ESTCP

FINAL REPORT

Efficient and Secure Cloud Computing for UXO Classification and Project Management

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ESTCP Project MR-201713

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14. ABSTRACT
UX-Classify is a cloud-based classification and project management application for the Military Munitions Remediation Program (MMRP) community. UX-Classify combines the benefits of cloud computing with proven EMI data inversion methods to provide a unique and transformative user experience for the technical data analyst as well as the entire MMRP product delivery team.

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1.0 INTRODUCTION

UX-Classify is a cloud-based classification and project management application for the Military Munitions Remediation Program (MMRP) community. UX-Classify combines the benefits of cloud computing with proven EMI data inversion methods to provide a unique and transformative user experience for the technical data analyst as well as the entire MMRP product delivery team.

1.1 BACKGROUND

The cleanup of military munitions, which is a high priority, Department of Defense objective, requires properly estimating the contamination at a given site, documenting all decisions and actions taken during the remedial action, and actively monitoring the quality characteristics of the data used to make the decisions. Tremendous success and advancements in all three areas have been realized by DoD researchers and consultants using Advanced Geophysical Classification (AGC) methods during the past decade.

The successful implementation of AGC methods is complex, detailed orientated, and requires trained data analysts. Broadband electromagnetic induction (EMI) data are acquired by complex and intricate sensors. Once acquired, the raw AGC EMI data must be processed using sophisticated data analysis software to make classification decisions.

UX-Analyze (desktop version) has been developed over the past two decades and is validated by the US government [DENIX webpage]. UX-Analyze, which is embedded into Seequent's Oasis montaj software package, has wide acceptance in the MMRP marketplace and was used as the classification software for eleven of the thirteen accredited firms during their required DAGCAP demonstration of capabilities test. UX-Analyze and ancillary non-Cloud based offerings utilize networked personal computers. This network architecture has fundamental problems with data accessibility, communications between team members, version control, and security that cannot be mitigated.

The focus of this work, UX-Classify, is a cloud-based EMI data classification software suite designed to facilitate transparent program flow, efficient processing, and excellent classification results. It builds upon previous classification technologies and benefitted from lessons learned while developing the UX-Analyze desktop routines. During its development, the software was referred to as UX-Analyze Cloud. The software has been renamed UX-Classify, however, to not infringe upon Seequent's UX-Analyze product. The development of the technology was guided by the following principles:

- Efficient data analysis modules
- Systematic firewalls
- Robust and transparent monitoring and tracking
- Institutionalize quality control (QC) measures and products
- Transparent data handoffs
- Solution for the entire project delivery team
- Auditability

The development of UX-Classify occurred over multiple years, as shown in Figure 1.

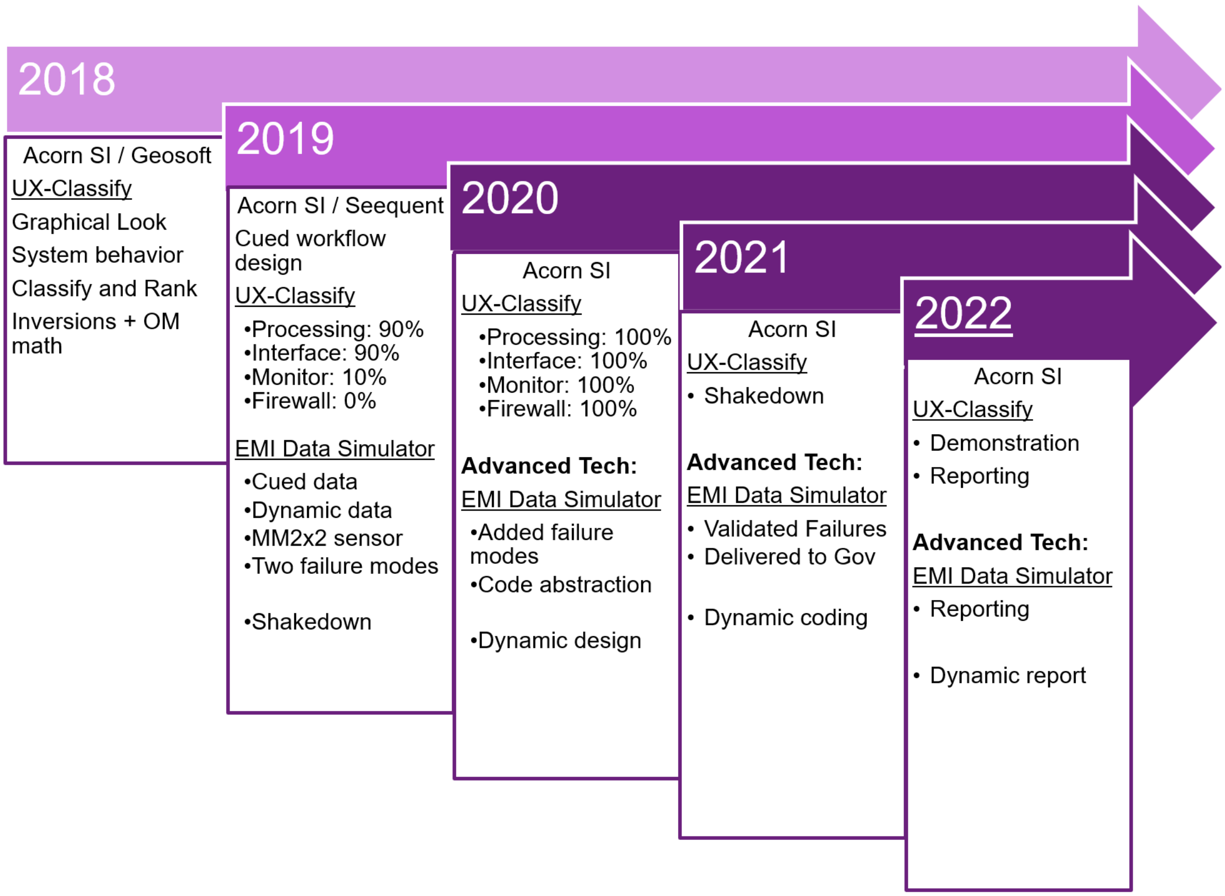


Figure 1. Summary of this Project's Development History.

1.2 OBJECTIVE OF THE DEMONSTRATION

The primary technical objective is to demonstrate and evaluate the efficacy of using a cloud-based classification and management application in support of MMRP projects that utilizes advanced geophysical classification (AGC) methods. The data analysis application under test is for cued EMI data collections because that was the primary collection mode at the time the project was proposed and scoped.

Two additional objectives were added to the project task during program execution. These objectives were to (i) develop designs and requirements for adding capabilities for processing EMI data collected while the sensor is moving (viz., survey mode), and (ii) enhance the UX-Simulator codes, previously referred to as UX-Simulator, to include common failure modes that can occur during data collection.

1.3 REGULATORY DRIVERS

In 2017, the DoD created the DoD Advanced Geophysical Classification Accreditation Program (DAGCAP). A long-term factor of the DAGCAP program is to establish a quality standard, and a quality program within each participating firm, that facilitates technically sound classification decisions when using broadband EMI data to investigate and identify buried munitions. Current classification software suites that are designed for networked personal computers (PCs) simply cannot facilitate the complete vision of the DAGCAP program. Many of the technical challenges can be satisfied, but the overall program flow, communication throughout the key participants in the Corps Project Delivery Team (PDT) and required auditing simply cannot be adequately controlled with classification schemes designed for networked PCs.

2.0 TECHNOLOGY

The main body of this report focuses on the UX-Classify technology and its demonstration. Individual reports for the (i) dynamic data processing flow design task and (ii) UX-Simulator task are presented in Appendix C and D, respectively.

2.1 TECHNOLOGY DESCRIPTION

UX-Classify is a cloud-based classification analysis and project management application (Figure 2). The software suite utilizes data inversion to extract and classify features intrinsic to buried metallic objects. It is a second-generation product in that it leverages lessons learned from the successful UX-Analyze desktop application that is embedded in Seequent's Oasis montaj commercial offering.

