Using Advanced Sensor Technologies to Optimize UXO Remediation at Nauru Airport

HISTORICAL SUMMARY

During World War Two, Nauru was attacked by both sides of the conflict. In December 1940, German auxiliary cruiser Komet shelled Australian mining facilities, oil storage depots, and the ship loading cantilever on Nauru. On 25 August 1942, Japanese troops captured Nauru and subsequently built an airfield on the island and operated for three years (26 August 1942 – 13 September 1945). At that time, Nauru was under Austrailian administration and occupied by the Japanese military as part of its operations in the Pacific. The most important infrastructure built by Japan was an airfield, which was the target of repeated Allied air strikes until the end of the war.

Scan here *to read about the project in the Nauru Bulletin (p. 9)*

INTRODUCTION

Upgrades to Nauru International Airport required subsurface works across the runway, taxiways, and apron in an environment with extensive, documented World War II bombing and naval shelling. The airport's role as the island's primary transport link made it critical to minimize operational disruptions while providing safe remediation of legacy unexploded ordnance (UXO). Funded by Austrailia's Department of Foreign Affairs and Trade (DFAT) and delivered in cooperation with the Government of Nauru (GoN), National Police, the Civil Aviation Authority, and Downer, Tetra Tech and Gap EOD conducted a targeted UXO survey and clearance program ahead of pavement replacement works. A cornerstone of the project's success was strong cooperation and advance planning with local stakeholders. Early coordination with GoN and airport representatives established evacuation procedures, access controls, emergency response pathways, and stakeholder communication protocols that allowed clearance activities to proceed safely while preserving airport operations.

METHODOLOGY

Tetra Tech and GapEOD employed advanced sensors to discriminate thousands of benign metallic clutter and potential ordnance. An initial 2023 towed electromagnetic screening survey returned 237 anomalies. Due to the critical need to minimize impacts to airport operations, in 2023 Tetra Tech redeployed Gap EOD's UltraTEM IV system with a refined data collection and processing capability that reduced this list by approximately 60 percent, to 96 anomalies. Field investigations used excavators and hand tools with engineering controls and strict safety procedures. Three UXO items were located beneath the existing runway footprint: two 500-lb aerial bombs and one 5-inch Naval projectile. Each item was neutralized in situ using controlled thermite burn techniques and protective works to limit potential fragmentation and blast effects. All three render-safe procedures were completed within 8 hours each, minimizing runway closure and protecting airport infrastructure.

KEY LESSONS

Advanced sensor systems and robust discrimination workflows can significantly reduce intrusive investigations on sensitive infrastructure sites. When combined with disciplined investigative procedures and strong coordination, precise geophysical profiling and insitu neutralization enabled safe, efficient remediation with minimal operational impact. Tetra Tech's work in Nauru demonstrates how data-driven geophysics, tailored render-safe procedures, and proactive stakeholder engagement can optimize UXO remediation on critical infrastructure projects and provide a scalable model for similar sites worldwide.

TETRA TECH

GapEOD Explosive Ordnance Detection

Classification Depth and Complex Scenarios for One-Pass AGC

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ESTCP

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This work is supported by ESTCP project MR25-8796

Introduction

We present recent work investigating the **depth of reliable classification** for One-Pass AGC. Using synthetic seeding we show that, given an estimate of the noise, a response curve can be used to predict classification depth at a specified multiplier of the noise. While detection depths are usually assumed to correspond to 5x noise multiplier, **our simulations indicate a 10x multiplier predicts depths at which almost all synthetic scenarios are classified correctly.**

We also investigate how **classification depth may be reduced in complex multi-object scenarios** where a deep target of interest (TOI) at the maximum classification depth is near (25 cm horizontal separation) a shallow clutter item.

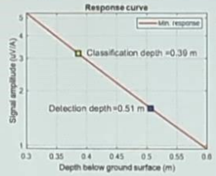
Classification Depth

Maximum classification depth depends on:

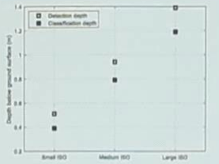
1. AGC sensor geometry and height
2. Target orientation and polarizabilities
3. Stop dig threshold
4. Noise

Response curve analysis accounts for all variables which control classification performance for single object scenarios, with a simplifying assumption that peak anomaly amplitude at a single detection channel is predictive of classification performance.

Synthetic seeding studies (see below) indicate a depth corresponding to **10x the noise** as a rule of thumb for the worst-case classification depth. This is a more conservative choice than a 5x threshold, which predicts the expected (or average) classification depth.



Response curve for a small ISO. Detection and classification depths assume 5x and 10x noise multipliers for a noise level of 0.3 uV/A for UltraTEM Portable Classifier data.



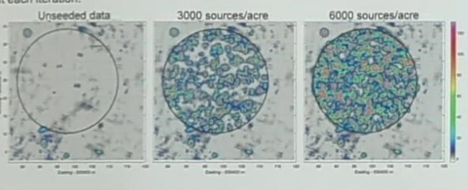
Predicted detection and classification depths for ISOs assuming 5x and 10x noise multipliers for a noise level of 0.3 uV/A for UltraTEM Portable Classifier data.

Due to the nonlinearity of the response curve, larger items see a larger absolute difference between predicted detection and classification depths.

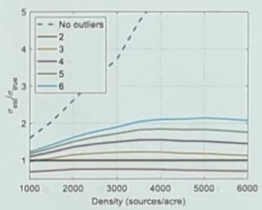
Noise estimation

A critical step in classification depth analysis is estimation of background noise. Background noise is typically estimated in dynamic AGC data by manually delineating anomaly-free areas of the data. This requires subjective decisions and may vary between analysts.

Here we consider a "trimmed" robust estimator of the noise designed to produce consistent noise estimates with minimal anomaly avoidance. This approach iteratively removes outliers that exceed a rejection threshold that is a specified number of standard deviations from zero. We also use a robust "median absolute deviation" (MAD) estimator of the noise standard deviation at each iteration.

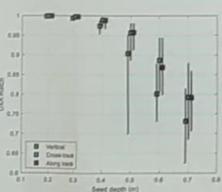


Left: UltraTEM Classifier data for testing noise estimates. We assume the estimated noise inside the black circle is the "true" noise and progressively add synthetic targets at increasing densities (middle and right) to test robust noise estimates.



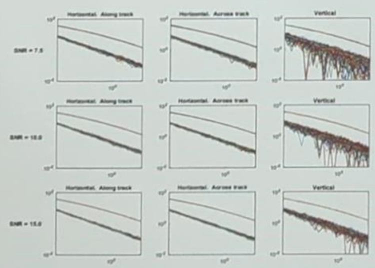
Iterative rejection of outliers can provide a nearly unbiased estimate of background noise standard deviations even at high source densities (e.g. ≥5000 sources/acre). We find that an outlier rejection threshold = 3 provides the best estimate of the background noise level for this example.

Verifying classification depth with synthetic seeding



Expected polarizability matches (using all polarizabilities) as a function of seed depth. These simulations assume Gaussian noise only.

