ESTCP
Cost and Performance Report

(MR-201230)

Demonstration of Advanced Geophysics and Classification Technologies on Munitions Response Sites

April 2016

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ESTCP

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Environmental Security Technology Certification Program (ESTCP) contracted URS Group, Inc. (URS) to complete a Demonstration of Advanced Geophysics and Classification Technologies on Munitions Response Sites (MRSs) at two project locations: Closed Castner Range, Texas; and Former Camp Hale, Colorado. Full information for each project location is contained in its respective Final Report.

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ACRONYMS

Acorn SI	Acorn Science and Innovation, Inc.
Black Tusk	Black Tusk Geophysics
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DERP	Defense Environmental Restoration Program
DGM	Digital Geophysical Mapping
DoD	Department of Defense
DQO	Data Quality Objective
ESTCP	Environmental Security Technology Certification Program
GPS	Global Positioning System
GSV	Geophysical System Verification
HE	High Explosive
HEAT	High-Explosive Anti-Tank
ID	Identification
IDA	Institute for Defense Analysis
IMU	Inertial Measurement Unit
ISO	Industry Standard Object
IVS	Instrument Verification Strip
MD	Munitions Debris
MEC	Munitions and Explosives of Concern
MMRP	Military Munitions Response Program
MRS	Munitions Response Site
mV	Millivolts
NA	not applicable
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRL	Naval Research Laboratory
QC	Quality Control
RMS	Root Mean Square
RTK	Real-Time Kinematic
Rx	Receiver
SARA	Superfund Amendments and Reauthorization Act

SI	Site Inspection
SSHP	Site Safety and Health Plan
TEMTADS	Time-domain Electromagnetic Multi-sensor Towed Array Detection System
TOI	Target of Interest
TSC	Trimble Survey Controller
Tx	Transmitter
URS	URS Group, Inc.
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance

EXECUTIVE SUMMARY

Environmental Security Technology Certification Program (ESTCP) contracted URS Group, Inc. (URS) to complete a Demonstration of Advanced Geophysics and Classification Technologies on Munitions Response Sites (MRSs) at two project locations: Closed Castner Range, Texas; and Former Camp Hale, Colorado. Full information for each project location is contained in its respective Final Report.

OBJECTIVES OF THE DEMONSTRATION

ESTCP and other collaborators have developed advanced electromagnetic induction sensors and geophysical data processing methods that have proven effective at classifying subsurface metallic objects as either targets of interest (TOI) (i.e., objects having the size, shape, and wall thickness associated with munitions and explosives of concern [MEC]) or non-targets of interest (non-TOI) (i.e., harmless scrap metal). These demonstrations served to:

- Demonstrate the cost and performance of these sensors and methods on increasingly challenging MRSs,
- Train Military Munitions Response Program (MMRP) contractors on the application of these sensors and methods to facilitate technology transfer and industry-wide adoption, and
- Identify opportunities for potential improvement of the sensors and classification methods.

TECHNOLOGY DESCRIPTION

At Closed Castner Range, URS provided overall site management (e.g., site preparation and validation digging), advanced instrument data collection, and data processing and classification. URS collected both dynamic and cued data using Time-domain Electromagnetic Multi-sensor Towed Array Detection System (TEMTADS) 2x2 in a litter configuration. URS used Geosoft Oasis Montaj UX-Analyze extension to process and classify the data.

At Former Camp Hale, URS provided overall site management (e.g., site preparation and validation digging), advanced instrument data collection, and data processing. URS collected both dynamic and cued data using TEMTADS 2x2 in a cart configuration. URS processed dynamic and cued TEMTADS data using Geosoft Oasis Montaj UX-Analyze extension. Acorn Science and Innovation, Inc. (Acorn SI) used a test version of UX-Analyze and Black Tusk Geophysics (Black Tusk) used proprietary software to classify anomalies using only the dynamic dataset.

DEMONSTRATION RESULTS

The TEMTADS 2x2 advanced geophysical sensor and advanced data analysis methods were effectively used in a production environment to characterize MEC hazards at both sites.

IMPLEMENTATION ISSUES

Industry-wide fielding of advanced geophysical sensor arrays will benefit from addressing several logistical and deployment-related concerns that would make the system more market-ready and improve deployment efficiency. The wide-scale use and acceptance of classification methods can be facilitated primarily through documentation of standardized methods and reconciling current policy/guidance inconsistencies.

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1.0 INTRODUCTION

1.1 BACKGROUND

Environmental Security Technology Certification Program (ESTCP) contracted URS Group, Inc. (URS) to test the effectiveness of advanced geophysical sensors and physics-based data analysis tools for anomaly classification on Munitions Response Sites (MRSs) at two project locations. Full information for each project location is contained in its respective Final Report.

- **Closed Castner Range**: URS used Time-domain Electromagnetic Multi-sensor Towed Array Detection System (TEMTADS) 2x2 in a litter configuration in both dynamic survey mode and cued mode to investigate individual anomalies. URS processed and demonstrated the use and performance of advanced anomaly classification methods using the Geosoft Oasis Montaj UX-Analyze extension. URS intrusively investigated each identified anomaly for full demonstration (ESTCP 2016a).
- **Former Camp Hale**: URS used TEMTADS 2x2 in a cart configuration in dynamic survey mode and cued mode. URS processed the TEMTADS data using UX-Analyze. Acorn Science and Innovation, Inc. (Acorn SI) used a test version of UX-Analyze and Black Tusk Geophysics (Black Tusk) used proprietary software to invert and classify dynamic data. URS intrusively investigated select anomalies using Black Tusk's prioritized dig list and validated performance in coordination with regulators (ESTCP 2016b).

1.2 OBJECTIVE OF THE DEMONSTRATION

Digital geophysical mapping (DGM) of former military ranges results in the identification and location of subsurface anomalies. Typically, very few of the total number of these anomalies are munitions and explosives of concern (MEC). The majority of these anomalies are harmless metallic objects (e.g., munitions fragments, small arms projectiles, range-related debris, or cultural debris). ESTCP and other collaborators have developed advanced electromagnetic induction sensors and geophysical data processing methods that have proven effective at classifying subsurface metallic objects as either targets of interest (TOI) (i.e., objects having the size, shape, and wall thickness associated with MEC) or non-targets of interest (non-TOI) (i.e., harmless scrap metal). These demonstrations serve to:

- Demonstrate the cost and performance of these sensors and methods on increasingly challenging MRSs,
- Train Military Munitions Response Program (MMRP) contractors on the application of these sensors and methods to facilitate technology transfer and industry-wide adoption, and
- Identify opportunities for potential improvement of the sensors and classification methods.

1.3 REGULATORY DRIVER

The ESTCP Live Site Demonstrations are executed under the guidance of the Department of Defense (DoD) MMRP, which is a portion of the Defense Environmental Restoration Program (DERP). DERP is the DoD program to execute environmental response consistent with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA); the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations 300); and Executive Order 12580, Superfund Implementation.

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2.0 TECHNOLOGY

2.1 TECHNOLOGY DESCRIPTION

URS used the following hardware and software technology at each demonstration site, as shown in Table 1.

Table 1. Technology Used at the Demonstration Sites

Demonstrated Technology	Closed Castner Range	Former Camp Hale
Advanced geophysical survey	Litter configuration of TEMTADS 2x2 array in dynamic survey mode and cued mode. Real-Time Kinematic (RTK) GPS mounted above the center of the array	Cart configuration of TEMTADS 2x2 array in dynamic survey mode and cued mode. RTK GPS mounted above the center of the array
Software for analysis of the advanced geophysical data	Geosoft Oasis Montaj UX-Analyze extension	Geosoft Oasis Montaj UX-Analyze extension *
Analysis methods	Library matching and clustering	NA *
Analysis categories	Category 0: Cannot analyze Category 1: Likely TOI Category 2: Cannot decide Category 3: Likely non-TOI	Category 0: Cannot analyze Category 1: Likely TOI Category 3: Likely non-TOI

* At Former Camp Hale, Black Tusk used proprietary software and Acorn SI used a test version of UX-Analyze to invert and classify dynamic data.

2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

2.2.1 Dynamic Data Collection with TEMTADS 2x2 Litter

Variations in the TEMTADS sensor height above ground surface can cause a higher or lower than expected instrument response. The length of the poles and size of the array precluded the ability to maintain consistent instrument height across uneven terrain, which was especially pronounced while traversing the narrow arroyos. Flex in the fiberglass poles and oscillation from natural walking motion led to amplified bouncing and swaying of the array, which increased as speed increased. This motion caused variations in instrument height as well as some slippage of the harnesses, which required periodic stopping to measure instrument height and adjust straps. By comparison, the cart-mounted configuration of TEMTADS has a relatively smaller footprint and maintains a more consistent and lower array height for both dynamic and cued data collection (based on the fixed wheel height, typically 20 cm).