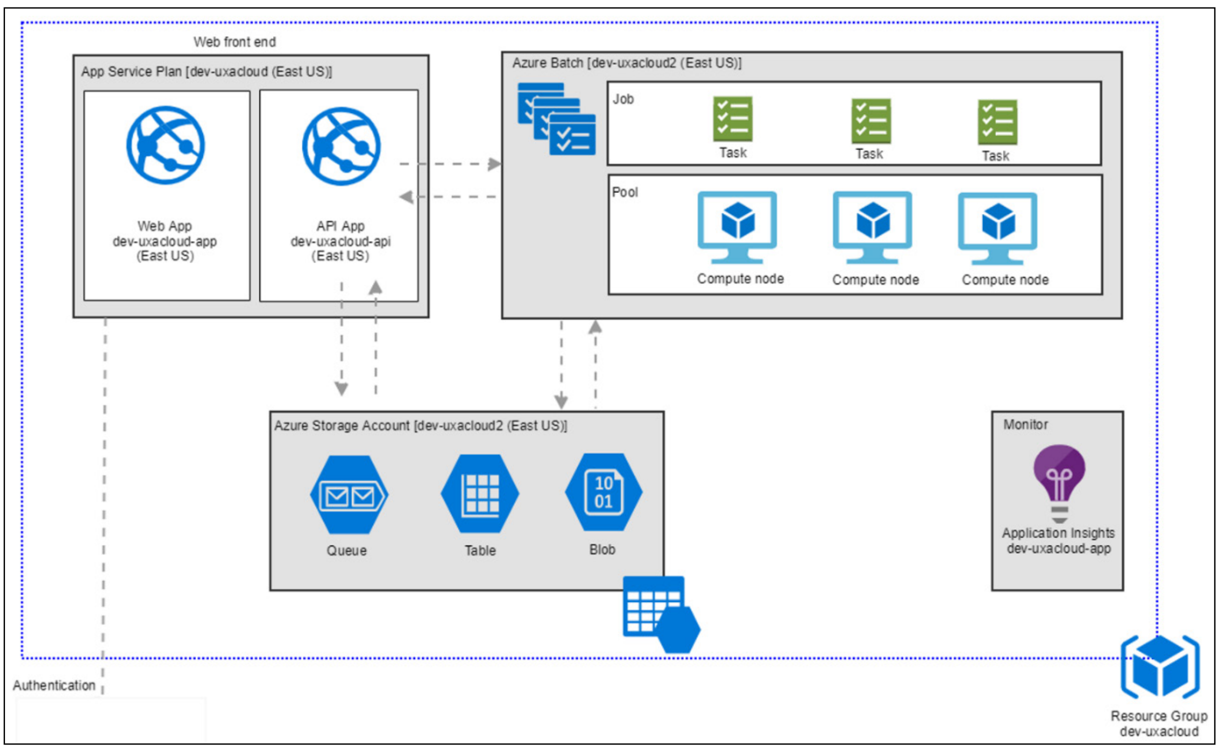


Figure 2. Schematic Drawing of the UX-Classify Architecture.

UX-Classify is composed of four components, a web application, an API service, data storage, and a processing engine.

Web Application: The web application is responsible for displaying information to the user and handling all user interactions. It is developed using Angular 6, an open-source web application framework led by the Angular Team at Google and others. Angular is used in many modern web applications. The web application code is written in TypeScript, which is a strict syntactical superset of Javascript and brings static typing checking to the language.

API Service: The application program interface (API) service handles the business logic and is written in ASP.NET WebAPI Core, which is a cross-platform, high-performance, open-source framework for building modern, cloud-based, Internet-connected applications. The code is written using the Microsoft C# language, a general-purpose, multi-paradigm programming language.

Storage: Data storage within UX-Classify utilizes Microsoft Azure Storage. Blob storage is used to store arbitrary binary data (images, HDF5 files, associated files). All uploaded files are also stored in their original format in blob storage for auditing purposes. On upload, data from each file will populate a set of tables. This is for performance and querying purposes. Tables are also used to store the results of processing.

Processing Engine: Data processing uses Azure Batch, a scalable job scheduling service. When work for tasks such as Import Data, Classify and Rank, etc. is required, a job is created in Azure Batch. Azure Batch schedules the job on a compute node to carry out the requested work. The storage service is used for the inputs and outputs of the work.

The UX-Classify solution is responsible for role-based access (assigned projects and roles). Authentication is delegated to Microsoft Azure embedded tools and functions. The UX-Classify solution also leverages several other Azure services to provide a robust and scalable system.

The UX-Classify data model includes the following items:

- Project - name and properties, such the owner and description
- User - user names (email) and roles of individual users that have role-based access to the project
- Library - metadata and polarizability signatures for library items
- Date Unit - details of survey data collected each day. Measured data are organized by collection date.
  - Measured Data - raw sensor data for each measurement collected on given day
- Geo Unit - spatial unit of data processing. After data have been processed, they are organized by Geo Unit.
  - Prepared Data - sensor data that have passed QC and have been leveled (background removed)
  - Source - result of the inversion of the prepared data (results of the other steps in the Classify and Rank or Validate Library processes are also stored similarly)
  - Seed - stores QC and QA seed information
  - Intrusive data - stores ground truth information.
- Associated Files - documents or reference files that may be uploaded to the project

Other tables, as depicted in the Data Model diagram, are used to efficiently structure data to meet the application requirements. The simplified data model shows the relationships between the types of data in the project (Figure 3). The system may read data from one or more tables in a process. Like the UX-Analyze desktop product, source information is ultimately derived from several tables (Source, LibraryMatch, SelfMatch, Cluster, and ClassifyRank). UX-Classify follows best practices for Azure table storage considering query performance and row size limits to achieve a maintainable and scalable solution.

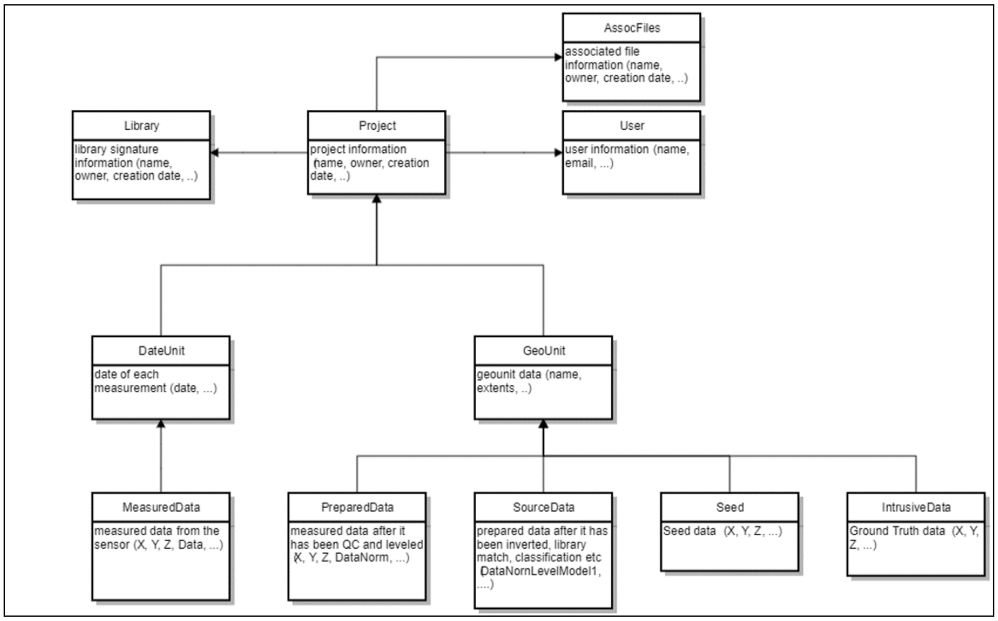


Figure 3. Simplified View of the UX-Classify Data Model.

As a cloud-based application, UX-Analyze does not require any software to be installed locally. After provisioning, the application is accessed through a web browser. The overall experience has been streamlined and tailored to provide a unique experience for the entire project development team. The look and feel of the user interface are presented in Figure 4.

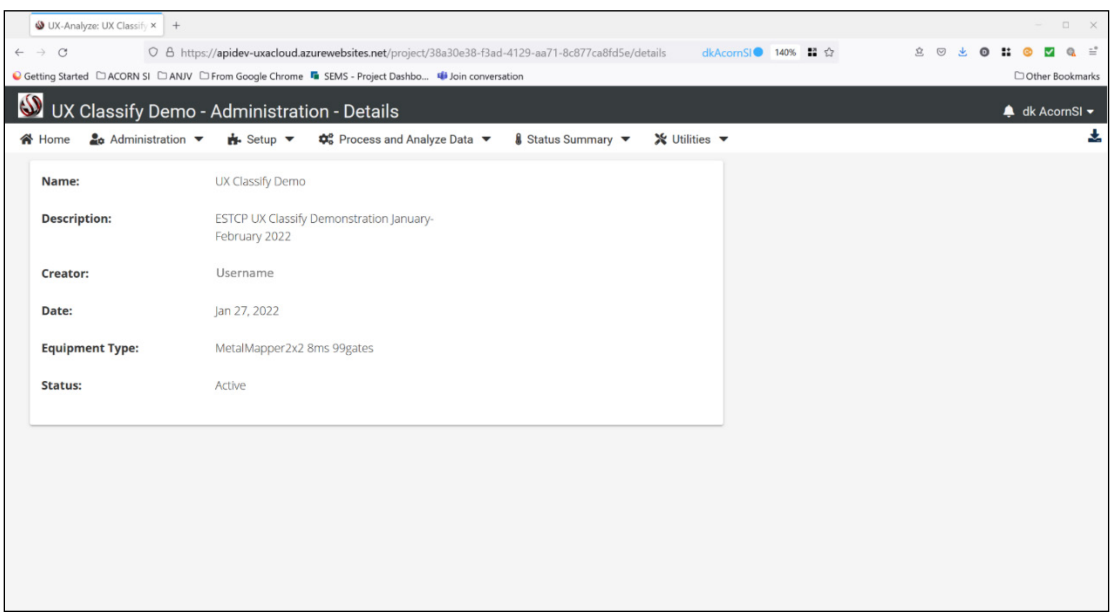


Figure 4. Screen Snapshot Showing the Top-level Page for a UX-Classify Project

The application is accessed using the five drop-down menus shown below. The menus include (1) Administration, (2) Setup, (3) Process and Analyze data, (4) Status Summary, and (5) Utilities. Each menu is introduced in the sections that follow.