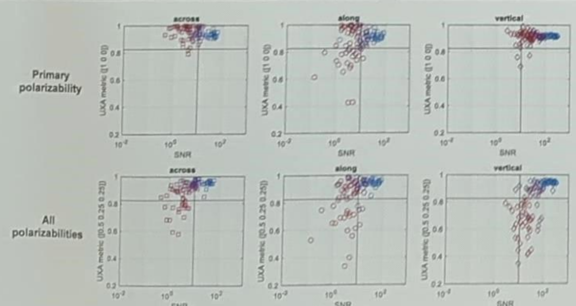
We observe lower expected polarizability matches and greater variability for vertically oriented targets.



Synthetic seeding simulations confirm that secondary polarizabilities are poorly constrained for vertically-oriented targets.

This is a consequence of weaker horizontal field excitations of secondary polarizabilities for vertical targets.

This effect is largely mitigated in classification by using primary polarizability matching.



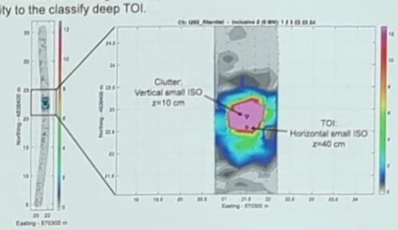
Polarizability matches for multiple realizations of synthetic seeds at varying SNR and orientation. Sources that are correctly classified at a 10x noise threshold are in the top right quadrant of each plot.

These simulations indicate that the majority of cases will be classified at the predicted maximum classification depth defined by a 10x noise threshold, provided the classifier accounts for poorly constrained secondary polarizabilities with a primary polarizability match.

Complex multi-object scenarios

Classification depth analysis accounts for site specific noise, but does not consider how classification performance may be degraded in multi-object scenarios. Here we investigate **how our ability to classify TOI at the maximum classification depth changes as the amplitude of signal from near-surface clutter increases.**

We consider the simplest case of a two-object scenario on a transect, with near surface clutter at 10 cm depth and at 25 cm horizontal separation from a small ISO at the maximum predicted classification depth of 40 cm for this data. In the following experiments we investigate how positional error and signal from the clutter affect our ability to the classify deep TOI.

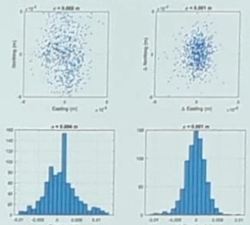


In this context **we define saturation as the peak signal of a detected anomaly relative to the peak signal from a TOI at the maximum classification depth.** For example, if we define the classification depth using a 10x noise multiplier, then a saturation value of 50 corresponds to a signal amplitude that is 500 times the noise (= 10x noise * 50). This definition will allow us to tie the saturation threshold directly to classification depth and site-specific noise.

Positional precision

Positional precision is an important control on our ability to recover accurate polarizabilities for multi-object cases when doing AGC with dynamic data (see simulation results below)

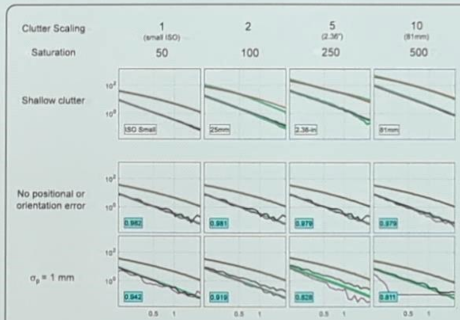
In this context we are concerned less with the absolute accuracy of sensor position and attitude, but rather the precision of these measurements as the sensor traverses over a target. To recover accurate polarizabilities in multi-object cases, we need precise measurements over a short distance (1-2 m) to minimize any spatial distortions in the measured dipolar anomalies.



Precision of RTK GPS positions during a static function test. This time series gives standard deviations of 2 mm and 4 mm for horizontal and vertical precision, respectively (left column). However, the point-to-point standard deviation in this time series is 1 mm for both horizontal and vertical positions (right column). We use this as an initial estimate of positional precision for our simulations, but also consider larger errors to account for reduced precision for a moving sensor.

Effect of saturation and positional uncertainty on classification of TOI at the maximum predicted classification depth

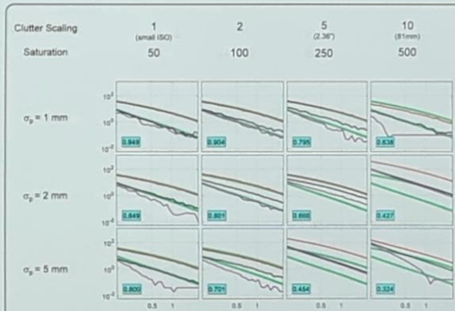
We now linearly scale the polarizabilities for the shallow clutter between 1 and 10 (as indicated by the "Clutter scaling" factor below). This scaling increases the approximate size of the near surface clutter from a small ISO to an 81mm mortar, with a commensurate increase in saturation in the data from 50 to 500. For each instance of the clutter scaling, we apply multiple realizations of zero mean Gaussian positional errors with standard deviations σ_p ranging from 0 mm to 5 mm. We also apply zero mean Gaussian errors with a standard deviation of 0.1 degrees to sensor pitch and roll. Independent errors are applied to each fiducial.



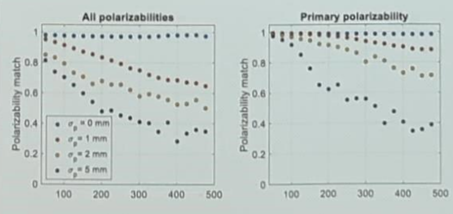
Top row: polarizabilities for near surface clutter item at 10 cm depth. We scale the polarizabilities of a small ISO up by the indicated "Clutter Scaling." This increases the corresponding saturation in the data.

Middle row: estimated polarizabilities for TOI (a small ISO at 40 cm depth). Cyan boxes indicate polarizability match using all three estimated polarizabilities. **In the absence of positional error, increasing saturation has no effect on polarizability accuracy for the range of clutter scaling (and saturation) considered here.**

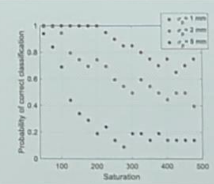
Bottom row: estimated polarizabilities for the same TOI, with a positional error of σ_p = 1 mm.



Dependence of estimated polarizabilities for TOI (a small ISO at 40 cm depth) on saturation and positional error (σ_p). **Increased saturation and positional error reduces expected polarizability accuracy.**



Expected polarizability misfit as a function of saturation and positional uncertainty (σ_p). **Increased saturation and positional error reduces polarizability accuracy in multi-object scenarios.**



Probability of correct classification as a function of saturation and positional uncertainty (σ_p). Probabilities are generated with multiple realizations of positional and orientation errors for each scenarios

Here we assume that a primary polarizability match > 0.9 is required for correct classification.

A saturation threshold of 100 gives a high probability of correct classification in these scenarios.