2.2.2 TEMTADS Dynamic Data Processing

Compared to a typical EM61 survey, the TEMTADS dynamic survey generated more files that were larger in size, and data processing was time consuming. The large file sets made it difficult to share data and collaborate with non-local colleagues. The increased processing time made it more time consuming to experiment and discover better ways of handling the data.

While URS was able to process TEMTADS dynamic data, classification of dynamic TEMTADS data was not an option within the commercially available UX-Analyze extension of Geosoft Oasis Montaj. Additionally, only cursory data reviews were possible of the daily dynamic Instrument Verification Strip (IVS) measurements.

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3.0 PERFORMANCE OBJECTIVES

Performance objectives for the demonstration projects, provided in Table 2 for Closed Castner Range and Table 3 for Former Camp Hale, serve as a basis for the evaluation of the performance and costs of the demonstrated technologies. Details regarding the results are provided in Section 7 of this report.

Table 2. Quantitative Performance Objectives for Closed Castner Range

Performance Objective	Metric	Data Required	Success Criteria	Results
Along-line measurement spacing	Point-to-point spacing from dataset	Mapped survey data	90% <25 cm along-line spacing	DQO* achieved. Refer to Section 7.2.
Complete coverage of the demonstration site	Footprint coverage	Mapped survey data	≥85% coverage at 0.6-m line spacing and ≥98% coverage at 0.75-m line spacing calculated using UX-Process Footprint Coverage QC* Tool	DQO achieved. Refer to Section 7.3.
Repeatability of IVS measurements	Amplitude of IVS seed items Measured target locations	Twice-daily IVS survey data	*Advanced Sensors Dynamic Survey:* RMS amplitudes ±30% at the 14th time gate. Down-track inverted location ±30 cm	DQO achieved except as noted in Section 7.4.
			Advanced Sensors Cued: Polarizabilities ±10%	DQO achieved. Refer to Section 7.4.
Cued interrogation of anomalies	Instrument position	Cued mode data	100% of anomalies where the center of the instrument is positioned within 40 cm of actual target location	99.8% of anomalies. Refer to Section 7.5.
Detection of all TOI	Percent detected of seeded items	Location of seeded items and anomaly list	100% of seeded items detected within 60 cm halo	DQO not achieved. Refer to Section 7.6.
Maximize correct classification of TOI	Percent of TOI placed in Category 1	Prioritized anomaly lists and dig results	Correctly classify 100% of TOI	97% of TOI. Refer to Section 7.7.
Maximize correct classification of non-TOI	Percent of correctly classified non-TOI	Prioritized anomaly lists and dig results	>75% of non-TOI classified in Category 3 while retaining all TOI	60%-70% of non-TOI. Refer to Section 7.8.
Specification of no-dig threshold	100% of TOI placed in Categories 1 or 2 and remainder of non-TOI placed in Category 3.	Prioritized anomaly lists and dig results	Threshold specified to achieve criteria above	DQO not achieved. Refer to Section 7.9.
Minimize number of anomalies that cannot be analyzed	Percentage of anomalies classified as Category 0	Inverted cued mode data and prioritized anomaly dig list	Reliable target parameters can be estimated for >95% of anomalies on the sensor's detection list	DQO achieved. Refer to Section 7.10.

Performance Objective	Metric	Data Required	Success Criteria	Results
Correct estimation of target parameters	Accuracy of estimated target parameters for seed items	Estimated and actual parameters (polarizabilities, XY locations, and depths [Z]) for seed items	Polarizabilities ±20% X, Y <15 cm (or 1 σ) Z <10 cm (or 1 σ)	DQO not achieved. Refer to Section 7.11.

* Data Quality Objective (DQO)
Quality Control (QC)

Table 3. Quantitative Performance Objectives for Former Camp Hale

Performance Objective	Metric	Data Required	Success Criteria	Results
Site-Specific Background	Establish background response	Background location response measurements	Comparison of background measurements at the same location during the course of the survey.	DQO achieved as noted in Section 7.1.
Along-line measurement spacing	Point-to-point spacing from dataset	Mapped survey data	100% <40 cm along line spacing, 98% <25 cm along-line spacing, and 80% <15 cm along line spacing	DQO achieved. Refer to Section 7.2
Complete coverage of the demonstration site	Footprint coverage	Mapped survey data	≥85% coverage at 0.6-m line spacing and ≥98% coverage at 0.75-m line spacing, and 100% of accessible area at 1.0-m line spacing calculated using UX-Process Footprint Coverage QC Tool	DQO achieved except as noted in Section 7.3.
Repeatability of IVS measurements	Amplitude of IVS seed items Measured target locations	Twice-daily IVS survey data	*Advanced Sensors Dynamic Survey:* RMS amplitudes ±30% at the 14th time gate. Down-track inverted location ±30 cm	DQO achieved as noted in Section 7.4.
			Advanced Sensors Cued: Polarizabilities ±10%	DQO achieved as noted in Section 7.4.
Cued interrogation of anomalies	Instrument position	Cued mode data	100% of anomalies where the center of the instrument is positioned within 40 cm of actual target location	DQO achieved except as noted in Section 7.5.
Detection of all TOI	Percent detected of seeded items	Location of seeded items and anomaly list	100% of seeded items detected within 60 cm halo	DQO achieved. Refer to Section 7.6.
Maximize correct classification of TOI	Percent of TOI placed in Category 1	Prioritized anomaly lists and dig results	Correctly classify 100% of TOI	Refer to Section 7.7 and Black Tusk ESTCP report.
Maximize correct classification of non-TOI	Percent of correctly classified non-TOI	Prioritized anomaly lists and dig results	>75% of non-TOI classified in Category 3 while retaining all TOI	Refer to Section 7.8 and Black Tusk ESTCP report.

Performance Objective	Metric	Data Required	Success Criteria	Results
Specification of no-dig threshold	100% of TOI placed in Categories 1 or 2 and remainder of non-TOI placed in Category 3.	Prioritized anomaly lists and dig results	Threshold specified to achieve criteria above	Refer to Section 7.9 and Black Tusk ESTCP report.
Minimize number of anomalies that cannot be analyzed	Percentage of anomalies classified as Category 0	Inverted cued mode data and prioritized anomaly dig list	Reliable target parameters can be estimated for >95% of anomalies on the sensor's detection list	Refer to Section 7.10 and Black Tusk ESTCP report.
Correct estimation of target parameters	Accuracy of estimated target parameters for seed items	Estimated and actual parameters (polarizabilities, XY locations, and depths [Z]) for seed items	Polarizabilities ±20% X, Y <15 cm (or 1 σ) Z <10 cm (or 1 σ)	Refer to Section 7.11 and Black Tusk ESTCP report.
Excavation of identified TOI	Percentage of anomalies classified as TOI verified to be "TOI" or "TOI-like" items	Prioritized anomaly list and dig results	>75% of intrusively investigated TOI anomalies are "TOI" or "TOI-like" anomalies	Refer to Section 7.12 and Black Tusk ESTCP report.
Excavation of identified non-TOI	Percentage of anomalies classified as non-TOI verified to be "non-TOI"	Prioritized anomaly list and dig results	100% of intrusively investigated non-TOI anomalies are non-TOI	Refer to Section 7.12 and Black Tusk ESTCP report.

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4.0 SITE DESCRIPTION

4.1 SITE LOCATION AND HISTORY

Fort Bliss is located in three counties, Dona Ana and Otero counties in New Mexico and El Paso County in Texas. The Closed Castner Range MRS is located between U.S. Highway 54 and the Franklin Mountains State Park. The MRS is now 7,007 acres, after acreage east of U.S. Highway 54 was transferred to non-DoD entities. Figure 1 shows the Closed Castner Range MRS and ESTCP study area.

Former Camp Hale is located approximately 70 miles west of Denver, Colorado, in the Rocky Mountains. The ESTCP Live Site Demonstration was conducted within a portion of the 382-acre East Fork Valley Range Complex MRA of Former Camp Hale. The East Fork Valley Range Complex is located approximately 10 miles south of Red Cliff and 18 miles north of Leadville east of U.S. Highway 24. The East Fork Valley Range Complex is located in Lake County in the White River National Forest. Figure 2 shows the East Fork Valley Range Complex and Former Camp Hale ESTCP study area.

4.2 SITE GEOLOGY

The Closed Castner Range study area and vicinity are within a physiographic province characterized by down-dropped basins (grabens) bounded by tilted fault block mountains. These grabens have been filled with heterogeneous, unconsolidated to poorly consolidated sediments. Any rainfall or melted snowfall that occurs in the valley either seeps into the porous valley deposits or evaporates from small pools, leaving deposits of gypsum, salt, or other minerals (e2M 2007). Ferrous geology is present in the Closed Castner Range. Relatively small deposits of Castner Limestone containing diabase (or dolerite) dikes and sills are located west of the Fusselman Dam area. It is suspected that before the installation of the dam, the potentially magnetic geology to the north of the dam eroded and was deposited in the alluvial fan at the base of the Franklin Mountains just west of the study area.