The Administration menu has three sub-menus that manage user access and roles, the QAPP and processing parameters, and the DOD UXO Signature Library.

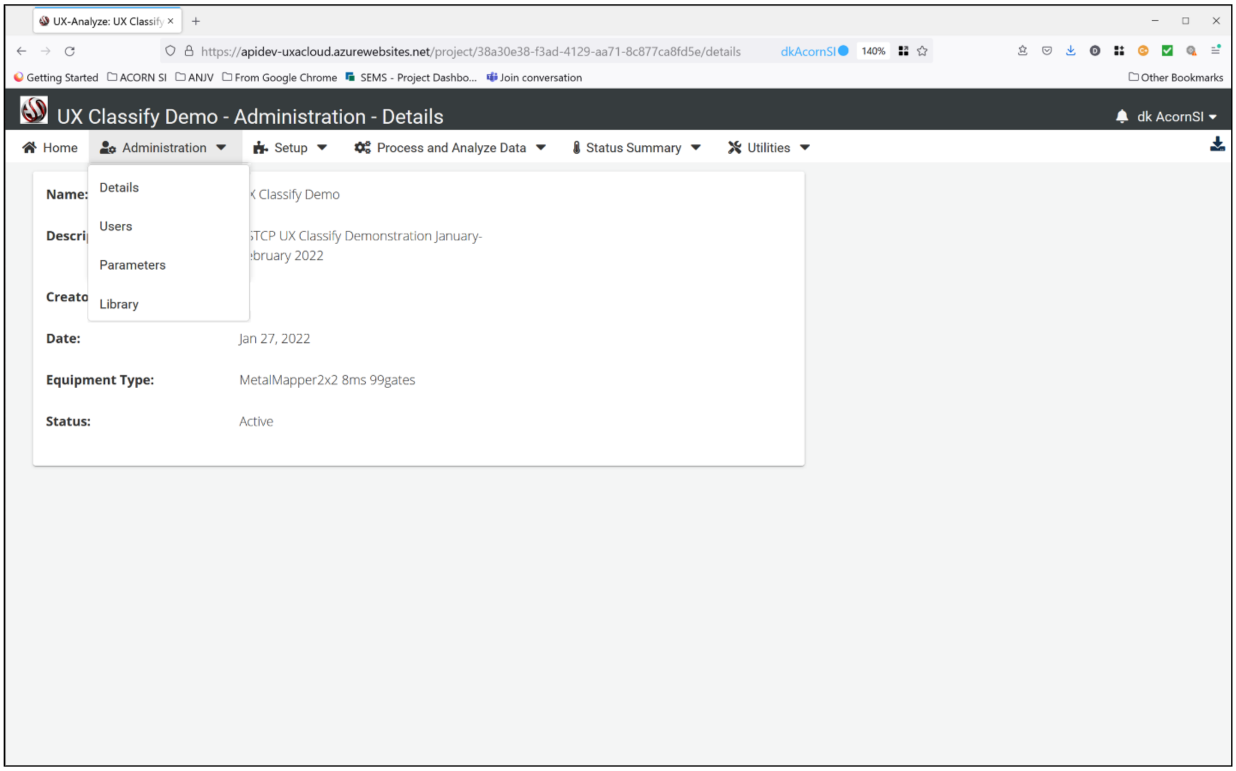


Figure 5. Screen Snapshot Showing the Administration Page.

This page is used to setup and define users, parameters, and hold munitions signature library.

Details Submenu: a basic GUI presenting the name, description, creator, date, equipment type, and project status.

Users submenu: a resource page that details user access and role. There roles include contractor, project owner (the funder and quality assurance oversight), and special interest group (aka., state regulator). The contractor can add/remove users for the contractor group. The project owner controls access for the project owner group and the special interest group.

Parameters submenu: a comprehensive list of all parameters utilized by the software package. This explicitly includes all DOD QAPP parameters specified in worksheet 22, as well as ancillary data processing and plotting parameters. The central nature of the parameters allows the software to efficiently require consistent parameter usage throughout all defined geo units within the project.

Library submenu: this page provides access to the DOD's TOI signature database and provides tools for identifying, selecting, and removing individual signatures that will be utilized as the site-specific library. An ancillary tool provides the capability for adding signatures to the site-specific library in the event they munitions of interest is not contained within the DOD's library.

The Setup menu has five sub-menus that setup and define site specific boundaries, planned data collections, IVS registrations, and system response information.

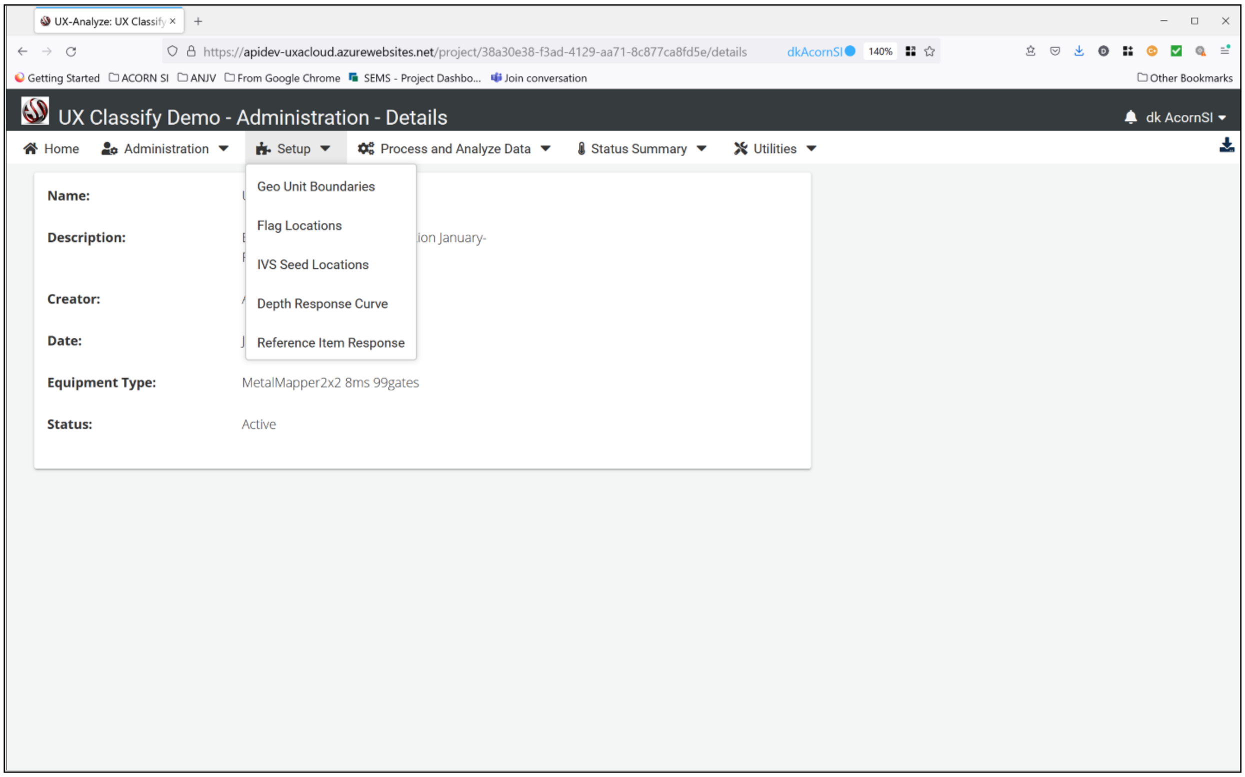


Figure 6. Screen Snapshot Showing the Setup Page.

This page is used to setup and define site specific boundaries, planned data collections, IVS registrations, and system response information.

Geo Unit submenu: a resource page to receive and store the coordinates for the geo units. As used here, the term geo unit refers to a contiguous space for processing and reporting purposes.

Flag Locations submenu: a list of all locations for which cued data collections are planned.

IVS Seed Locations submenu: a list of XY coordinates that define the spatial location(s) for the IVS.