Conclusions

Successful one-pass classification in complex multi-object cases depends not only source separation (or density), but also:

1. **Saturation (i.e. signal of clutter relative to targets of interest at the maximum classification depth**
2. **Precision of position and attitude measurements**

Simulation results indicate a saturation threshold of 100 (equal to 1000x the noise assuming a 10x noise multiplier for the classification depth). Additional measurements are recommended to needed to verify these results.

REMEDIAL DESIGN AT WAIKOLOA MANEUVER AREA FORMERLY USED DEFENSE SITES PROJECT 02 AND PROJECT 04 (AREAS B, O, Q, J), ISLAND OF HAWAII, HAWAII

SITE OVERVIEW

- Munitions Response Site (MRS) comprises 4,481.1 acres
- Used as a military training range during World War II
- Current land use is a mixture of residential, commercial, industrial, agricultural, and recreational.

REMEDIAL DESIGN SCOPE

The objective was to prepare the design necessary to implement the Remedial Actions (RAs) selected in the Decision Documents.

Data Collection Site View

GEOPHYSICAL INVESTIGATION RESULTS

Remedial Design fieldwork was necessary as the Decision Document used outdated technologies impacting selected remedy effectiveness and cost as well as a requirement to assess previous removal action work.

Highlights:

- ▶ Successfully used advanced geophysical classification (AGC) sensors to detect and classify munitions in Hawaiian environment with challenging geology and areas of rugged terrain.
- ▶ Further refined AGC data analysis approach to filter out interfering geologic responses.
- ▶ Determined anomaly, source, and target of interest (TOI) density estimates for a refined Conceptual Site Model (CSM).

INTRUSIVE INVESTIGATION RESULTS

- Conducted 44,804 intrusive investigations
- Recovered 38 munitions and explosives of concern (MEC) and 3,270 munitions debris (MD) items

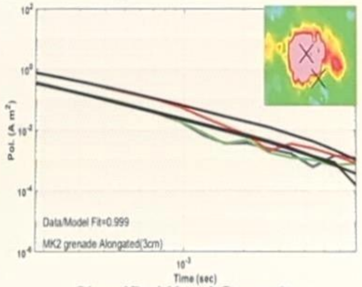
Highlights:

- ▶ Successful implementation of reduced exclusion zone (EZ) based on AGC size estimate using a miniature open front barricade (MOFB).
- ▶ Identified digs divided into their estimated size category by munition type and the relative EZ was applied.
- ▶ Developed standard operating procedures and gained approval of an Explosives Safety Submission (ESS) amendment to implement.
- ▶ Coordinated evacuations in over 300 properties.
- ▶ Refined TOI densities for the RA.

APEX Sensor (Cart Mode)

UltraTEM Person Portable Classifier

MPV



Classified Hand Grenade

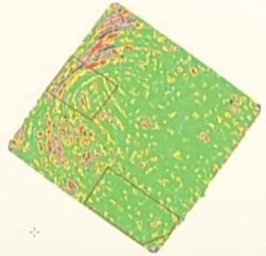
Intrusive Operations

MOFB to Support Intrusive Operations

APEX Sensor (Litter Mode)

UltraTEM Screener

Metal Mapper 2x2



Geologic Soil Response in Agricultural Area

Intrusive Operations

Reduced EZ in a Neighborhood

Acknowledgements: U.S. Army Corps of Engineers (USACE) Huntsville Center, USACE Honolulu District, and USACE Environmental and Munitions Center of Expertise; Contractor: HGL, and Subcontractors: Parsons Government Services, Inc. and Na Ali'i-ERRG JV

Temsense, LLC

Operational Depth Ranges for AGC: Robust Detection and Reliable Classification - A Case Study

Dr. Thomas Bell, Glenn Harbaugh, and Dr. Daniel Steinhurst

Introduction:

The bounds of an AGC sensor system's depth of detection and depth of reliable classification of a given TOI have been an open question since the inception of AGC and the fielding of the foundational sensor systems that brought the methodology into existence. The recently signed-out DoD QSR v3.0 and supporting DAGCAP SOPs codified this need into an upcoming requirement for AGC hardware vendors to address individually.

Methodology:

Temsense LLC has developed a workflow to evaluate the operational depth ranges for a given TOI using the DAGCAP-validated Temsense system. Known intrinsic properties of the TOI are synthetically seeded into segments of real-world, anomaly-free background data over the range of reasonable extrinsic seed parameters such as depth, azimuth angle, dip angle, and the footprint of the array.

- **Detection is based on the criterion that the monostatic, *z*-axis signal exceeds five times (5x) the RMS noise level at a time gate centered on 0.137 ms.**

- **Classification is based on the criterion that the polarizabilities estimated from signal plus noise data match the corresponding library polarizabilities with a standard library match metric value of at least 0.825. The performance of this criterion is also compared to that of signal exceedance of ten times (10x) the RMS noise level.**

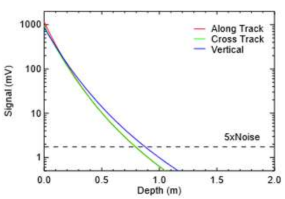
Reliable Detection Depth:

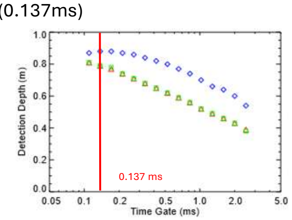
- Response curves were calculated for three orientations:
  - along track, cross track and vertical (nose down)
- RMS noise levels for stretches of anomaly-free survey data
- Early time gates are more favorable for detection because signal amplitudes generally decay faster with time than the noise does

Peaks with an SNR ≥ 5 are detectable to depths of ≥10 munition diameters, in keeping with the empirical USACoE "11x rule"

Target	Along Track (m)			Cross Track (m)			Vertical (m)			Diameters
	min	med	max	min	med	max	min	med	max	avg, med
37mm	0.42	**0.48**	0.50	0.43	**0.48**	0.50	0.45	**0.52**	0.54	**13.3**
SISO	0.39	**0.45**	0.47	0.42	**0.45**	0.47	0.48	**0.57**	0.59	**14.7**
60mm	0.66	**0.72**	0.73	0.68	**0.72**	0.73	0.71	**0.77**	0.79	**12.3**
MISO	0.73	**0.79**	0.81	0.75	**0.79**	0.81	0.80	**0.87**	0.89	**13.6**
105mm	1.07	**1.11**	1.13	1.07	**1.11**	1.13	1.01	**1.05**	1.07	**10.4**
LISO	1.12	**1.16**	1.18	1.12	**1.16**	1.18	1.06	**1.11**	1.13	**10.0**
155mm	1.31	**1.35**	1.36	1.31	**1.35**	1.36	1.12	**1.16**	1.17	**8.3**

MISO (0.137ms)





Targets of Interest:

A range of TOI sizes evaluated:

- 37mm 37mm projectile AP-T M74
- 60mm 60mm mortar M49A5
- 105mm 105mm projectile M1
- 155mm 155mm projectile M107
- SISO Schedule 80 small ISO
- MISO Schedule 80 medium ISO
- LISO Schedule 80 large ISO

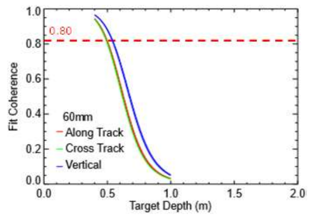
Dynamic Classification Depth:

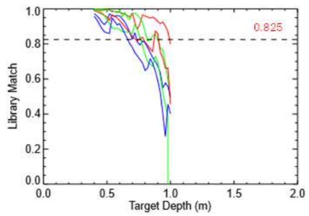
Inversion results calculated for synthetically seeded TOI, three orientations:

- Along track, cross track and vertical (nose down)
- For single passes (RI transects), and multi-pass (lawn-mower) surveys

Reliable classification depths based on a library match threshold of 0.825 are shown for single and multi-pass inversion.

