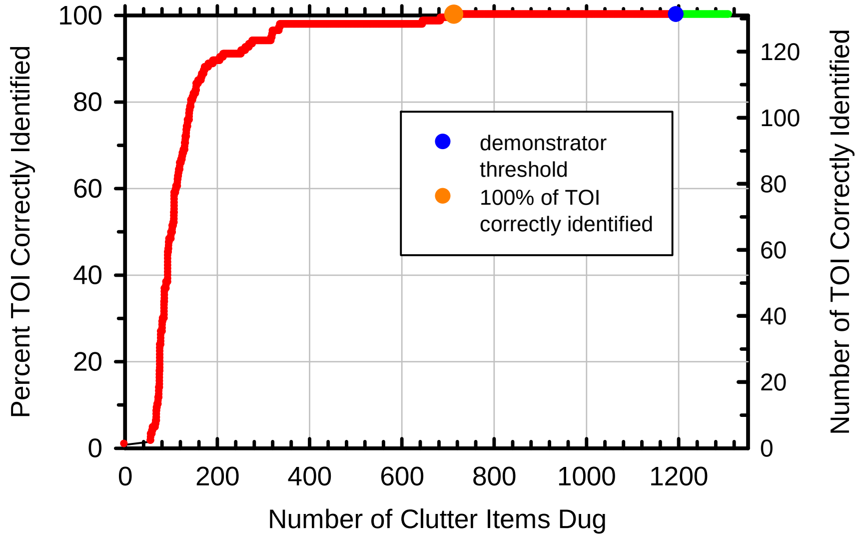

Figure 6-4. Results of Sky analysis of EM61 data

6.2 Analysis by Production Geophysics Companies

Geophysicists from Parsons and CH2M HILL also analyzed the MetalMapper data sets that each contractor respectively collected. The results of the Parsons analysis are shown in Figure 6-5. This classification is excellent. The analyst is able to correctly identify all but about 285 of the total 1310 clutter items, for a potential savings of about 75% of clutter digs. Again, the figure reflects that target 1965, an ISO seed, was incorrectly classified as clutter. This is the same seed that was missed in the analysis by SAIC of the same data set. The Parsons analyst indicated similar difficulties.

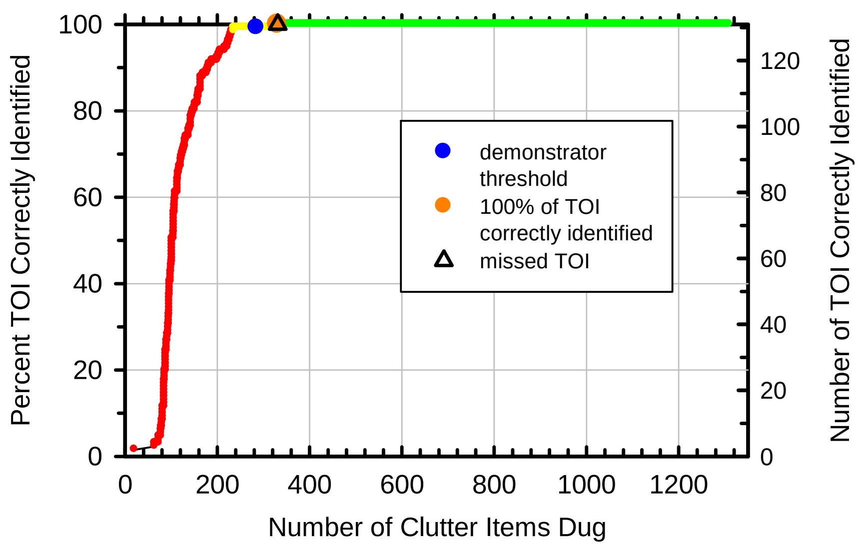

Figure 6-5. Results of Parsons analysis of MetalMapper data acquired by Parsons

Figure 6-6 shows the results of the CH2M HILL analysis of their MetalMapper data. These results show the right general trend, in that the red part of the curve rises steeply initially and the green part flattens out. But, this analyst placed a large number of anomalies in the yellow "can't classify" category and it is clear he had difficulty with a number of TOI that appear in the green "high confidence clutter" category. We do not believe that this is due to any major differences in the quality of the MetalMapper data collected, as other analysts in the developer community achieved good results with the CH2M HILL data. Rather, we believe that additional training is needed on the analysis side so that all analysts can spot quality problems in the numerous steps that are involved in the classification process.