Depth Response Curve submenu: a resource tool that predicts the sensors' response, given a user-defined munitions type and depth. This information is used to help determine appropriate detection thresholds.

Reference Item Response submenu: a resource tool that stores the instruments' response that forms the comparison basis during subsequent Sensor Function Tests.

The Process and Analyze Data submenu is the workhorse menu for the contractor because it provides access to data handling, data processing, QC, classification, and review resources. Raw data are accepted as input at the top of the menu, and the verified/validated classification dig list and dig results are presented to the user, along with appropriate file downloads, at the bottom.

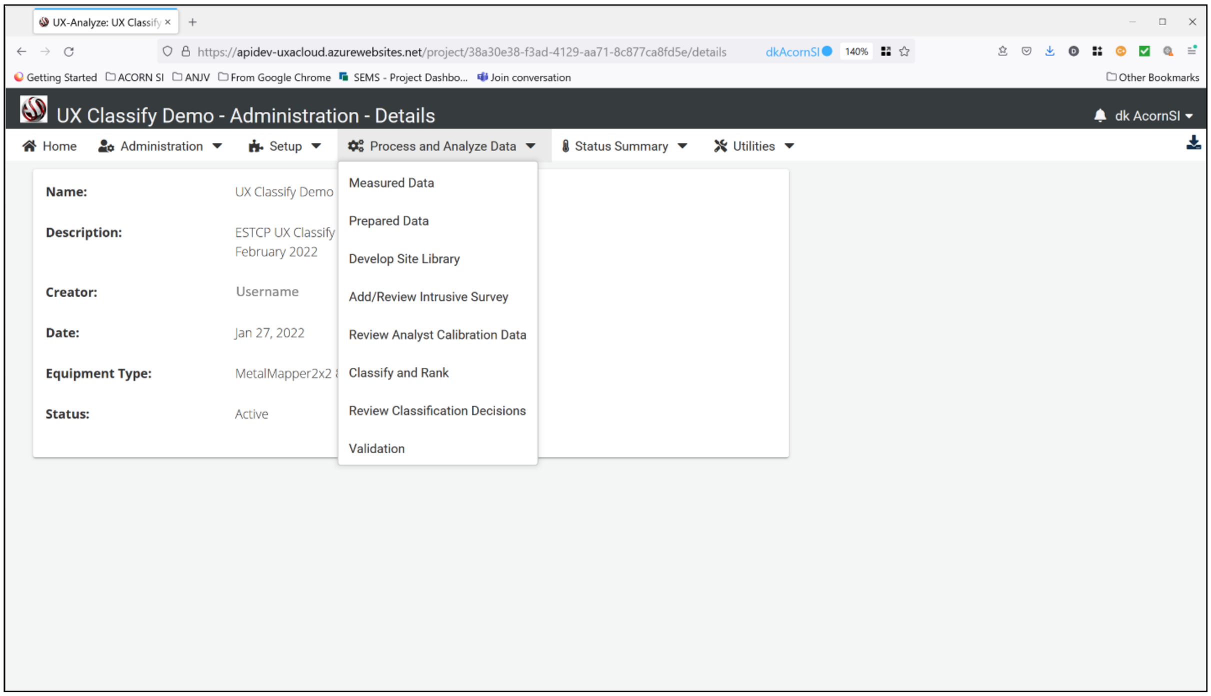


Figure 7. Screen Snapshot Showing the Process and Analyze Data Page.

This page provides the contractor's team data processing, visualization, and classifying capabilities.

Measured Data submenu: a complex resource that allows the contractor's team to upload data, perform QC checks, and manually pass/fail each day's data. QC checks appropriate to each data type (SFT, SBR, SBG, SQC, SAM) are executed. It also provides details regarding the nature and number of the day's collections. A sequence of checks and processes are utilized, including three-source inversions, to perform the QC checks.

Prepare Data submenu: this page presents data that have passed all QC checks, organized by geo units.

Develop Site Library submenu: sophisticated page providing the means to review inversion results in context with the signature library to assure that all clusters are explained.

Add/Review Intrusive Survey submenu: a resource that accepts dig information resulting from an intrusive investigation and merges/aligns it with geophysical data based on spatial location.

Review Analyst Calibration Data submenu: a page dedicated to the review of intrusive information and adding signatures to the site-specific library (if desired).

Classify and Rank submenu: the main classification resource. This page utilizes the site-specific library and generates a classification dig list. It also allows the user to select validation/verification sources.

Review Classification Decisions submenu: resource that reviews the classification results after integration of the intrusive results.

Validation submenu: provide the means to review and approve the validation data results.

The Status Summary page is the communication window for the project team. It provides status updates regarding data collection (temporal based acquisitions), data processing (analysis of spatially registered data), detailed weekly reports, as well as information regarding which munitions were found, where they were found, and the depths at which they were found.

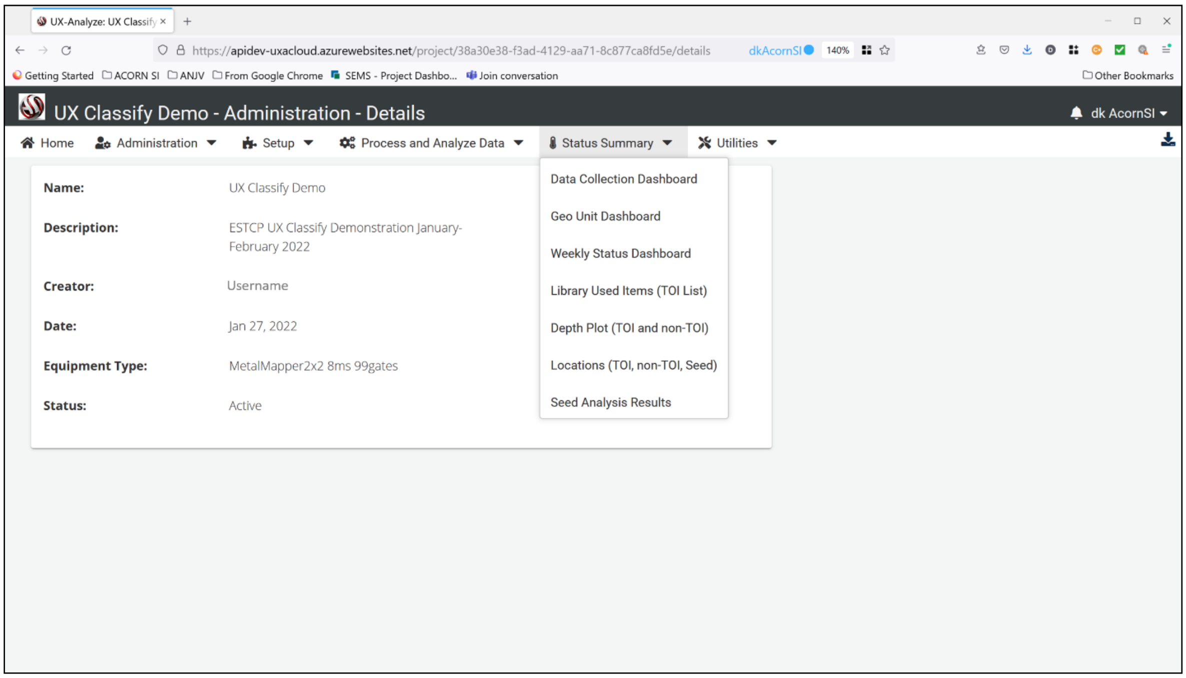


Figure 8. Screen Snapshot Showing the Status Summary Page.

This page is the communication window through which the product development team can assess overall status as well as detailed classification results for each Delivery Unit, throughout the project's duration.

Data Collection Dashboard submenu: graphic description of data collections in time. Additional information for this key page is presented below.

Geo Unit Dashboard submenu: graphic summary of project status by geo unit. Additional information for this key page is presented below.

Weekly Status Dashboard submenu: graphic summary of project progress by week. Additional information for this key page is presented below.

Library Used Items submenu: a resource page that shows a summory of the TOI types, numbers, and signatures.

Depth Plot submenu: graphic summary of TOI types and depths (classification and intrustive).

Location submenu: Simple map showing the locations of TOI, non-TOI, and QC Seeds.

Seed Analysis Results submenu: a dedicated page facilitating the efficient review of QC seeds (and QA seed as appropriate based on the users' role).

Three subpages within the Status Summary page warrant an introduction because they are key to keeping the product delivery team informed. The first of the key subpages is the Data Collection Dashboard (Figure 9). This page allows all project team members to view the status of raw sensor data that automatically passed, or was manually allowed to pass, built in QC tests. Each days' data collection is summarized on the left-hand portion of the GUI while the right-hand side provides daily totals and access into specific measurement types. This daily update is automatically available to all team members once the contractor's QC geophysicist manually passes the day's collections, in full compliance with DOD's AGC QAPP requirements.