- Multi-pass inversion improves performance the most for the larger, deeper targets.
- The library match-based metric is derived from the standard UX-Analyze AGC workflow.
  - Accurately reflects how an AGC job is typically conducted.
- The SNR ≥10x criterion appears to be a reasonable surrogate for single pass transects but appears overly conservative for the deeper targets and multi-pass inversion.
- Multi-pass inversion the 0.825 library match criterion yields detection depths which average about 30% deeper than corresponding 10x classification depths.
- Multi-pass inversion (left) and classification (right) results for the 60mm mortar.

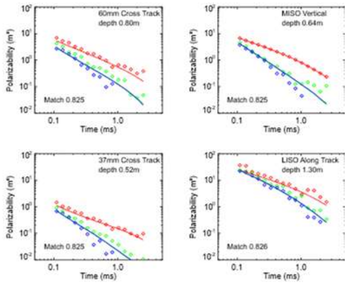




Target	Inversion	Along Track (m)			Cross Track (m)			Vertical (m)			Diameters
		min	med	max	min	med	max	min	med	max	avg, med
37mm	Single Pass	0.48	**0.54**	0.54	0.4	**0.42**	0.56	0.32	**0.34**	0.34	**11.7**
	Multi Pass	0.57	**0.63**	0.66	0.49	**0.53**	0.61	0.34	**0.39**	0.59	**14.0**
SISO	Single Pass	0.46	**0.49**	0.5	0.3	**0.47**	0.53	0.24	**0.25**	0.25	**12.1**
	Multi Pass	0.5	**0.55**	0.58	0.4	**0.44**	0.54	0.25	**0.43**	0.49	**14.2**
60mm	Single Pass	0.56	**0.58**	0.58	0.64	**0.67**	0.8	0.6	**0.63**	0.63	**10.4**
	Multi Pass	0.73	**0.92**	0.99	0.77	**0.8**	0.82	0.66	**0.67**	0.73	**13.3**
MISO	Single Pass	0.58	**0.61**	0.84	0.68	**0.71**	0.83	0.54	**0.56**	0.78	**10.4**
	Multi Pass	0.83	**1.05**	1.07	0.78	**0.84**	0.87	0.59	**0.62**	0.66	**13.9**
105mm	Single Pass	0.94	**0.94**	0.95	1.06	**1.09**	1.16	0.68	**0.69**	0.69	**8.6**
	Multi Pass	1.22	**1.26**	1.39	1.33	**1.42**	1.43	1.02	**1.06**	1.34	**11.9**
LISO	Single Pass	0.99	**0.99**	0.99	1.14	**1.17**	1.18	0.91	**0.92**	0.92	**9.0**
	Multi Pass	1.3	**1.31**	1.36	1.34	**1.44**	1.47	1.06	**1.09**	1.2	**11.2**
155mm	Single Pass	1.2	**1.21**	1.21	1.3	**1.31**	1.31	1.1	**1.11**	1.12	**7.8**
	Multi Pass	1.51	**1.53**	1.55	1.58	**1.59**	1.6	1.22	**1.22**	1.24	**9.3**

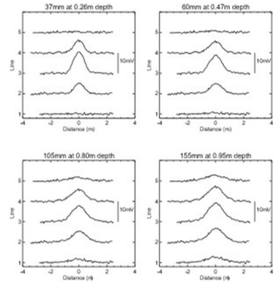
Examples of estimated and library polarizabilities at the 0.825 threshold.

Would a rational data analyst declare all four "TOI"?

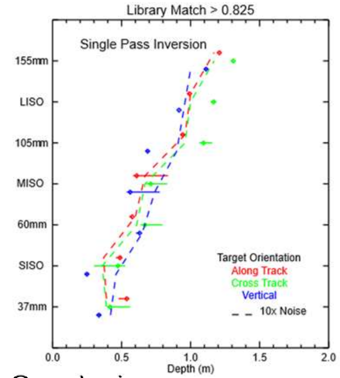


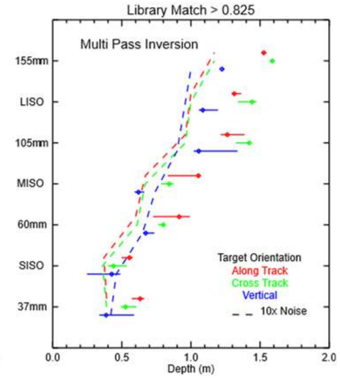
Examples of calculated data chips at 0.137 ms with SNR ≈30

Larger, denser data chips yield better fits, but lower fit coherence



Depth is that at which the library match drops below 0.825 for the first time in our simulations. The horizontal lines run from the minimum to the maximum in the target location window, with the symbols plotted at the median.





Conclusions:

Reliable depths of detection, and importantly, the range of possible values, are presented for a typical range of TOI. TOI detection is robust at an SNR ≥5. Classification is robust for library match metrics of ≥0.825.
Using a threshold of an SNR ≥10 for classification also works well for smaller, shallower items, but appears to be overly conservative for larger, deeper items.
Site-specific variations (*i.e.*, geology, noise floor) will also impact depth performance and should be evaluated on a case-by-case basis.

These results can help guide a project team to make informed decisions about project goals and metrics at all stages of the remediation process.

Contact us:

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ACORNSI
VIBRANT MINDS | VITAL SOLUTIONS

uXclassify

Combining AGC Analysis and Program Management

Overview

Advanced Geophysical Classification (AGC) demands precision, coordination, and seamless data flow. Yet traditional workflows often struggle with scattered files, communication gaps, and time-consuming processes. **uXclassify** transforms that reality.

uXclassify, a cloud-based software suite designed to support AGC programs, mitigates challenges with data handling, communication, and coordination across teams by providing:

- Cloud-based access with no local installation
- Streamlined data management and reduced repetitive tasks
- Real-time project tracking and progress updates

Our integrated AGC data-analysis tools in a user-friendly interface allows data analysts to focus on technical decisions, managers to focus on execution, and government stakeholders to focus on quality and defensibility of results.