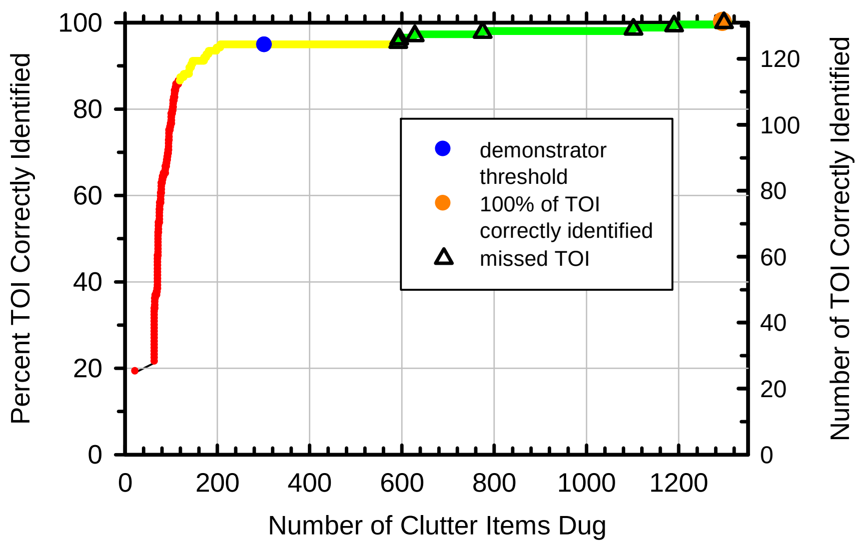

Figure 6-6. Results of CH2M HILL analysis of MetalMapper data acquired by CH2M HILL

7. Cost Comparison

The demonstration took place on a small part of the former Camp Beale site and incurred costs for many items specific to a demonstration that would not be needed in an application of classification to a real site. Nevertheless, we can extract meaningful projected performance for the technology and apply reasonable industry unit costs for various elements to arrive at a total cost comparison for clearing an example 100-acre site with and without the use of classification.

We made the following assumptions:

- The example takes place in an area with similar munitions types and the same density of anomalies as seen in the demonstration. Excluding the seeds, there were 1338 anomalies in the 6-acre demonstration area.[1] Extrapolating, we would expect about 22300 anomalies in a similar 100-acre area, with 22266 clutter.
- Two TOI were found during the intrusive investigation of the 6-acre area, for a rate of 0.33 TOI per acre. In a 10-acre site we predict about 33 native TOI.
- The baseline is an EM61 survey with 0.5-m line spacing. This would be used to select anomalies for digging without classification and the same anomalies would be interrogated with MetalMapper and classified.

[1] This number differs slightly from the 1310 anomalies that were scored above because there are 28 instances where there were two detection anomalies that required investigation, but only one object was recovered.

- The site is seeded at a rate so on average one seed will be encountered each day of MetalMapper data collection. With an estimate of 22,300 total anomalies and a production rate of 200 anomalies per day, we seed a conservative 125 inert items. These QC seeds would be used whether classification was used on the site or not.
- The classification performance is as achieved by Parson, as shown in Figure 6-5, with ~75% of the clutter correctly identified and remaining undug.
- The unit costs are as shown in Table 8-1.

Table 8-1. Unit cost assumptions

Item	Units	Cost
Digs	Per hole	$125
MetalMapper Classification	Per anomaly	$25 and $35
EM61 Survey Data Collection and Analysis	100 acres	$94,000
Seed Emplacement	125 seeds	$22650

With these assumptions the costs were calculated using the elements shown in Table 8-2. If classification can be done from $35 per anomaly including both data collection and analysis, which is consistent with the projections of the production companies based on this demonstration, a 45% overall savings is possible. If this cost can be lowered to $25 to classify each anomaly, the potential project savings increases to 52%.

Table 8-2. Cost Comparison for 100 acres of comparable Camp Beale site

Item	No Classification		Classification		
	Quantity	Cost/$	Quantity	Cost/$ ($35 per MM)	Cost/$ ($25 per MM)
Seeds	125 items	65,600	125 items	65,600	65,600
EM61 Survey	100 acres	94,000	100 acres	94,000	94,000
MetalMapper Classification	n/a	0	22425 anomalies	784,875	560,625
Seeds Dug	125	15,625	125	15,625	15,625
Native UXO Dug	33	4,181	67	4,181	4,181
Clutter Dug	22,266	2,783,250	5677	695,830	695,830
TOTAL		2,920,075		1,617,461	1,393,211
Percent Savings				**45%**	**52%**

8. Conclusions

Classification was used on the former Camp Beale to successfully identify all of the TOI and eliminate about 75% of the clutter. Production contractor field crews from two different vendors collected high quality cued MetalMapper data. Both production contractor geophysicists and the developers of classification methods were successful in using these data to achieve substantial classification. Among the production geophysicists, there was considerable variation in performance. Some had difficulty with identifying about 5-10% of the TOI. Additional training is needed so that all analysts are able to identify problems that can be encountered in the multiple analysis steps required in classification.

In two ways the former Camp Beale is a challenging site. First, the TOI included small 37-mm projectiles, as well as seeded small ISO's for the first time. These items are similar in size to the much of the clutter. Second, the geology at the site produced moderate soil responses that affected the data analysis. Anomaly density was moderate, at about 250 per acre, and did not present any particular difficulty.

Attempts at classification using the EM61-MK2 were not successful at this site, likely due to the requirement to classify small objects of a size comparable to much of the clutter. This is consistent with the results of the prior demonstration at the former Camp Butner, where both the presence of small targets and high anomaly density led to poor classification using the EM61 data.

9. Acronyms

BRAC	Base Realignment and Closure
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Site
GPS	Global Positioning System
IMU	Inertial Measurement Unit
ISO	Industry Standard Object
IVS	Instrument Verification Strip
QC	Quality Control
SERDP	Strategic Environmental Research and Development Program
TOI	Target of Interest
UXO	Unexploded Ordnance

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