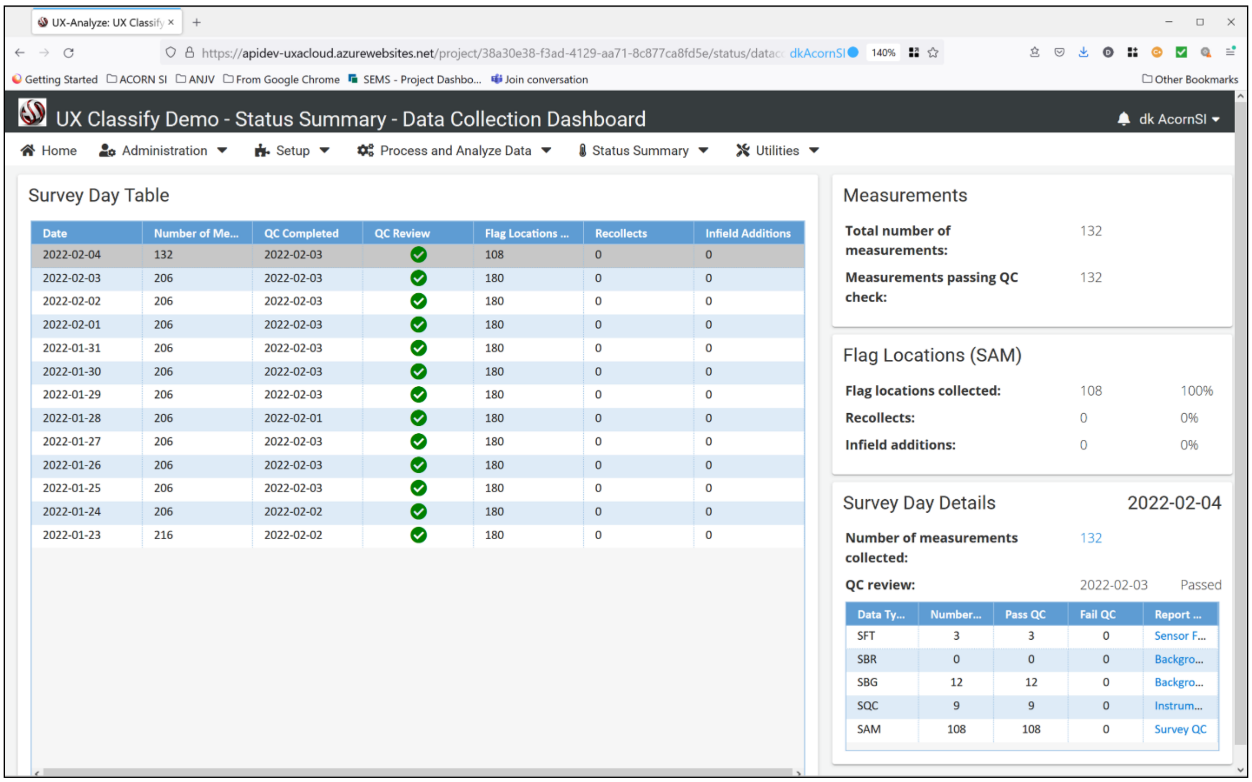


Figure 9. Screen Snapshot Showing the Data Collection Dashboard.

This page presents a summary of the data collected as a function of time and provides detailed access if needed.

This page, and many subsequent pages, utilize a green color to indicate that all QC measures and metrics have been passed. Yellow and red symbols identify instrument collections in which at least one of the QC'd metrics fail. Users can sort the collections by individual channels, allowing them to quickly identify questionable data, which naturally requires extra attention, or confirm that all data pass the QC measures.

The second key subpage of the Status Summary menu is coined the Geo Unit Dashboard (Figure 10). Like the Data Collection Dashboard, it concisely summarizes programmatic status. Unlike the Data Collection Dashboard whose focus is temporal, however, this page presents results of data analysis as a function of space. It presents, for each defined Geo Unit, an overview on the left-hand side and a detailed view on the right. The Geo Units are user defined but could, for example, represent 100x100ft grids. In addition to revealing analysis results, it also tracks and displays data handoffs between the contractor, QA geophysicist, and third-party regulator.

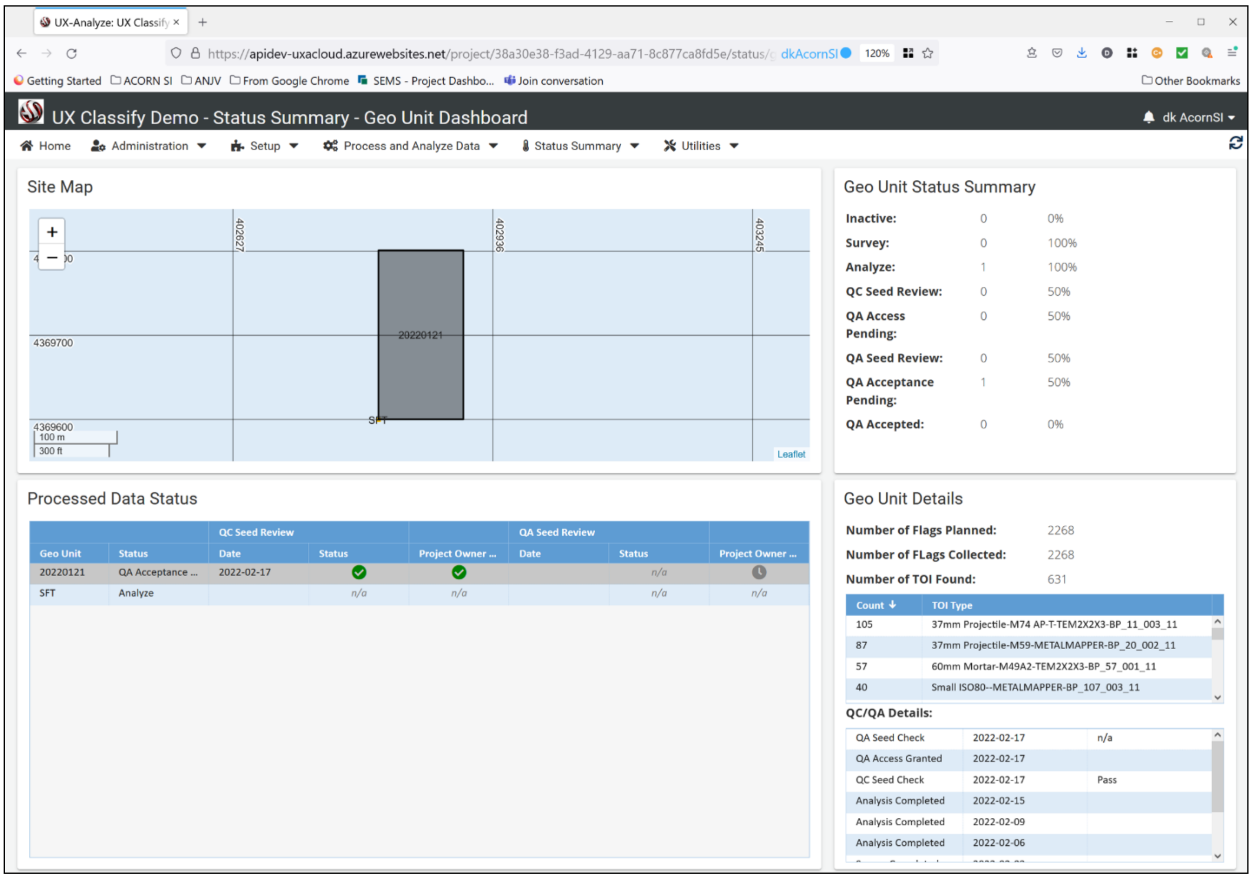


Figure 10. Screen Snapshot of the Geo Unit Dashboard.

This page presents a summary of the processed data as a function of space (defined by Delivery Units) and provides detailed access if needed. It also provides the means for allowing access to the government QA team and then to the third-party regulator team.

The third key subpage of the Status Summary menu is the Weekly Status Summary. This page presents an at-a-glance reporting of the project for each week of activity since the projects' beginning. It explicitly shows key numbers regarding raw data collections and Geo Unit status for the week, since project inception, and percent complete.