Material in this poster provides an introduction, but watching short videos and an in-depth trial is needed to fully appreciate the full capabilities and benefits **uXclassify** offers.

Data Flow & QC/QA & Approvals

The menus of **uXclassify** are designed to follow the natural data flow from collection, data QC and coverage assessment, to AGC decision and intrusive investigation validation.

Along the way, data are reviewed and assessed by the Geophysical Classification Organization (GCO) analyst(s) and QC geophysicist(s). All decisions and associated records are archived.

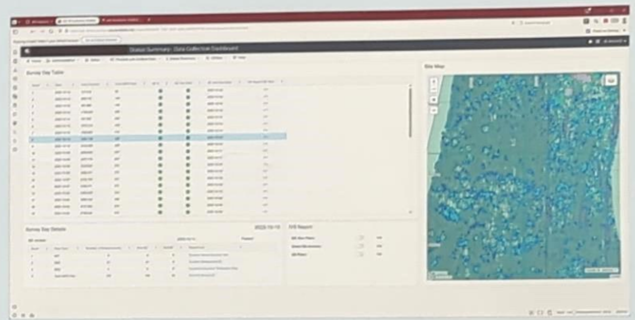
Data transfer is controlled by the GCO Project Geophysicist. Once authorized, downstream access to the QA Geophysicist is instant.

Programmatic assessments and approvals are required and documented for data level and survey unit deliverables. All approvals, including government QA approvals and/or rejections, are available for review via the dashboards.

On-Demand Status Summaries

Keeping the entire PDT informed is a priority of **uXclassify**. We created several automatically-updated dashboards to facilitate information sharing:

- data collection (temporal)
- Geo unit (spatial grid)
- weekly status summaries (both)
- data analysis (for the analysts)
- survey & delivery unit
- intrusive results, and others...



Benefits of uXclassify

Contractor	**QC Geophysicist**
• Regain control of AGC Analysis • Monitor progress • Easily assess coverage • Transfer data instantly • Reduce analyst level of effort	• Purpose-built QC capabilities • Intrinsic approval process • Custom QC tools • Assess QC seeds ahead of data analysts
QA Geophysicist • On-demand progress updates • Custom QA tools • Receive products instantly • No local software installs • Accomplish QA goals on time	**Regulator** • Stay informed via on-demand project updates • Review QC and QA results • On-demand access to project deliverables

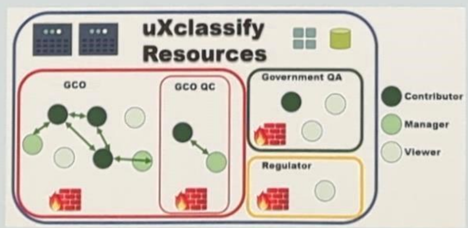
Entire Product Delivery Team

- Communicate efficiently and transparently
- Cultivate remote workforce resources
- Effectively share documents via an on-line document repository
- Mitigate version control of software, data, and documents
- Record and preserve AGC processing and decision making
- Systematic and systemic firewalls
- Audit trail of data analysis, approvals, and user access

User Access & Firewalls & Setup

Once the online experience is provisioned, the GCO, Government QC, and regulators share the online processing and management resource.

- Hard-wired firewalls protect information within roles



Project wide settings established by the Project Geophysicist include processing parameters, site-specific AGC library, GIS boundaries, instrument verification strip details, and geodetic reference locations.

Intrinsic controls ensure consistent processing for all Geo Units. If processing parameter changes are made late in the game, semi- and auto-rework capabilities save the day for the GCO.

Miscellaneous Goodies

uXclassify is DAGCAP approved for APEX and UltraTEM one-pass data and MPV and Geometrics 2x2 cued data. Ancillary data approvals are in process - a one-stop shop for HDF5 data.

uXclassify provides an on-line, persistent *Document Repository* that allows access to AGC-related deliverables; including, large files such as QAPPs and GIS data.

Audit logs for processing activities, processing parameters, user access history, and source reports are automatically generated.

Synthetic seeding tools allow single- and site-wide multiple-source scenarios to be easily incorporated into the analysis flow for data usability assessments.

Please contact dkeiswetter@acornsi.com if interested in experiencing a revolutionary AGC experience.

Complementary products include **uXfieldqc** and **uXsimulate** – ask about them as well.

Fort Irwin Range Clearance
Safely Clearing MEC and MDAS for the National Training Center

Jeff Smoak[1] and David Feiertag[2]
[1]Seres Engineering & Services, LLC (*jcsmoak@seres-es.com*). [2]Koman Government Solutions, LLC (*dfeiertag@komangs.com*).

Background and Purpose

NTC covers over 753,000 acres in San Bernardino County, California between Los Angeles and Las Vegas, and is currently an instrumented training facility that is used for force-on-force and live training of heavy brigade-sized military forces. Various types of munitions, bombs, rockets, land mines, grenades, projectiles, and small arms have been used at Fort Irwin.

A fatal incident at a scrap metal facility in 1997 prompted the initiation of an enhanced inspection process that has developed and been continuously refined over the last 28 years.

The **five-tier inspection** process, developed in conjunction **with the USACE LA District**, emphasizes **thorough inspection, documentation**, and **accountability.** The process has evolved via continuous improvement practices by 4 contractors. During the most recent KGSERES contract the process has proven **100% effective at eliminating safety incidents.**

Pre-Inspection Activities

Communication and Coordination

Site Manager communicates weekly with the NTC Range Control office who assigns the area of the range complex. Constant communication with Range Control is maintained for access to the range to ensure safe distance from active training rotations. The location of items that were placed on hot stakes is reported to Range Control for map updates.

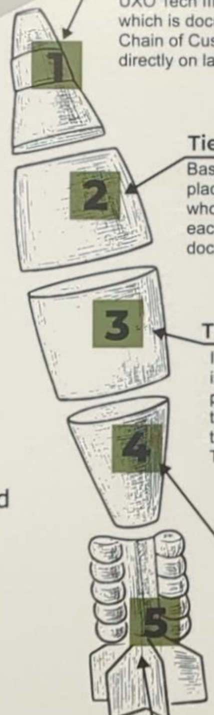
Planning and Training

Following receipt of area assignment from Range Operations, site management evaluates, records, and conducts reconnaissance in the area to evaluate anticipated ordnance, terrain, and site features.

Daily safety briefings and weekly UXO refresher training topics are tailored to inform the field staff of anticipated hazards and site conditions.

Resource and Equipment Deployment

Field staff are organized in teams comprised of UXO Tech IIIs, Tech IIs and Tech Is with operations directed by the Field SUXOS. Contractor-owned equipment is maintained onsite by the site mechanic who provides both routine preventative maintenance and repairs of site equipment. Equipment is deployed to assigned areas each week.



Tier 1: Initial Identification and Collection

UTVs are used to clear 1km x 1km grids following the Sweep Line Operations SOP. Energetic material-free items are placed in baskets and identified as MPPEH by a UXO Tech III or II. This completes the Tier 1 inspection, which is documented by the UXO Tech's signature on the Chain of Custody (CoC) card attached to the basket or directly on larger items.