The Former Camp Hale is located in the Southern Rocky Mountains physiographic province. The southern Rocky Mountains consist primarily of a group of north-south mountain ranges of roughly anticlinal structure, with cores of igneous and metamorphic rocks flanked by steeply dipping sedimentary rocks. The former Camp Hale property is located in the Eagle River Valley in an area previously known as Eagle Park. Carved by glaciers and dammed by a glacial moraine, the mountain basin contains thick lake, stream, and glacial deposits (Shaw 2008a).

4.3 MUNITIONS CONTAMINATION

Based on records reviewed in the Site Inspection (SI) Report (e2M 2007), the Closed Castner Range MRS potentially contains munitions items related to:

- flares;
- signaling items;
- training simulator devices;
- screening smoke;
- grenades (hand, rifle, smoke);
- small, medium, and large projectiles (20 millimeter [mm]–155mm);

- mortars;
- rockets; and
- small arms.

URS Group, Inc. conducted a Wide Area Assessment Field Demonstration project in Closed Castner Range from 2009 to 2011, which included surface clearance actions and target anomaly investigations. MEC discovered during this project included 37mm projectiles and 2.36-in. rockets in addition to the discovery of a significant amount of 155mm high explosive (HE) projectile munitions debris (MD) (URS 2012).

According to the SI (Shaw 2008b), the specific types of conventional munitions used at Camp Hale were:

- Small arms: .22-, .30-, .45-, and .50-caliber ammunition;
- Demolition and bulk explosives;
- Hand Grenades: practice, smoke, and fragmentation;
- Rifle Grenades: practice, smoke, and high-explosive anti-tank (HEAT);
- Landmines: Mine, Anti-Tank, Practice, M1; Mine, Anti-Tank, HE, M1A1;Mine, Anti-Tank, M4;
- Rockets: 2.36-inch rockets (bazooka) – practice, smoke, and HEAT; 3.5-inch rocket (bazooka) – practice, smoke, and HEAT; 3.25-inch anti-aircraft target rockets; 2.75-inch aircraft rockets;
- Mortars: 60mm, 81mm, and 4.2-inch – practice, illumination, and HE; and
- Projectiles: 37mm, 40mm, 57mm, 75mm, 76mm, 90mm, 105mm, 106mm, and 155mm HE and HEAT