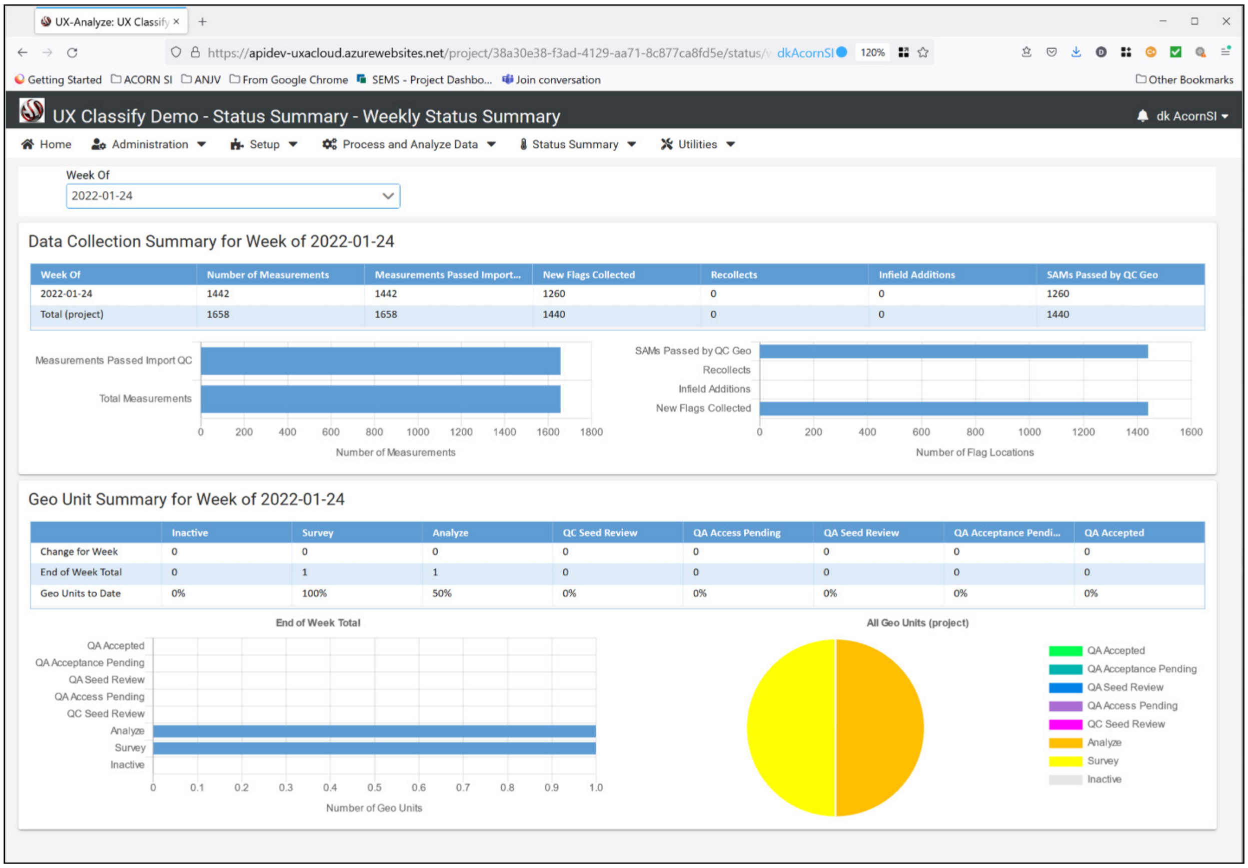


Figure 11. Screen Snapshot of the Weekly Status Summary Page.

This page provides the PDT with a weekly synopsis of the daily collection efforts and data processing status (by Delivery Unit or grids).

The Utilities page provides access to miscellaneous project files (if any) that users want archived along with the project, as well as project activity and audit reports.

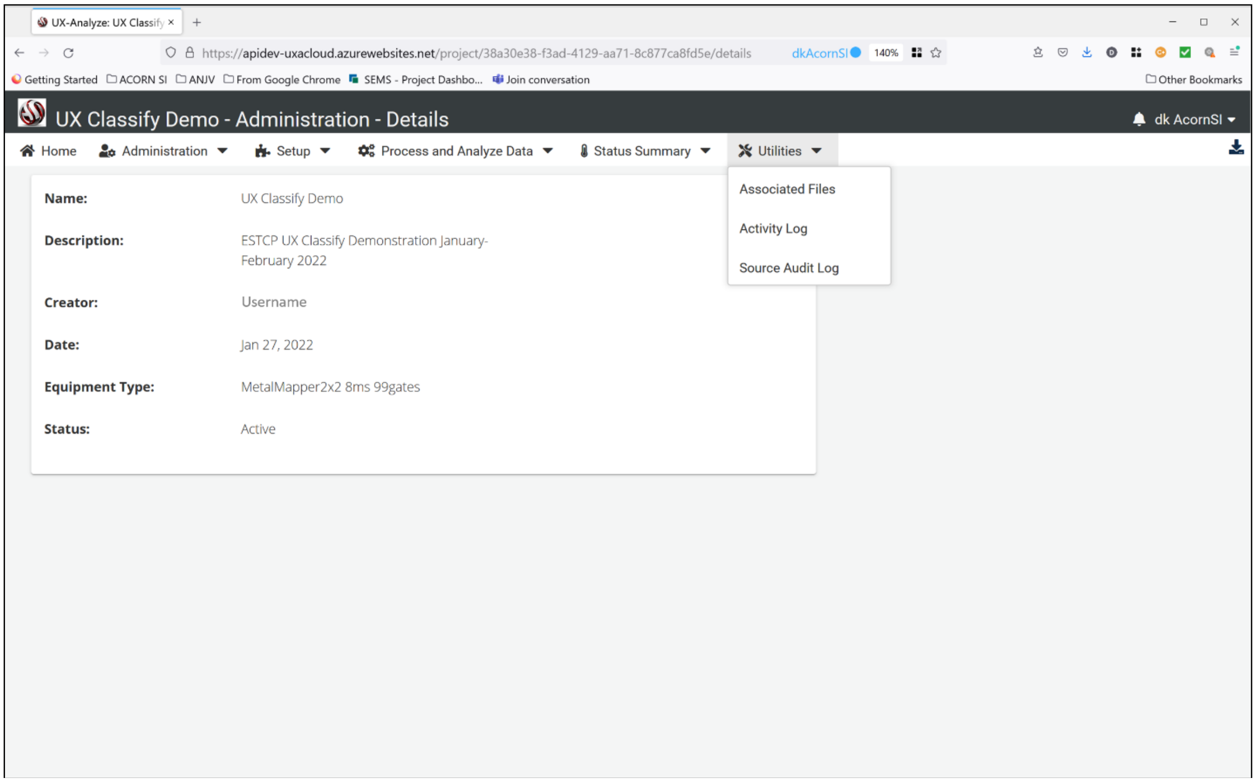


Figure 12. Screen Snapshot Showing the Utilities Page.

Associated Files submenu: resource page to store user files.

Activity Log submenu: list of all project actions.

Source Audit Log submenu: provides audit trail information in support of each source-specific decision.

2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The advantages of this technology are the result of a unique project management approach, strict adherence to the AGC QAPP, and the revolutionary achievements of Cloud technology. Specific advantages include:

1) No local software installations required
2) Institutionalized QC measures
3) Systematic firewalls
4) Robust and user-friendly monitoring of project activities

5) Transparent and efficient data transfer

6) Solution for the entire project delivery team

A limitation of this technology is that it requires an active internet connection.

Alternate technologies are software solutions designed for networked PC. Table 1 compares the two technologies for key attributes.

Table 1. Comparison of Key Attributes for PC- and Cloud-based AGC Processing Schemes

Attribute	PC Based	Cloud Based
Security	compartmentalized	uniform
Communication	compartmentalized	transparent
Version control & activity logging	compartmentalized	automated
IT requirements	Local	Internet
Processing speed	Local and limited	On demand
Cost basis	Per system and infrastructure	Per use

3.0 PERFORMANCE OBJECTIVES

Table 2. Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
Detection of all TOI	Percent detected of all emplaced TOI at the user defined stop dig point	Location of emplaced TOI Prioritized dig list	100%
Reduction of false positives	Number of false positive eliminated at the user selected stop dig point	Location of emplaced TOI Prioritized dig list	>40%
Location Accuracy	Displacement error from ground truth. Radial error	Location of emplaced TOI Estimated location from analysis of EMI data	≤ 25cm
Qualitative Performance Objectives			
User experience	Acceptable user interfaces and functionality	User poll responses	Positive remarks or constructive criticism. We will internalize and respond to negative feedback, if received.

Qualitative performance reviews are a critical component to this demonstration. They do not, however, lend themselves to objective success criteria. To solicit honest, mature responses we asked four people very familiar with AGC methods and MMRP objectives to participate in the demonstration and provide feedback. Participants include senior data processors form a commercial firm (data analyst and QC), a DAGCAP/USACE geophysicist, and an active state regulator that serves on ESTCP's AGC technical advisory committee. Although all four are experienced with MMRP technologies, processes, and goals, none of them had previous experience with, or detailed knowledge of, the UX-Classify software.

To introduce the software to the users, Acorn SI presented each participate with a two-hour introduction and provided access to a pre-demonstration data product so that they could gain familiarity with the software if they desired.

The third-party data analyst, QC geophysicist, government QA, and state regulator were each asked to answer a questionnaire. The specific questions are presented below.