Tier 2: Certification of No Energetic Material

Baskets and larger items with CoC card and signatures are placed in an MPPEH staging area. A UXO Tech II or Tech III who did not provide the Tier 1 inspection physically removes each item from the basket and inspects it before certifying and documenting the inspection by signing the CoC or item.

Tier 3: Verification of No Energetic Material

Immediately following the Tier 2 inspection, the material is visually inspected by a UXO Tech III who did not perform prior inspections. Verification is conducted in the same location as the Tier 2 inspection and utilizes the same process for inspection and documentation as Tier 2 (signature on CoC or item).

Tier 4: Inspection Prior to Processing

Collected items are loaded into trailers and transported to the processing pad. Inspection occurs as materials are unloaded. Items are marked with color coding to designate the required processing method. Marking assures processing staff the material has completed Tier 4 inspection.

Tier 5: Final inspection

Processed material is inspected by the UXOQCS and SUXOS who sign a DD Form 1348-1A certifying the material as MDAS. The material is placed in serial numbered boxes, sealed, and stored in a locked container. Serial numbers and weights of each box are listed on the 1348-1A which serves as a manifest during the shipment off site for flashing and recycling.

Outcomes during the KGSERES 4.5-Year Contract

743,845 Pounds of MDAS Removed and Processed

336,062 Acres Cleared

184,194 Man-Hours Completed

85,450 Live MEC Items Encountered

0 Explosive-Related Incidents

Method Benefits

Coordination with NTC insures training area utilization plan best serves upcoming training rotations.

Focused planning, communication and training improves efficiency in the field and reduces both performance and safety risks.

Access to full-time UXO staff and equipment maintained by an on-site mechanic increases efficiency as resources are available as-needed.

Five-Tier process provides consistent and safe operations while utilizing proven SOPs.

Tier 2 certification inspection performed by Tech II or higher establishes the MPPEH as MDAS prior to removal from the range.

Tier 3 verification futher reduces risk of undetected explosive residues.

CoC provides accountability of inspection staff and documentation of tier progress.

Tier 4 inspection provides additional level of safety for processing staff prior to mechanical mutilation and disfigurement operations.

Our comprehensive Mutilation Manual illustrates what is required for safe, effective and efficient processing of recovered items.

Introduction of energetic items into MDAS shipments is prevented by 5-Tier inspection and CoC controls.

Full-time on-site staff are able to provide economical and real time support to NTC to respond to mission needs as required.

DEMIL crew utilizes mechanical processes for mutilation of MPPEH per DoD instruction 4160.28 DEMIL program. We developed a formal Mutilation Manual that provides SOPs for the actions needed to process all items collected at NTC. The processing pad is equipped with band saws, gas, and plasma torches, chop saws, shear, hoists and hand tools.

References and Credits

Image Credit: KGSERES JV

KGSeres 8(a)JV. (2024). Standard Operating Procedure: Site Mutilation/Disfigurement Procedures. Fort Irwin Range Maintenance Project, Fort Irwin, CA.

KGSeres 8(a)JV. (2024). Sweepline Standard Operating Procedures. Fort Irwin Range Maintenance Project, Fort Irwin, CA.

U.S. Department of Defense (DoD). (2011 and 2022). DoD 4160.28, Defense Demilitarization Instruction: Procedural Guidance. Available Online at: <https://www.esd.whs.mil/DD/>.

Next-Gen Robotic Services

FOR MMRP SAFETY & PRODUCTION EFFICIENCY

Northwest ROBOTIC SERVICES

AN ASRC INDUSTRIAL COMPANY

REPRESENTATIVE PROJECTS



Former Navy Dump Metals Removal & Revetment Construction

KFS, US Army Space & Missile Defense Command | Kwajalein Atoll, RMI

CHALLENGE NWDD was contracted to remove metals along 2,000 ft of exposed shoreline near historic Navy dump sites from WWII. Burned debris had fused into thick slag, and excavation revealed multiple MEC anomalies, including a 50 lb bomb and MK35 5-inch projectiles.

SOLUTION NWDD retrofitted **two on-island 30–40 T excavators** with proprietary robotic kits and **built a blast box command center compliant with EM-385-1-1 safety standards.** The robotic systems completed **high-impact excavation, hydraulic hammering, and metals removal, safely removing over 20,000 CY of MEC- and PCB-contaminated soil without incident.**

2019



Remote Controlled Services for Environmental Remediation

Aptim Federal Services, US Navy | Adak Island, AK

CHALLENGE Excavation and clearance at a former munitions disposal site on a rocky Bering Sea beach, exposed to high winds and heavy rain. Remote location required extensive logistics for equipment delivery. No MEC hazard assessment was completed.

SOLUTION NWDD Robotic Services deployed **two 40 T remotely operated excavators to remove munitions and explosives of concern (MEC-impacted) soil** from an armored **blast box nearly 1,000 ft away.** Achieved **100 CY/day production** with screening support for **18 UXO technicians,** clearing **over 7,700 CY in half the time** of previous armored long-reach methods.*

2021



Robotics MMRP Services & Other Explosives Related Services

Dawson Zapata JV, US Army Corps of Engineers | Fort Indiantown Gap, PA

CHALLENGE PWS identified areas with extremely high anomaly density and sensitive MEC, including 3.5-inch rockets and white phosphorus rounds. Hazard assessment noted a 338 ft HFD for 105 mm TNT rounds and a 77 ft MFD for unintentional detonations.

SOLUTION NWDD deployed a **remotely operated 35 T excavator with a 3 CY trommel screen bucket,** enabling **safe excavation to 2 ft bgs** while maintaining a **4,000 ft setback.** High production and safety performance led to abandoning the original mag-and-dig plan. **Over 4,000 CY of soil was excavated, sifted, and cleared in 15 days.** During operations, a white phosphorus round detonated, but **NWDD's remote system ensured zero injuries and maintained full safety**—an outcome impossible under conventional methods.

2023


BEFORE


AFTER

Range Maintenance

US Army Corps of Engineers | Camp Shelby, MS

CHALLENGE Range maintenance required over large project site with heavy vegetation, protected wetlands, etc. Work performed in advance of MEC Reconnaissance Surveys in artillery, mortar, and tank dedicated impact area over site area of 433 acres.

SOLUTION NWDD mobilized **two remotely operated 35–40 T excavators** equipped with a Quadco hot saw, 5-finger grapple, Diamond mower, and tree shear. These attachments are **cross-compatible with either machine, enabling continuous work** as tasks change with terrain and vegetation. Due to advancements in NWDD's BVLOS system, NWDD's robotic machines averaged **4 acres per day—cut, mowed, and ground**—compared to only 1 acre per day with the previous robotics contractor.**

ONGOING



Robotic Heavy Equipment Systems to Support MEC Operations

USA Environmental / US Army Corps of Engineers | Vieques, PR

CHALLENGE Extreme remote range clearance requiring multiple high-impact tasks, including vegetation removal, land clearing, soil sifting, remote winch operations for underwater MEC recovery, demilitarization of inert ordnance, and scrap metal processing.