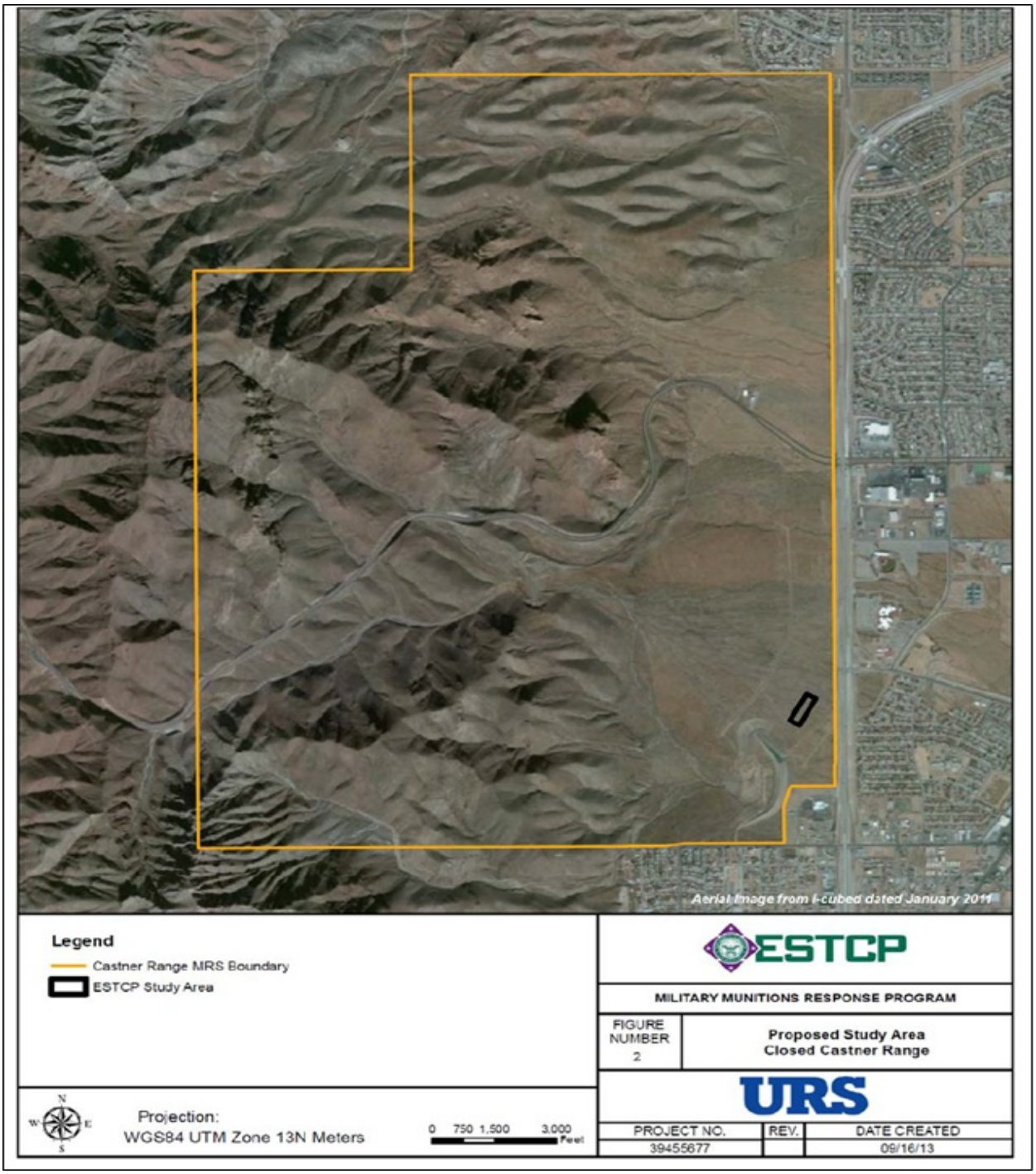

Figure 1. Closed Castner Range ESTCP Study Area

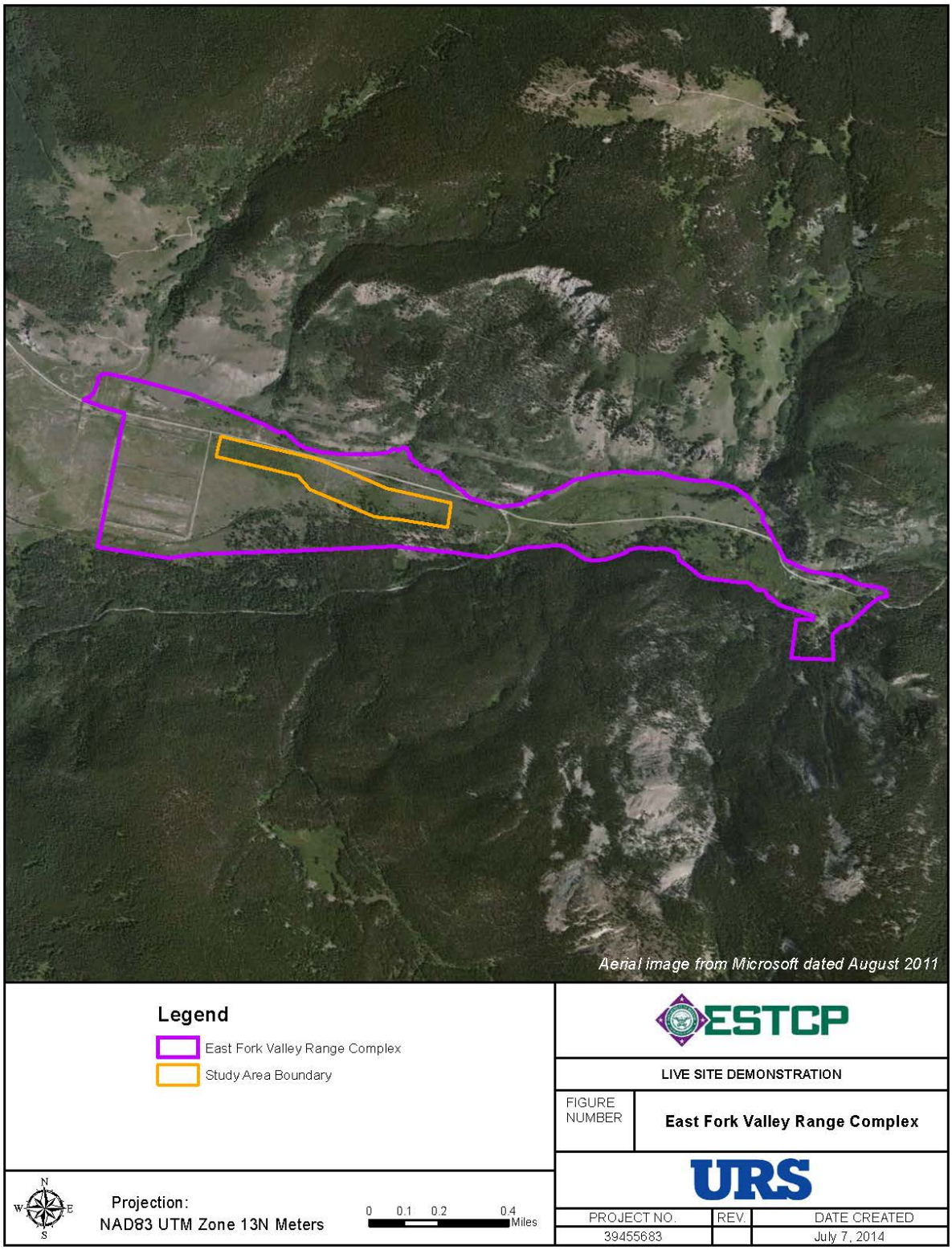

Figure 2. Former Camp Hale ESTCP Study Area

5.0 TEST DESIGN

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

This section discusses the activities that were executed by URS in support of this project, as shown in Table 4.

Table 4. Project Components for the Demonstration Sites

Project Component	Closed Castner Range	Former Camp Hale
Demonstration/ Work Plan	• Project Kickoff • Demonstration Plan • SSHP*	• Project Kickoff • Demonstration Plan • SSHP
Site Preparation	• 5-acre demonstration site • 60 seed items • Vegetation trimmed (except cactus) • IVS installed	• 33-acre demonstration site • 58 seed items • Vegetation trimmed (except trees) • IVS installed
TEMTADS 2x2 Data Collection	• 5.02 acres dynamic survey completed (0.6 m line spacing) • 1,495 cued targets over 2.5 acres	• 10.5 acres dynamic survey completed (0.4 m line spacing) • 1,742 cued targets over 7.6 acres
TEMTADS 2x2 Data Processing	Processed cued and dynamic data with Geosoft UX-Analyze	Processed cued and dynamic data with Geosoft UX-Analyze
TEMTADS 2x2 Data Analysis and Classification	• Inverted cued results for each target for classification using library matching and clustering augmented by visual data review • Dig/No Dig List produced for demonstration analysis	Performed by Black Tusk Geophysics and Acorn SI
Intrusive Investigation	• 1,525 target locations intrusively investigated (full demonstration) • Each anomaly photographed and attribute information (e.g., nomenclature, size, depth, position, and orientation) collected	• 1,371 target locations intrusively investigated (prioritized target list and validation digs) • Each anomaly photographed and attribute information (e.g., nomenclature, size, depth, position, and orientation) collected

*SSHP Site Safety and Health Plan

5.2 SITE PREPARATION

Before geophysical data collection began, URS confirmed the location of two previously emplaced geodetic control points at Closed Castner Range and oversaw the installation of two geodetic control points at Former Camp Hale. URS Unexploded Ordnance (UXO) technicians escorted the vegetation cutting team and emplaced blind seed items: 60 small Industry Standard Objects (ISO) at Closed Castner Range and 58 medium ISO at Former Camp Hale. The location, depth, and general orientation were recorded for each emplaced seed item. URS also installed an IVS consistent with the specifications and descriptions contained in *Geophysical System Verification (GSV): A Physics-Based Alternative to Geophysical Prove Outs for Munitions Response* (ESTCP 2009). ISOs were used as reference seed items.

5.3 DATA COLLECTION

5.3.1 TEMTADS 2x2 Sensor in Dynamic Survey Mode

At Closed Castner Range and Former Camp Hale, the dynamic mode survey consisted of complete coverage in the study area and subsequent data processing to identify metallic targets and create a prioritized target list. At Closed Castner Range, dynamic data were collected using TEMTADS 2x2 in a litter configuration, as shown in Figure 3. At Former Camp Hale, dynamic data were collected with TEMTADS 2x2 in a cart configuration using standard and longer transmitter (Tx) and receiver (Rx) cables, as shown in Figure 4 (left, standard cables; right, longer cables). Data were collected along parallel transects with nominal separation between transects (0.6 m at Closed Castner Range and 0.4 m at Former Camp Hale), and at a sample rate and survey pace slow enough to ensure nominal down-line spacing (less than 25 cm at Closed Castner Range and less than 15 cm at Former Camp Hale). Additionally, at Closed Castner Range the field team walked additional transects parallel to several arroyo features (generally perpendicular to the primary transect direction), which allowed for a more consistent instrument height and better quality data. Survey position were recorded and logged during the dynamic survey using a real-time kinematic (RTK) global positioning system (GPS).

Figure 3. Closed Castner Range Dynamic Data Collection Using the TEMTADS 2x2 Litter

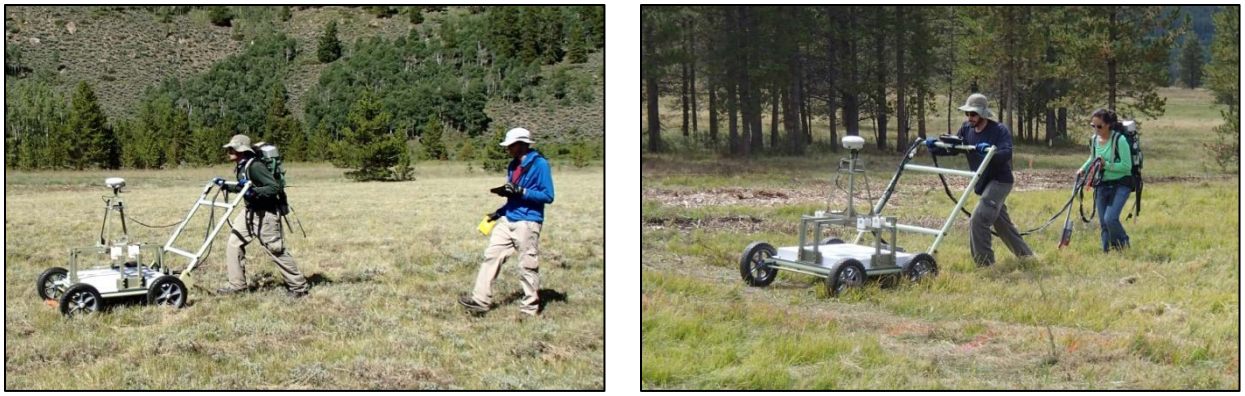

Figure 4. Former Camp Hale Dynamic Data Collection Using the TEMTADS 2x2 Cart

The following quality checks were performed while collecting advanced sensor data in dynamic mode:

- IVS (generally twice daily);
- Background IVS (morning);
- Sensor height verification (Closed Castner Range only; periodically throughout day);
- Battery strength verification (periodically throughout day); and
- Configuration and initialization files verification (periodically throughout day).

At Closed Castner Range, a litter sensor height of 35 cm was ascertained as ideal to allow for quality data collection while considering terrain, ergonomic, and equipment design limitations. Instrument height was checked periodically using a tape measure.

Raw data were collected and stored by the TEMTADS system as .tem files. The .tem files were converted to .csv files for import into data processing software using Convert TEMTADS, a software program provided by U.S. Naval Research Laboratory (NRL).

5.3.2 TEMTADS 2x2 Advanced Sensor in Cued Mode

At Closed Castner Range, the cued survey consisted of collecting static data over 1,495 anomalies identified from 2.5 acres of dynamic survey data. At Former Camp Hale, the cued survey consisted of collecting static data over 1,742 anomalies identified from 7.6 acres of the TEMTADS dynamic survey data. Measurements were repeated as necessary due to offsets of the sensor relative to the anomaly source or other data quality issues. Additionally, background responses were measured periodically where no metallic source was known to be present. At Closed Castner Range, the field team collected a total of approximately 2,200 cued data measurements including re-collect, background, and IVS measurements. At Former Camp Hale, the field team collected a total of approximately 2,468 cued data measurements including re-collect, background, IVS, and sensor function tests.

The survey team used the Trimble Survey Controller (TSC) and RTK GPS to navigate to each previously uploaded anomaly location and positioned the array at that location. The operator used the tablet to collect a cued data measurement (Figure 5). The instrument's pitch, roll, and yaw angles automatically were measured by the inertial measurement unit (IMU). These angles and the GPS measurements were used to calculate the sensor center location.

Figure 5. Cued Data Collection at Closed Castner Range (left) and Former Camp Hale (right)

The TEMTADS system allows for a real-time single-dipole inversion by the field team using the tablet. Using this function, the field team checked the instrument response and ensured the sensor was centered over each anomaly. If the sensor was located greater than 30 cm away from the center of a detected anomaly, the field team adjusted the sensor location accordingly and collected another cued data measurement. The GPS coordinate and cued data for the new location was identified with the original anomaly identification (ID) plus a modifier indicating that it was an added data point offset from the original anomaly location.