1. What comes to mind when you think of UX-Classify?
2. What do you like about UX-Classify?
3. Did you find any aspect difficult to follow? Yes/No. If yes, please explain which one.
4. How difficult was the learning curve (scale 1-10 (best)). How can we improve?
5. What was your first impression when you entered UX-Classify?

6. Within the scope of this cued-focused software, are there any capabilities that we are missing?
7. How would you rate the ease of use?
8. Was the audit trail suitable? Yes/No. If no, what information should we add.
9. Are the user roles and permissions transparent?
10. Was the data transfer process clear and efficient?
11. QC Geophysicist: Are you satisfied with the QC tools? If not, please explain.
12. QA Geophysicist: Are you satisfied with the QC tools? If not, please explain.
13. Third Party (Regulator): Was the level of data access and transparency appropriate? If not, what should we consider adding?
14. Analyst: was the wait time between pages acceptable?
15. Analyst: was it easy to make data accessible, on a per GeoID basis, for QA and Regulators?
16. Analyst: was the workflow (layout and order of menu items) easy to follow? If not, how could it be improved?
17. Did you find the Status Summary/Data Collection Dashboard useful? Improvements?
18. Did you find the Status Summary/Geo Unit Dashboard useful? Improvements?
19. Did you find the Status Summary/Weekly Status Dashboard useful? Improvements?
20. If you could add any feature to UX-Classify, what would it be and why?
21. If you could choose a feature to develop further, what would it be and why?

3.1 OBJECTIVE: DETECTION OF ALL MUNITIONS OF INTEREST

3.1.1 METRIC

Percent detected of all synthetically seeded TOI.

3.1.2 DATA REQUIREMENT

To assess this metric, we need to know the location of emplaced TOI and the analyst dig list.

3.1.3 SUCCESS CRITERIA

The success criteria is 100%.

3.2 OBJECTIVE: REDUCTION OF FALSE POSITIVES

3.2.1 METRIC

Number of false positives eliminated at the user selected stop dig point.

3.2.2 DATA REQUIREMENT

Required documents include the analysts' prioritized dig list.

3.2.3 SUCCESS CRITERIA

Success will be declared if the total false positives is less than or equal to 40%.

3.3 OBJECTIVE: LOCATION ACCURACY

3.3.1 METRIC

Radial error in XY location for emplaced TOI.

3.3.2 DATA REQUIREMENT

To assess this metric, we require emplaced TOI locations and XY locations from the analysts' dig list.

3.3.3 SUCCESS CRITERIA

Success will be declared if the XY radial error less or equal to 25cm.

4.0 SITE DESCRIPTION

Government personnel utilized AcornSI's UX-Simulator to generate cued MM2x2 data and supporting QC data (backgrounds, sensor function tests, instrument verification strip data), as well as QC Seed information. Prior to the demonstration, the AcornSI team modified the UX-Simulator software to allow for the generation of sites up to 50 acre and two hundred thousand sources.

For this demonstration, the government created a six-acre site with 2,000 plus sources (not including QC data listed above). The UX-Simulator software collects 180 cued collections per day, which resulted in data being collected over a 13-day span from 1-23-2022 to 2-4-2022 (Figure 13 and Figure 14). Breaking up the collections into realistic daily bundles is realistic and allows for the normal product flow to be more thoroughly tested than an unrealistic, single-day, data collection event.

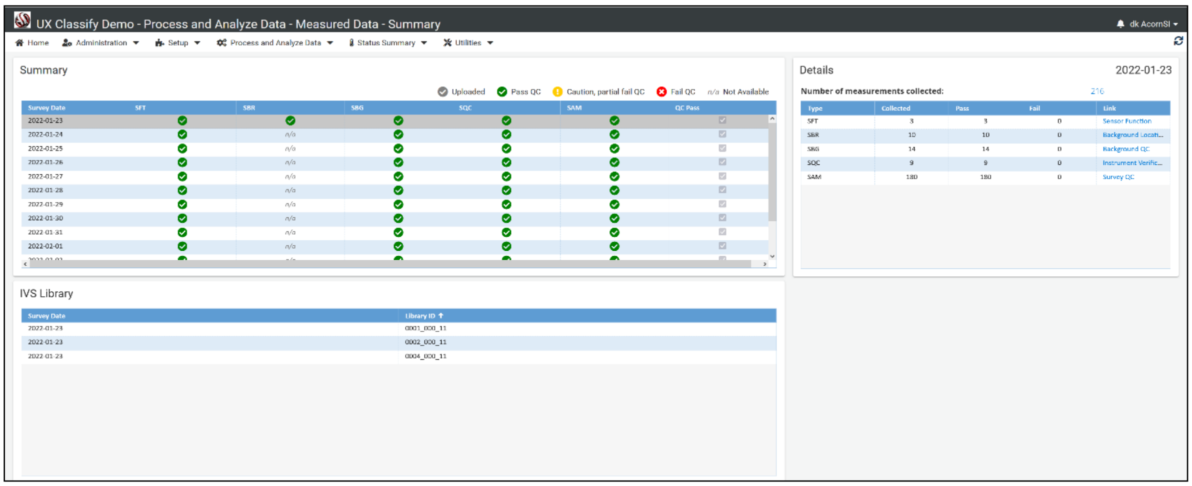


Figure 13. Screen snapshot of the Measured Data Summary – Showing a Portion of the Daily Data Recordings.

The top right section provides details for the day selected (highlighted in grey).

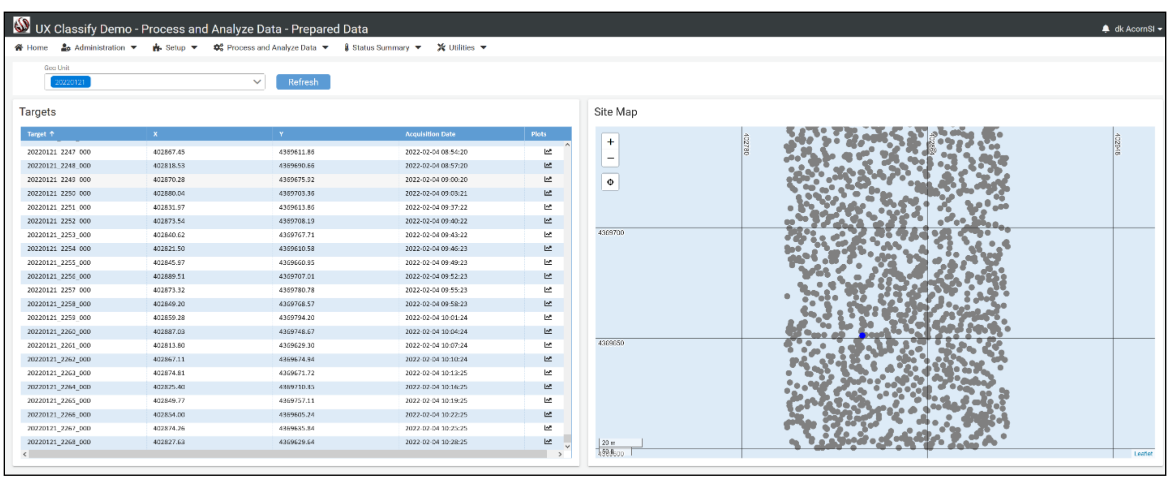


Figure 14. Screen Snapshot of UX-Classify GUI Showing the Locations of Each of the Cued Collections Under Investigation.

4.1 MUNITIONS CONTAMINATION

Reference signatures for the following munitions are included in the UX-Simulator, 20mm, 37mm, 60mm, 81mm, 105mm, and 155mm.

For this demonstration, the government included 37mm projectiles, 60mm mortars, 81mm mortars, 105mm projectiles, and 155mm projectiles. Small ISO's were used as QC and QA seeds.

The number, type, and burial depth of TOI, non-TOI, and QA/QC seeds were firewalled from the analyst and AcornSI team until after the final classification dig list was submitted and scored.

5.0 CONCEPTUAL EXPERIMENTAL DESIGN

UX-Classify is a data analysis and program management solution. As such, the focus of this demonstration is (1) deriving polarizations that are consistent with its proven predecessor software package, (2) the analysts' experience, and (3) the Governments' QA geophysicists' experience.

The input data for this demonstration must be collected with, or simulated for, a MM2x2 sensor. The MM2x2 sensor was the only system available during the development of UX-Classify so the software assumes its design parameters and data format (HDF5 v0). Moreover, because real data projects only excavate the sources for some of the anomalies, simulated data provide a much richer and more thorough data sample.

The overall design of this demonstration follows:

1. A government representative generates MM2x2 data using DAGCAPs UX-Simulator program. We recommended generating 1,000 to 2,000 anomalies, which represents roughly eight to fifteen days' worth of cued collections, depending on how many cued collections are allowed to be generated per day.