SOLUTION NWDD deployed a **40 T robotic excavator with an armored mobile command center and a suite of hydraulic attachments.** This **"Swiss Army Knife"** approach **enabled diverse MEC removal tasks without extra mobilization time or cost.** NWDD's system increased **brush clearing and mowing to 1.5–2 grids per day** versus 2 grids per week using previous methods.***

OVERVIEW

Northwest Demolition's (NWDD) Robotic Services division operates a suite of remote-controlled heavy equipment units in support of complex MMRP applications. This platform can be used to operate virtually any hydraulic or electric piece of equipment, including, but not limited to:

- Hydraulic Excavators
- Front-End Wheel Loaders
- Articulated Haul Trucks
- Screening Plants
- Trommel/Screening Buckets
- Hydraulic Shears
- Magnet
- Rotary Mower and Flail
- Rotary Shredder
- Tree Shears/ Hot Saw
- Hydraulic Winch
- Grapple
- Impact Hammer

Applications in support of MMRP projects include:

- When MGFD exceeds achievable working distance using conventional methods (e.g., armored long-front excavator, MK35 5-inch projectile, etc.)
- In advance of MEC hazard assessment (e.g., land clearing)
- In hazardous environments such as unstable ground, limited line of sight (LoS), elevated working surface, etc.
- Consolidation, movement, or handling of uncharacterized spoils

WHY ROBOTICS?

RAPID DEPLOYMENT

NWDD's robotic equipment system can be **deployed anywhere heavy equipment can be mobilized.** With new electronic systems, NWDD's robotics kit can be installed in **less than 1 week.** Existing systems can be operable in **less than 1 day.**

PERFORMANCE

NWDD's proprietary platform allows for conventional operation of mechanized equipment **at nearly zero loss of fidelity versus in-cab operation.** On MMRP projects, this results in:

- **2x production** for excavation over conventional armored long- reach methods*
- **4x production** over competitor's robotic systems**
- **5x production** for land clearing, mowing, and vegetation removal***

UXO SAFETY

This system allows for **high impact operation in MEC-containing areas while maintaining a safe distance for on-the-ground personnel.** NWDD's systems can achieve **working distances of up to 10 mi,** including in work sites with **beyond visual line of sight (BVLOS) challenges** such as steep topography or dense vegetation.

INTERPRETING MIXED SIGNALS: THE IMPACT OF INTERFERENCE ON CLASSIFICATION PERFORMANCE AT CAMP SAN LUIS OBISPO

Jacobs   white river technologies

Jennifer Weller, Jacobs, Denver, CO

Jonathan Miller, White River Technologies, Inc., Lebanon, NH

Cheryl Webster, U.S. Army Corps of Engineers, Albuquerque, NM

US Army Corps of Engineers®

Abstract

Data quality and signal interpretability for advanced geophysical classification data collected in support of the remedial action at Munitions Response Site (MRS) 07, Camp San Luis Obispo, San Luis Obispo County, California, were complicated by two key sources of signal interference: geological noise and high-density metallic clutter. Blind and non-blind seed data were used to identify and quantify interfering signals, enhancing the reliability and accuracy of detection and classification.

Geological noise at MRS 07 was characterized by the pervasive presence of small, scattered pockets of ferromagnesian minerals and rocks, which introduced significant subsurface heterogeneity across the MRS. This interference degraded the signal-to-noise ratio, particularly for smaller and deeper targets, and produced false positive signals with polarizabilities that closely resembled those of the targets of interest (TOI) in the site library. Ultimately, this geologic noise presented challenges to the classification process by masking legitimate targets, leading to misclassification, and increasing the number of false detections that required investigation. Additionally, a 0.2-acre area of anomalous terrain, characterized by non-native fill material elevated up to 1.5 meters above the native substrate, introduced significant topographical variability. This variability altered the sensor's standoff distance, which, in turn, amplified soil response sensitivity and generated a high volume of false-positive detections. A key challenge was the inability to isolate the signals of discrete geologic pockets, which often closely mimicked the polarizabilities of the specific TOI in the site library. Furthermore, unlike regions such as Hawaii or the southeastern U.S., where broad, low-frequency responses are characteristic, alternative filtering parameters failed to effectively and reliably enhance the target signals. Mitigating these issues required adjustments to the classification process. Seed data were successfully used to establish a set of discriminatory characteristics for potential TOI affected by extraneous geologic noise signals. These characteristics were then quantitatively parameterized and used to re-evaluate the classification data using a standardized set of criteria. However, the introduction of an interfering geologic signal led the classification model's feature extraction process to overestimate the size of buried items at increased depths relative to the ground truth.

In a 0.24-acre area identified as a former grenade target area, high-density fragmentation debris from historical training operations resulted in a saturated response area with an anomaly density exceeding 10,000 per acre. Following analog-based subsurface reduction, the anomaly density within a 0.18-acre area remained above 4,000 per acre. The initial reduction resulted in the removal of over 218 pounds of metallic debris, including grenade fragmentation as small as 1 by 1.5 centimeters, down to 0.30 meter. Following review of non-blind seed data, adjustments were made to the detection parameters to mitigate interference from the remaining high anomaly density. The tile detection offset parameter was modified from 0.65 to 0.45 meter. This modification improved detection results for both non-blind and blind seeds, which were subsequently classified as TOIs. Performance was notably improved under conditions of high anomaly density and for seeds placed at depths approaching the maximum reliable detection depth. As with the examples of geologic noise interference, the classification prediction for seeds in areas of high anomaly density was overestimated in terms of size and depth.

These findings possess significant technical implications for the munitions response community, intersecting with several key operational and methodological challenges. These challenges are as follows:

- **Site Characterization:** The need for enhanced methodologies during the Remedial Investigation phase to improve estimates of data density, usability, and reliability for developing the conceptual site model
- **Blind Seed Protocols:** The need to define and standardize protocols regarding the location and burial depth of quality control, validation, and non-blind/data usability seeds
- **Environmental Factors:** The persistent difficulties encountered due to challenging terrain, geology, which complicates geophysical surveys and can impact the reliability of the classification including size and depth predictions
- **Prediction Measurement Quality Objectives (MQOs):** The need to improve MQOs related to classification parameter predictions, especially as related to size and depth estimations

Environmental Factors

Data Quality: Degraded the signal to noise ratio, specifically impacting classification of smaller/deeper targets.
Survey Effectiveness: Masked legitimate targets, caused misclassification errors, and increased the number of false detections requiring investigation.
Target Classification: Led to several classification MQO failures related to size, depth, or library match for 4 blind QC seeds placed at the anticipated maximum classification depth (30 cm) (Figure 1). Adjustments to leveling process did not result in an overall performance improvement.
Geologic Noise: Pervasive, scattered pockets of ferromagnesian material introduced significant subsurface heterogeneity (Figure 2).
Target Identification: Produced false positive signals with polarizabilities closely resembling TOI in the site library (Figure 3).
Dirt Mounds: Variable terrain height (up to 1.5 m above native ground) and responsive soil across the 0.2-acre area of off-site fill, combined with the higher field strength of the APEX-Mini coils, resulted in amplified soil response sensitivity and a high number of false-positives (Figure 4).