The following quality checks were performed while collecting advanced sensor data in cued mode:

- IVS (generally twice daily);
- Background response measurement (generally hourly; more frequently if restarting equipment or changing field conditions);
- Sensor Function Test (Former Camp Hale only; morning and as necessary);
- Battery strength verification (periodically throughout day); and
- Configuration and initialization files verification (periodically throughout day).

At Former Camp Hale, a new background measurement procedure was developed requiring a central measurement plus four offset measurements (0.4 m in the four cardinal directions) prior to establishing a background location. Additionally, the Sensor Function Test was created by NRL and added to the TEMTADS 2x2 software prior to the Former Camp Hale project (i.e., it was not available at Closed Castner Range).

Raw data were collected and stored by the TEMTADS system as a pair of files with the same root name and two different file extensions (.tem and .gps). The files were converted to .csv files for import into data processing software using Convert TEMTADS software program provided by NRL.

5.4 VALIDATION

Intrusive investigations were completed at the Closed Castner Range and Former Camp Hale demonstration sites to determine whether the identified targets were MEC, munitions debris, or harmless scrap.

At Closed Castner Range, URS developed a target list from the TEMTADS dynamic data collection and associated data processing/analyses. All cued targets were excavated for this demonstration project.

At Former Camp Hale, Black Tusk developed a prioritized target list from processing and classifying both the dynamic and cued advanced sensor data. URS excavated targets using the prioritized dig list and validated performance of the study by excavating an additional 110 anomalies past the dig/no dig threshold (by prioritized order and randomly selected). The excavated anomalies met the classification criteria (i.e., size and shape) providing the additional data quality assurance requested by the Colorado Department of Public Health and Environment (CDPHE) and ESTCP. Several areas within the study boundary were not classified and proceeded directly to excavation (mag and dig) due to either a high concentration of anomalies or data collection accessibility issues (i.e., terrain, trees).

For both projects, the target list, in Universal Transverse Mercator (UTM) coordinates with expected depth below ground surface, was provided to the reacquisition teams in tabular and grid map form on a Trimble Yuma tablet for recording electronic field notes and on a Trimble TSC3 for GPS navigation and recording. The reacquisition team navigated to the target location with Trimble TSC3 and R8 RTK GPS. Subsurface anomalies were manually excavated in accordance with EM 385-1-97 (U.S. Army Corps of Engineers [USACE] 2008). If no metallic objects greater than 2.5 cm were found after digging the reacquisition target location within a 30-cm radius circle to 10 cm below the specified depth, URS abandoned the dig location and reported the result as “no contact.”

Dig results included detailed descriptions, actual recovered locations, and photographs. At Closed Castner Range, one MEC item was recovered; a 105-mm projectile. At Former Camp Hale, three MEC items were found; two 81-mm mortars and one 60-mm illumination round. Figures 6 and 7 show a digital photograph of each of the recovered MEC items for Closed Castner Range and Former Camp Hale, respectively. All MEC were properly disposed.

Figure 6. MEC Recovered at Closed Castner Range

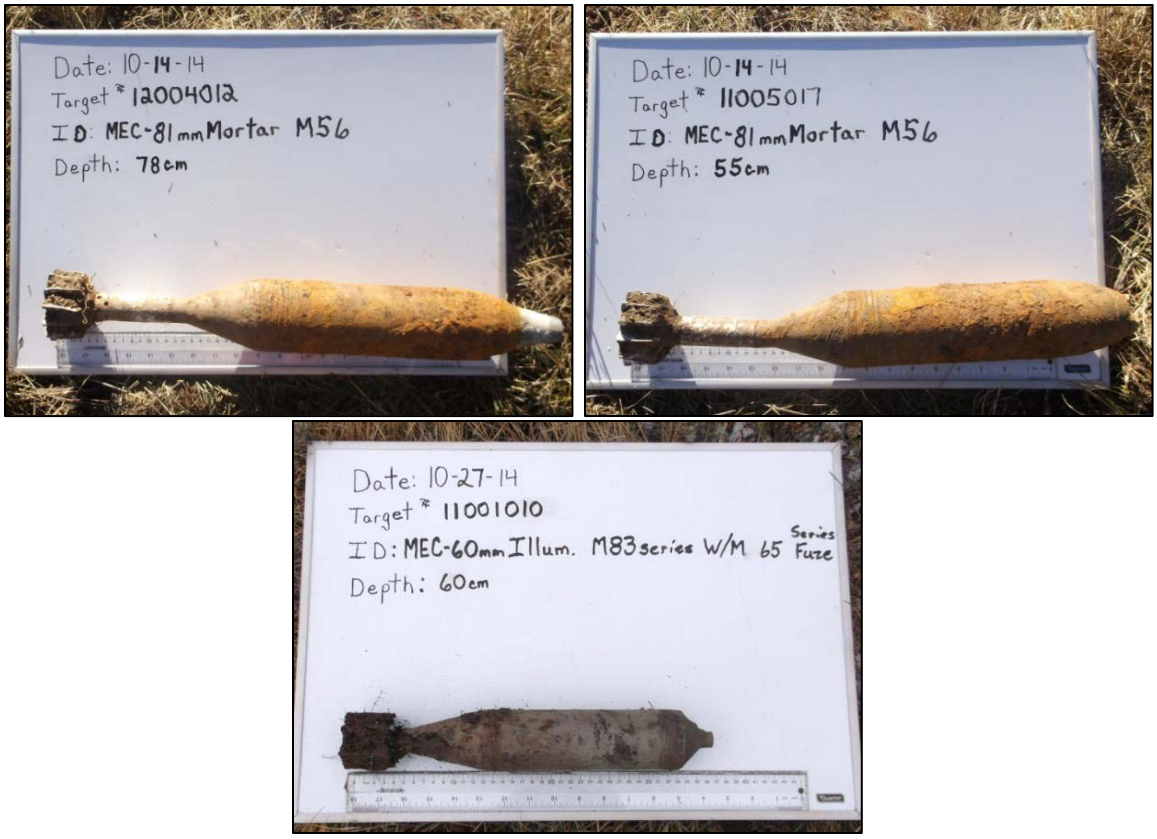

Figure 7. MEC Recovered at Former Camp Hale

6.0 DATA ANALYSIS AND PRODUCTS

6.1 TEMTADS DYNAMIC DATA

6.1.1 Processing

For both Closed Castner Range and Former Camp Hale, URS imported and processed TEMTADS dynamic data daily. URS used the UX-Analyze extension contained in Geosoft Oasis Montaj (version 8 at Closed Castner Range, and version 8.2 at Former Camp Hale). The processing procedures relied heavily upon the scripts and workflows developed by SAIC/Leidos. The first set of scripted commands filtered the transmitter currents, output reports on current channels, calculated time differences, flagged and interpolated over records with the same time, and calculated speed and heading. The second set of scripted commands created the "_located" database with median filtered monostatic responses, and created the channel of time gates 0 through 16 skipping time gate 1. Time gate 1 was not used due to inherent instrument noise.

6.1.2 Identification of Anomalies

At Closed Castner Range, URS developed the target selection criteria of 15 millivolts (mV)/Amp (current-corrected voltage) on the sum time gate channel by taking the lowest expected detection response of a horizontal small ISO at 0.14 m depth and applying a 20% buffer. The lowest expected ISO response of 19 mV/A was based upon twenty IVS runs collected over five days. The standard deviation of background noise varied between 3 to 5 mV/A on the sum time gate channel, depending on the dataset. Using the higher background noise value of 5 mV/A, a target selection criteria of three times the background standard deviation also yielded a target selection criteria of 15 mV/A. The target selection threshold yielded approximately 3,000 anomalies within the five-acre demonstration area. URS selected 15 of the 30 grids within the demonstration area and collected cued data on all identified anomalies within the selected grids.

At Former Camp Hale, Black Tusk and Acorn SI picked peaks and inverted the dynamic data based on a detection threshold consistent with a 60 mm mortar (medium ISO) at depth of 60 cm, resulting in an initial list of dynamically-selected anomalies. Based on an evaluation of the quality of the data at each anomaly, the team decided to address each anomaly in one of three ways: Dynamic Classification, Cued Data Collection, or Mag and Dig.

- Dynamic Classification: Where dynamic data were of sufficient quality to classify anomalies as either TOI/non-TOI, these anomalies were placed on the dig list. This was the preferred project approach by the project team (ESTCP, CDPHE, URS, Black Tusk, and Acorn SI). Black Tusk and Acorn SI performed classification of dynamic data using their proprietary software and a testing version of UX-Analyze, respectively.
- Cued Data Collection: Where dynamic data was not of sufficient quality to make a TOI/non-TOI decision, cued data were collected and classified for these anomalies. Both Acorn SI and Black Tusk participated in picking cued targets within the study area based on the dynamic TEMTADS data.
- Mag and Dig: After review of the dynamic data, the decision to use mag and dig was deemed the only option for portions of the study area. High densities of anomalies were identified in the central portion of the project area. Additionally, steep terrain and tree cover affected GPS coverage (i.e., other than Fix Quality 4) and proved difficult for data collection in the southeastern portion of the project area.

6.2 TEMTADS CUED DATA

6.2.1 Processing

At Closed Castner Range, URS used Geosoft UX-Analyze version 8 and scripts developed by SAIC/Leidos to process and invert the TEMTADS data. Background statistics and decay plots were generated, outlying background data were unselected from the database, and the data were leveled. A SAIC/Leidos script was used to run a single object solver, match betas to a library, create library match plots, merge flag XY locations, create TEM data maps, create dynamic data maps, create decay maps, calculate data metrics and flag out of specification targets using the "comments" channel. Inversion results were reviewed to determine whether data would be of sufficient quality to classify the target anomaly source. Both single- and multi-source inversions were reviewed for data quality, to determine whether the inversion fits cohesions were greater than 0.8, signal amplitude was greater than 1 mV/Amp, and the inverted anomaly source locations were within 0.4 m of the TEMTADS location. Inverted results that did not meet these criteria were selected for re-collection. If the results were already re-collected data, no further attempts were made to collect additional data.

At Former Camp Hale, URS imported and processed cued data files for target and background using UX-Analyze version 8.2. URS mapped the target and background locations in Montaj to verify spatial distribution. Using UX-Analyze QC tools, URS reviewed survey data outlier flags (i.e., current, flat line, GPS, IMU, and saturation), statistics and decay plot overlays for each background location, and leveled the survey data (i.e., removed background) based on proximal time and location.

6.2.2 Classification

At Closed Castner Range, URS performed full cued data analysis and classification after field work concluded using UX-Analyze version 8.3. Generally, default setting parameters in the Process Data menu were not overridden except where necessary to meet project-specific criteria.

- Validate Library: URS excluded library items with low matches and selected unexpected TOI for ground truth using the Validate Library processing menu and scatter analyses.
- Ground Truth Request 1: Confirmed seven TOI plus discovery of a new 37 mm TOI that URS added to the project-specific library.
- Classify and Rank: URS matched single and multiple object solutions to the validated library and created a prioritized target list. Selected additional ground truth locations based on cluster analysis and initial ground truth results.
- Ground Truth Request 2: Confirmed four TOI plus discovery of a second new 37 mm TOI that URS added to the project-specific library. URS re-ran the Classify and Rank menu was using the revised library, resulting in a new prioritized list
- Verification of Digs: ESTCP/ Institute for Defense Analysis (IDA) provided ground truth information for the dig portion of the prioritized list. A third new TOI (25 mm projectile) was found and added to the library. The initial portion of the prioritized list (already dug) was retained, but the undug portion of the list was reprioritized and additional items matching to the new 25mm projectile were added as digs.
- Final Ranked Anomaly List: URS submitted a final ranked anomaly list based on the library match, cluster analysis, and ground truth results to ESTCP/IDA.

At Former Camp Hale, Black Tusk performed classification of cued data with their proprietary software using library matching and clustering. Black Tusk selected 100 targets for ground truth digs to down select targets and refine project-specific anomaly classification. The 100 ground truth digs included three TOI: two 81 mm mortars and one 40 mm illumination round.

6.3 DATA PRODUCTS

Table 5 provides the general prioritized target list statistics for Closed Castner Range. The URS prioritized target list using the UX-Analyze library matching method identified 97% of the TOI in the dig portion of the list (Categories 1 and 2). This included a 105-mm projectile (MEC), 37-mm and 25-mm projectile frag (MD), and seeds. The number of targets on the dig list (including training targets) was 639, which was 43% of the total cued targets. URS ranked fuzes as TOI in the final prioritized target list; however, fuzes were determined by ESTCP to be non-TOI for scoring purposes. Inclusion of fuzes resulted in 148 digs (Categories 1 and 2) that actually were non-TOI.

Table 5. General Prioritized Target List Statistics for Closed Castner Range

List Name	TOI Identified		Training Targets		Cannot Analyze		List Length		Total Targets
	Qty.	%	Qty.	%	Qty.	%	Qty.	%	
FtBliss URS UXA-LM None 2x2 Custom s2v2	38	97%	131	9%	66	4%	639	43%	1,491

One TOI (CR-1341) was identified in Category 3, the no-dig portion of the list. The difficult TOI was a small ISO recovered at 23 cm bgs. A 21.5 cm tall rock was located on the surface, which affected the placement and height of the sensor array for the cued field measurement. The center of the cued shot array location met distance tolerances to the emplaced seed item location (34 cm); however, the highest library match was to a fuze part and the inverted item decision statistic was only 0.31, so the item was placed in Category 3.

At Former Camp Hale, Black Tusk provided a final ranked anomaly list for both dynamic and cued classification using library matching and ground truth results. All seed items within the study area were recovered. URS excavated targets using the prioritized dig list and validated performance of the study by excavating an additional 110 anomalies past the dig/no dig threshold (by prioritized order and randomly selected). No TOIs were found thereby providing the additional data quality assurance requested by the CDPHE and ESTCP.

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7.0 PERFORMANCE ASSESSMENT

A summary of the performance objectives and results for both demonstration projects are located in Section 3, Table 2 (Closed Castner Range) and Table 3 (Former Camp Hale), of this report.

7.1 SITE-SPECIFIC BACKGROUND

During the cued survey at both project sites, URS collected background response measurements generally hourly. More frequent measurements were collected if equipment was restarted or field conditions changed.

At Closed Castner Range, no measurement metric was associated with site-specific background data.

At Former Camp Hale, URS collected a series of measurements at the center of a potential background location plus 0.4 m offsets in each of the four cardinal directions. After review by the data processor, the flagged location was marked as a suitable background location for cued survey. The background measurements were compared to others taken at the same location during the course of the cued survey.

7.2 ALONG-LINE MEASUREMENT SPACING

URS used Geosoft's Oasis Montaj UX-Process Sample Separation analysis module to calculate along-line measurement spacing.

At Closed Castner Range, over 99.9% of the data met the along-line objective of less than 25-cm spacing. This result was better than the performance objective of 90%. These results exclude areas that could not be surveyed due to vegetation.

At Former Camp Hale, the sample separation objectives of at least 80% at 15-cm spacing, 98% at 25-cm spacing, and 100% at 40-cm spacing were met. These results exclude areas that could not be surveyed due to vegetation and terrain.

7.3 COMPLETE COVERAGE OF THE DEMONSTRATION SITE

URS used UX-Process Footprint Coverage QC Tool to calculate dynamic data coverage.

At Closed Castner Range, the footprint coverage objectives of at least 85% coverage at a 0.6-m instrument footprint and at least 98% coverage at 0.75-m were met. These results include areas that could not be surveyed due to vegetation.

At Former Camp Hale, the footprint coverage objectives of at least 85% coverage at a 0.6-m instrument footprint, at least 98% coverage at 0.75-m, and 100% coverage at 1-m were met, except for the 1-m instrument footprint in the 13001-13002 grids, where steep terrain and tree cover limited accessibility and GPS coverage. For grids 13001 and 13002, the 1-m instrument footprint achieved 99.7% coverage instead of the required 100% coverage. These results exclude areas that could not be surveyed due to vegetation and steep terrain.

7.4 INSTRUMENT VERIFICATION STRIP RESULTS

URS collected TEMTADS IVS data generally twice-daily for both projects. Responses were compared for each type of data collected (dynamic or cued) at each project location.

At Closed Castner Range, the expected dynamic IVS response was estimated by calculating a running average of the sum of all four sensors at the 14th time gate. A small percentage of the dynamic IVS tests did not meet the +/- 30% repeatability metric. In the IVS runs that failed, a response slightly outside of the criteria was measured over one of the five seed items. This may be due to inconsistent positioning with the litter. Slight deviations in line path and carry height can cause a higher or lower than expected response.

At Former Camp Hale, since inversion of dynamic data was not possible in UX-Analyze, Black Tusk provided data to support this objective during the beginning of the survey. The Root Mean Square (RMS) amplitudes for the IVS were within ±30% at the 14th time gate, and the down-track inverted location was within 30 cm for the days data were available.

For the cued survey at both projects, since the exact polarizabilities of each seed item are not known (each seed was not measured for comparison), they were estimated by comparing against the highest library match for each item. At Closed Castner Range, all cued seed items matched to a small ISO at 0.96 or higher. The deltas for the inverted locations in the X and Y directions were within 15 cm and the Z direction was within 10 cm. At Former Camp Hale, all cued seed items matched to a medium ISO at 0.97 or higher. The deltas for the inverted locations in the X and Y directions were within 5 cm and the Z direction was within 2 cm.