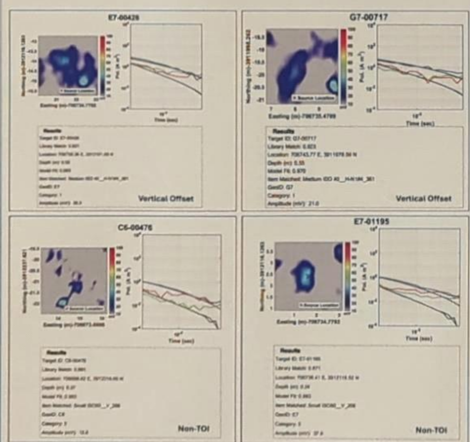


Figure 1. Classification Results for Failed QC Seeds

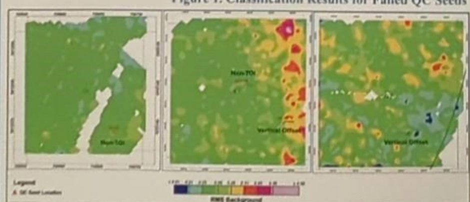


Figure 2. Noise Analysis for Failed QC Seeds


Figure 3. Examples of Digs with Geologic Response

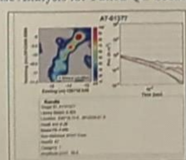


Figure 4. Soil Sensitivity False Positive

Prediction MQOs (Confirm Derived Features)

The data demonstrate that inherent physical and environmental factors make the current MQOs related to confirm derived features match ground truth unattainable with the site having a 62% failure rate (Figure 4):

- **Environmental/Subsurface Variables:** Geologic response, site specific subsurface conditions, and variations in target orientation (Figure 5), size, and depth introduce variability that AGC sensors cannot entirely overcome.
- **Physical and Resolution Limits:** AGC sensors have resolution limits that prevent the precise characterization of every item.
- **Non-Unique Interpretations:** A variety of subsurface conditions can yield similar signatures, leading to non-unique interpretations.
- **Library Constraints:** The quality of library entries used for comparison, a critical part of the classification process, also imposes limitations (Figure 6).

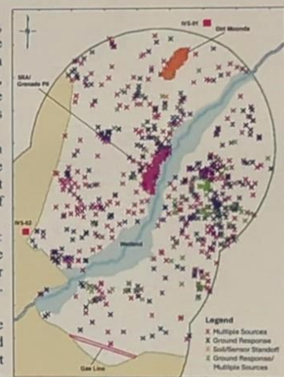


Figure 5. Prediction MQO Failures

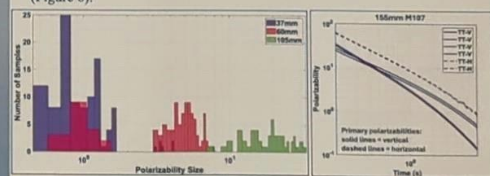


Figure 6. Polarizability Uncertainties – DoD Library and Orientations

Library-based size estimates can lead to size prediction MQO failures due to the variability in the size of library entries. This uncertainty was compounded by challenging site conditions including high anomaly density and geology.

Blind Seeding

Validation Seeds (Figure 7):

- Provided assurance of AGC and intrusive processes across diverse, noise/density environments, including the grenade target area (SRA).
- Depths align with NAOC recommendations of seed placement at 50–30% of required detection depth for small ISO at 30 cm.

QC Seeds (Figure 7):

- Emphasize need for strategic placement to gain data usability insights not apparent in initial project planning.
- Allowed development of quantitative CAs.

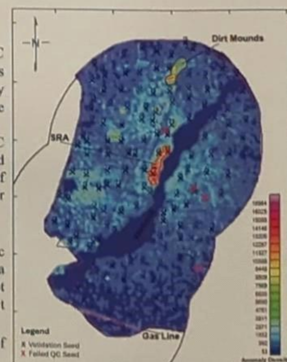


Figure 7. Density/Seeding Map

Site Characterization

Limited characterization of the site during the RI included:

- Incomplete identification of the grenade target area.
- Shortage of CSM documentation regarding munitions potentially present.
- Inadequate identification of geologic noise conditions.
- Non-identification of mounds of off-site fill.
- A remediation depth greater than the capability of the electromagnetic induction sensing technology.

Successes

Despite the challenges presented the RA was ultimately successful:

- 98% of QC seeds and 100% of validation seeds met classification MQOs
- Grenade target area identified and delineated
- 4 MEC items (max depth 38 cm) and over 1,300 MPPEH items (max depth 95 cm) recovered
- Significant reduction in unnecessary excavations: approximately 90% based on detections and 92% based on classified sources

Conclusions/Recommendations

Environmental Factors: A key challenge was the inability to isolate the signals of discrete geologic pockets, which often closely mimicked the polarizabilities of the specific TOI in the site library. Furthermore, unlike regions such as Hawaii or the southeastern U.S., where broad, low-frequency responses are characteristic, alternative filtering parameters failed to effectively and reliably enhance the target signals. Mitigating these issues required adjustments to the classification process.

Prediction MQOs: The MQOs requiring confirmation that derived features perfectly match ground truth must be revisited due to inherent technical limitations. While AGC remains highly valuable for making informed, risk-based decisions on anomaly excavations, the precision needed for a 100% confidence match between a target's exact features and ground truth is technically unachievable for every buried item. The MQOs therefore need urgent revision to reflect these realities.

Blind Seed Protocols: The data support NAOC recommendations to standardize protocols regarding validation seed burial depth. It additionally demonstrates the importance of placing QC seeds in a manner that informs potentially unknown data usability limitations.

Site Characterization: Robust site characterization during the RI phase is essential for developing accurate RAOs and ensuring successful project outcomes. The issues encountered underscore the importance of employing robust methodologies during the RI to improve data density estimates, improve understanding of data usability issues, and the reliability of the CSM. Effective characterization ensures that:

- RAOs accurately defined: A full understanding of the scope and nature of contamination, driven by clear, data-rich objectives, allows for the establishment of achievable goals.
- Appropriate technologies/depths : Understanding the physical reality of the site - such as fill height, geologic conditions, and contamination depth -enables the establishment of feasible and effective remediation depths for the specific munition types and the selection of suitable technology.
- Efficiency: A comprehensive CSM derived from a robust data set prevents costly surprises and operational failures during remediation, ultimately leading to a more efficient, successful, and cost-effective project.

Acknowledgements

The authors wish to acknowledge and thank their esteemed colleagues and the project teams at Jacobs, WRT, and USACE for their invaluable support and assistance. Sincere appreciation is also extended to Katura Willingham for her outstanding leadership throughout this project.