7.5 CUED INTERROGATION OF ANOMALIES

The objective is considered met if 100% of anomalies are detected within 40 cm of the target location.

For the Closed Castner Range project area, the array was within 40 cm of the cued data collection flag in all except two locations (99.9%). One target was located in an area of dense vegetation inaccessible to the array, and one target file did not have an associated GPS file transmitted with the TEM file, so positioning information could not be ascertained. Of note, 37 dig locations were selected by the processor based on additional targets found during preliminary processing, so they did not have unique target flags during cued data collection for comparison using this metric.

For the entire Former Camp Hale project area, 99.3% of the instrument positions were within 40 cm of the cued flag location. Specifically, for data collected in grids 11001-11005 and 12001-12005, where GPS coverage and terrain were good, all but one of the 1,375 instrument positions (99.9%) were within 40 cm of the cued flag location. For data collected in grids 13001 and 13002, where GPS coverage was spotty and terrain challenging, all but 12 of the 366 instrument positions (96.7%) were within 40 cm of the cued flag location.

7.6 DETECTION OF ALL TARGETS OF INTEREST

The objective is considered met if 100% of the seeded items are detected within a halo of 60 cm.

At Closed Castner Range, several small ISO were not detected and located within a 60 cm halo of their predicted locations. Seed items either were not detected, were not selected as separate targets, or were located in areas inaccessible to the sensor. Refer to the Final Report for further information.

At Former Camp Hale, all of the blind seeds (medium ISO) were detected within 60 cm of their predicted locations.

7.7 MAXIMIZE CORRECT CLASSIFICATION OF TARGETS OF INTEREST

The objective is considered to be met if all of the TOI are correctly labeled as TOI on the ranked anomaly list.

At Closed Castner Range, the prioritized target list identified only 97% of the TOI in the dig portion of the list (Categories 1 and 2). One TOI (CR-1341) was identified in the no-dig portion of the list (Category 3). Refer to Section 6.3 for additional information regarding CR-1341.

At Former Camp Hale, the prioritized anomaly lists placed 100% of recovered TOI in the dig/ ground truth portion of the list. Refer to the Black Tusk ESTCP report for more information.

7.8 MAXIMIZE CORRECT CLASSIFICATION OF NON-TARGETS OF INTEREST

The objective is considered to be met if more than 75% of the non-TOI items can be correctly labeled as non-TOI while retaining all TOI on the dig list.

At Closed Castner Range, the prioritized target list identified only 60% of the non-TOI correctly, and all TOI were not identified on the dig portion of the list (refer to Section 7.7). If fuzes, which were considered TOI in the final prioritized target list, were moved to Category 3, then 70% of the non-TOI would have been identified correctly.

At Former Camp Hale, no TOI were recovered in the QC digs past the stop dig point. Refer to the Black Tusk ESTCP report for more information.

7.9 SPECIFICATION OF NO-DIG THRESHOLD

The objective is considered to be met if the dig / no-dig threshold results in more than 75% of the excavated non-TOI items were correctly labeled as non-TOI, while correctly identifying all the TOI.

At Closed Castner Range, the dig/no-dig threshold missed one difficult TOI by 665 digs, and only 60% of the non-TOI items were correctly labeled as non-TOI. Refer to Section 6.3 regarding the missed TOI (CR-1341) and Section 7.8 regarding non-TOI classification.

At Former Camp Hale, TOI were recovered in the dig portion of the list, and no TOI were recovered in QC digs past the stop dig point. Refer to the Black Tusk ESTCP report for more information.

7.10 MINIMIZE NUMBER OF ANOMALIES THAT CANNOT BE ANALYZED

The objective is considered to be met if reliable parameters can be estimated for more than 95% of the anomalies on the detection list.

At Closed Castner Range, less than 5% of the anomalies were in Category 0, cannot analyze. This objective was met.

At Former Camp Hale, reliable target parameters were estimated for 99.9% of the dig list. Several areas were delineated by the project team as unsuitable for advanced classification and were excavated (i.e., mag and dig). Refer to the Black Tusk ESTCP report for more information.

7.11 CORRECT ESTIMATION OF TARGET PARAMETERS

The objective is considered to be met if the seed item estimated polarizabilities are within ± 20%, the estimated X, Y locations are within 15 cm (1 σ), and the estimated depths (Z) are within 10 cm (1 σ).

At Closed Castner Range, since the exact polarizabilities of each seed item are not known (each seed was not measured for comparison), the polarizations were estimated by comparing primary polarizability against the highest library match for each item. For 25 of the 28 cued seed locations, the highest library matches for the primary polarizability were to small ISOs at greater than 0.92, the Category 1 threshold. For three of the seed locations, the highest library matches were to items other than small ISOs; refer to the Final Report for additional information. For the X, Y locations, 43% of the dig flag locations were within 15 cm of the recovered item location and 93% were within 40 cm. Refer to Section 6.4.1 of the Final Report for more information regarding flag location variabilities. For the Z locations, 93% of inverted estimated depths were within 10 cm of the recovered item depth. The overall mean error for all cued seeds was 1 cm too shallow, and the median error was even with the recovered depths.

At Former Camp Hale, seed items were correctly identified. Refer to the Black Tusk ESTCP report for more information.

7.12 EXCAVATION OF ANOMALIES

At Closed Castner Range, no measurement metric was associated with excavation.

At Former Camp Hale, the objective will be considered to be met if greater than 75% of the items identified as TOI are TOI or TOI-like anomalies and 100 % of the items identified as non-TOI are non-TOI. Refer to the Black Tusk ESTCP report for more information.

8.0 COST ASSESSMENT

8.1 COST SUMMARY

Table 6 presents a simple cost summary for the technology used at the demonstration sites for this project.

Table 6. Cost Model for the Demonstration Sites

Cost Element	Closed Castner Range		Former Camp Hale	
	Data Tracked During Demonstration	**Estimated Costs**	**Data Tracked During Demonstration**	**Estimated Costs**
Project Planning	Develop project-specific documents: • Project Kickoff • Demonstration Plan • SSHP	$49,651	Develop project-specific documents: • Project Kickoff • Demonstration Plan • SSHP	$34,987
Site Preparation	Set up onsite project area Vegetation trimming Install blind seed items • Labor • Equipment rental • Supplies • Travel	$74,499	Set up onsite project area Vegetation trimming Install blind seed items • Labor • Equipment rental • Supplies • Travel	$81,304
TEMTADS Data Collection and Processing	3-4 people (field team) data collection and processing • Dynamic data collection on 5 acres • Cued data collection on 2.5 acres: o 1,495 anomalies (2,200 cued shots including re-collect, background, and IVS measurements) Project Geophysicist • Equipment rental • Supplies • Travel	$120,140	3-4 people (field team) data collection and processing • Dynamic data collection on 10.5 acres • Cued data collection on 7.6 acres: o 1,742 anomalies (2,468 cued shots including re-collect, background, IVS, and sensor function measurements) Project Geophysicist • Equipment rental • Supplies • Travel	$234,575
TEMTADS Data Analysis/ Classification	Dynamic: over 3,000 targets picked Cued: 1,491 targets fully classified	$24,202 29 minutes/ anomaly $16/ anomaly	NA*	NA

Cost Element	Closed Castner Range		Former Camp Hale	
	Data Tracked During Demonstration	Estimated Costs	Data Tracked During Demonstration	Estimated Costs
Validation Digging	7 UXO Technicians Equipment rental Supplies Travel • 1,525 targets (including recovery of 30 seed items in dynamic area) • 1,941 anomalies (including anomalies found in 30+ cm radius of target)	$259,990 $134/ anomaly $170/target location	8 UXO Technicians (includes four days awaiting regulatory approval of final dig list) Equipment rental Supplies Travel • 1,371 targets (including mag/dig locations that had high concentration of anomalies or accessibility issues) • 2,650 anomalies (including anomalies found in 30+ cm radius of target)	$236,169 $89/ anomaly $172/target location

*Not Applicable (NA)

8.2 COST DRIVERS

The primary cost considerations associated with the selection and broad implementation of advanced geophysics and classification technologies are:

- Cost of data collection with advanced sensor arrays (primarily labor, per diem, and equipment rental/repair);
- Cost of data processing, analysis, and anomaly classification (primarily labor); and
- Cost savings associated with reduction in number of anomalies requiring intrusive investigation (primarily labor, per diem, and equipment rental).

URS used TEMTADS for data collection at both project sites. While most costs appear to be comparable between the two TEMTADS demonstrations, costs for data collection and processing were higher at Former Camp Hale than Closed Castner Range. While the number of cued anomalies collected was similar, the dynamic acreage covered was greater, cued production rates were lower (due to TEMTADS data collection software issues), but the lodging and per diem were higher at Former Camp Hale than at Fort Bliss. While the intrusive field portion looks comparable in number of targets and cost between the two projects, Former Camp Hale costs would be expected to be higher considering lodging and per diem costs as well as the downtime awaiting regulatory approval of the final dig list. However, many of the anomalies at Former Camp Hale were mag/dig locations, which did not require reacquisition of target locations and likely equalized the costs between the two projects.

At Closed Castner Range, a surface clearance was not conducted due to the Government shutdown. Uneven terrain (slopes, rocks) and vegetation precipitated the need to collect dynamic data using a hand-carried litter, which slowed production rates and added noise to the data. Several seeds were missed during initial processing using techniques within UX-Analyze available at the time of the demonstration project. The presence of ferrous rocks, frag, and small TOI resulted in additional digs.

8.3 COST BENEFIT

The primary driver for developing advanced geophysics and classification technologies is to reduce the total cost associated with executing munitions responses. DoD recognizes that a large portion of the munitions response budget is and will be spent excavating and removing harmless metal fragments and non-munitions-related metal from MRSs. The implementation of advanced geophysics and classification has been demonstrated to reduce the total number of anomalies requiring intrusive investigation (i.e., excavation) by 60% to 90% in demonstration/validation projects. For advanced geophysics and classification to be broadly employed, these technologies must cost less to implement than the intrusive investigations that would be avoided by their implementation.

At Closed Castner Range, URS was able to correctly classify 60% of the non-TOI (70% if fuzes are not considered TOI) using TEMTADS 2x2 in litter mode and classifying cued data using UX-Analyze library matching. URS performed full validation digging of each anomaly identified through cued classification at the Closed Castner Range, which are reflected in the intrusive costs in Table 6. For an actual production site, only a portion of the anomalies would have been excavated based on the results of geophysical classification. Advanced classification would have resulted in cost savings associated with 60-70% fewer digs. However, it is important to note the quality issues were encountered with advanced classification application at this project site. Using refined processing and classification techniques (e.g., dynamic inversion and classification) and better instrument attachments (e.g., litter poles with less flex) may result in better quality data that can achieve even fewer digs.

At Former Camp Hale, the analysis approach incorporated both dynamic classification as well as standard cued classification. Intrusive investigation used a selective approach similar to a production project. URS excavated targets using the prioritized dig list and validated performance of the study by excavating an additional 110 anomalies past the dig/no dig threshold (by prioritized order and randomly selected). The majority of the intrusively investigated targets were located in areas that were not conducive to advanced classification and where “mag and dig” were performed. These included an area with a high concentration of anomalies and areas with instrument accessibility issues. These mag and dig areas accounted for 999 (73% of total) target locations and 2,018 (76% of total) recovered metallic items. Therefore, intrusive costs for only the advanced classification portion of the project would be lower than those presented in Table 6.

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9.0 IMPLEMENTATION ISSUES

Advanced geophysical sensors and advanced data analysis methods in a production environment were used to characterize MEC hazards at Closed Castner Range and Former Camp Hale. Because URS' role in the Live Site Demonstration Program is to evaluate the implementation of these advanced sensors and classification methods from the perspective of a large-scale MMRP production company, URS documented issues/recommendations that will support implementation on an industry-wide scale. Additional details can be found in the Final Reports for each project.

9.1 TEMTADS 2X2 LITTER: CLOSED CASTNER RANGE

9.1.1 Transport

The terrain and vegetation at Closed Castner Range did not afford the field team the ability to locate the storage area near the study area so that the TEMTADS could be moved by hand. The equipment had to be placed sideways in a pickup truck (with the ten-ft poles extending beyond the width of the truck bed) and driven down a sloped and rocky dirt road to the IVS. URS used foam blocks and small equipment transportation cases, as suggested by NRL, to support and stabilize the system during transport but due to the rough unpaved road, the equipment underwent strong and sustained jostling while in transit.

9.1.2 Weight and Ergonomics

The combined weight of the array (approximately 125 lbs) and backpack (approximately 35 lbs) required frequent breaks during data collection in an attempt to manage fatigue and avoid injury. URS-fabricated harnesses to help distribute the weight more evenly, allow some freedom of motion, and minimize slips, trips, or falls. Since the equipment was secured to the backpack and frequent personnel switches were necessary, the same backpack was worn by multiple users. Personal fit adjustments were limited, thereby making the ergonomics not ideal for every user.

9.1.3 Anomaly Locating

In other studies, field personnel used a pole-mounted RTK GPS (i.e., detached from the geophysical equipment) to navigate to each anomaly location and emplace non-metallic pin flag marked with the anomaly ID prior to cued data collection. At Closed Castner Range, rocky soil and weather conditions (i.e., wind) precluded the ability to place and retain flags. Therefore, the field team used the RTK GPS mounted on the litter-configured TEMTADS along with the TSC controller to navigate to each point and immediately collect cued data. Rocks, vegetation, and/or terrain added to the difficulty of centering the sensor over the anomaly location.

9.1.4 Length of Litter Poles and Bouncing/Swaying Array

NRL provided ten-ft fiberglass poles to suspend the array for the Closed Castner Range project. In general, the litter configuration led to bouncing and swaying of the array during dynamic data collection that increased as walking speed increased. While some oscillation is unavoidable due to the natural walking motion, it was noted that the poles themselves also had flexibility. Additionally, the length of the poles precluded the ability to operate the array at a consistent height while traversing the narrow and steep arroyos. The bottom of the runners frequently touched the ground on either side at the top of the arroyo and the array was suspended at a much higher than the nominal survey height from the bottom center of the arroyo. This led to the appearance of false anomalies for the data collected at the tops of the arroyos and false clear areas at the bottom/inside the arroyos.

The field team walked additional transects parallel to arroyo features in an effort to obtain data with a more consistent array height. After completion of the Closed Castner Range field work, NRL procured nine-ft litter poles made from sturdier carbon fiber, with handles to allow for adjustments in user heights.

9.1.5 Coil Failure

A transmitter board failure occurred during the Closed Castner Range data collection. Tablet readings showed abnormal readings on coil 1 and then registered a flat line. The field tablet allowed the team to recognize the problem quickly, but troubleshooting the problem took almost an entire work day. Initial attempts to check and replace the cables and batteries did not remedy the problem. The direct cause of the abnormal readings and coil failure could not be located. However, after switching coil 1 and 2, the TEMTADS began operating normally.

9.2 TEMTADS 2X2 CART: FORMER CAMP HALE

9.2.1 Longer Transmitter (Tx)/Receiver (Rx) Cables

An alternate instrument configuration was tested where the standard Tx and Rx cables were replaced with longer versions. The use of longer cables allowed the backpack to be carried by personnel separate from the cart operator during data collection. Additionally, it allowed the backpack to be staged on the ground while personnel lifted the cart into the bed of the pickup truck for daily transport between the demonstration area and storage area. However, use of the longer cables resulted in faster battery charge depletion than with the standard-length cables. This required more diligent monitoring of battery usage by field personnel.

9.2.2 Data Collection Software

The field team experienced issues with the data collection program throughout the project. Program freezes required restarting the computer and additional QC checks. The instrument developers were aware of issues with serial communication inherent in the system. An updated data collection program was released at the end of the project, but the field team did not test it due to time constraints.

9.3 PROCESSING AND TARGET PICKING: CLOSED CASTNER RANGE

9.3.1 Size and Number of Files

A typical data collection day for one team yielded 800MB of raw data and approximately 3GB or processed data. Each data processing step took between 5 and 80 minutes, and so many steps were combined into automated scripts. The large data files made it difficult to share and collaborate with non-local colleagues, and the advanced sensor processing time made it difficult to experiment and discover better ways of handling the data (e.g., determining the best background subtraction files).

Cued data classification using the Geosoft Oasis Montaj Version 8.3 Processing menu was slow and caused multiple failures. After troubleshooting with the software developers, the errors were attributed to lack of computer space (files were inexplicably reaching 10s of GB without defragmenting) and available memory (after multi-day continuous processing runs). URS acquired a new computer and worked with the developers to run the Processing menu in shorter pieces with manual checks and file management between each process.

9.3.2 Standardized Workflow and Parameters

While a user's manual exists for the TEMTADS 2x2 instrument, limited guidance for processing data in UX-Analyze was available during the Closed Castner Range demonstration project. A robust user's manual that includes guidance and standard parameters would be beneficial for future implementation.

The standard TEMTADS library did not contain every TOI found at Closed Castner Range. Cued data files associated with three items found at Closed Castner Range were added to the library for matching, but the cued data were not of ideal quality and resulted in additional matches to non-TOI.

9.3.3 File Naming

Anomaly flag names were revised between field collection (date and a sequential file number), initial processing and digging (alpha-numeric grid identifier and anomaly number [each grid numbered 1-n]), and final classification (unique numerical identifier throughout the cued study area). The majority of renaming occurred due to software workflow compatibility issues. Based on lessons learned at Closed Castner Range and discussion with the software developers, a new naming convention was established prior to the Former Camp Hale project.

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