2. The analyst reads the data, checks the data for adequate quality, then inverts and processes the data through to a classification decision for each anomaly.

3. The QC geophysicists interacts as appropriate given constraints and guidelines of the DoD's AGC-QAPP and Engineer Manual (EM) 200-1-15. This included explicitly confirming data-based QC metrics pass for all collected data (time based) and that all QC seeds are correctly classified. These checks must be completed for each data collection and/or each geounit delivery prior to allowing the QA reviewer access.

4. The Governments QA geophysicists interacts as appropriate given constraints and guidelines of the DoD's AGC-QAPP and Engineer Manual (EM) 200-1-15.

5. Quantitative and qualitative metrics and comments are gathered and recorded.

6.0 DATA ANALYSIS PLAN

6.1 PREPROCESSING

The data set consists of one cued MM2x2 EMI data file, in HDF5 v0 format, for each anomaly under test. The software package examines each file and performs basic quality control checks and evaluations. Next, the data is merged with the appropriate background measurement and levelled (background subtraction).

To facilitate performance monitoring, the user must first complete UX-Classify's Administration, and Setup menus. Specific tasks within the Administration menu include setting up the projects' users, QAPP and related parameters, and signature library. Specific tasks within the Setup menu include defining the site boundaries, flag locations, and IVS locations as well as establishing the Depth Response curve for the smallest munition item of concern.

6.2 PARAMETER ESTIMATION

Data inversion algorithms based on the dipole model are embedded into UX-Classify. The inversion routines utilize the same basic code structure as that used for UX-Analyze Desktop, and UX-Simulator. They have proven success at more than 20 ESTCP Live Site Demonstration programs. Additionally, eleven of the thirteen DAGCAP accredited firms utilized these routines during their APG DAGCAP assessment.

The inversion routines accept as input the spatially registered and INS orientated EMI data and returns size and burial depth estimates, fitted X and Y locations, polarizabilities, and model coherence for 1, 2, and 3-source scenarios.

6.3 ANALYST CALIBRATION DATA

For the statistical classification, we used the data over the IVS to adjust the default threshold. Normally, analyst training digs would be requested. Although we anticipated requesting a few 10's of analyst training digs, the default thresholds were deemed to be appropriate by our third-party analyst.

6.4 CLASSIFICATION

The classification decision was derived using the methods that are embedded into the UX-Classify software.

The UX-Analyze decision statistic calculated using following equation:

Range of time channels — Polarizability — Weighting on each polarizability — Time gate

$$\phi = \sum_{i=1}^{3} W_i \exp\left(-\frac{1}{2} \left(\frac{\left(\sum_{j=1}^{N} \left| L_i^{est}(t_j) - L_i^{ref}(t_j) \right| \right)}{scaleFactor} \right)^2 \right) \qquad L_1 : \beta_1 \quad L_2 : \beta_1 / \beta_2 \quad L_3 : \beta_1 / \beta_3$$

Equation 1

The decision statistic is used to determine the final classification category:

Category 0: Cannot analyze (dig)

subcategory 1 - cannot extract reliable polarizations

subcategory 2 - too far from

subcategory 3 - poor fit coherence

subcategory 4 - unreasonable depths and negative betas

subcategory 5 - no betas - inversion did not finish

Category 1: TOI (dig)

subcategory 1 - good, combined Library Match statistic fit to TOI library

subcategory 2 - QC TOI - good visual match but statistic less than TOI threshold (optional)

Category 2: Cannot decide (dig)

subcategory 1 - combined Library Match statistic using TOI Library and a lower threshold

subcategory 2 - QC possible TOI - reasonable visual match to TOI but statistic less than TOI threshold (optional)

Category 3 is clutter (do not dig)

subcategory 1 - combined Library Match statistic less than TOI threshold

6.5 DATA PRODUCT SPECIFICATION

Quantitative Metrics: The data analyst used UX-Classify to generate a classification dig list. The list included fitted XY locations, fitted depth estimates, decision metrics, decision categories, and final classification decision.

Qualitative Metrics: The qualitative metrics were gathered using a targeted questionnaire followed up with personal telecoms. The questionnaire provided data for user opinions related to training, ease of use improvements, functional improvements, and bugs.

7.0 PERFORMANCE ASSESSMENT

7.1 TECHNICAL

After correcting a logic error associated with how coincident sources are classified (detailed in Appendix 16), the demonstration dig list was scored using the standardized scoring software included in UX-Simulator. The results are shown in Figure 15 and summarized in Table 3. Note that although there were over 2,000 decisions included on the final dig list, the ROC curve presents results for only the first 1,000 classifications due to a limitation imposed by the scoring algorithms.

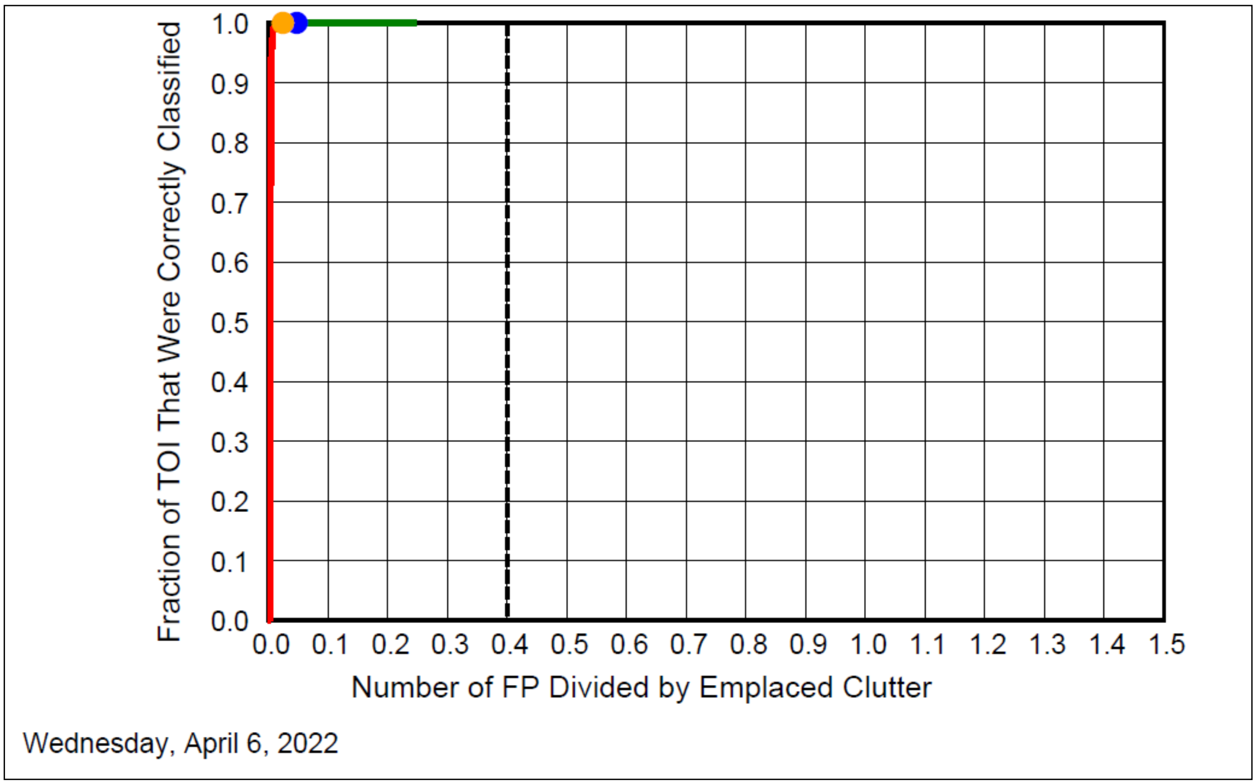


Figure 15. ROC Curve Resulting from this Demonstration.

The ROC curve was produced using DAGCAP's UX-Simulator software. On this plot, the (1) analyst's operating point (blue circle) represents the performance for the threshold specified in the ranked dig list, (2) the optimum point (orange circle if applicable) represent the point on the curve that minimizes the number of false positives while maintaining zero false negatives, (3) the red line is the portion of the ROC curve before the operating point, (4) the green line is the portion of the ROC curve after the operating point, and (5) the black dashed line represents the maximum allowable false positive rate.

Table 3. Technical Summary

Number of Decisions (sources)	2268
Number of Cannot Analyze	7
Number of True Positives	441
Number of False Positives	85
Number of False Negatives	0
Number of True Negatives	1742
Reduction of False Positives	96%

Project performance objectives from Section 3 and performance results are presented in Table 4.

Table 4. Project Objectives and Results Summary.

Performance Objective	Metric	Data Requirements	Success Criteria	Performance
Quantitative Performance Objectives				
Detection of all TOI	Percent detected of all emplaced TOI at the user defined stop dig point	Location of emplaced TOI Prioritized dig list	100%	100% Pass
Reduction of false positives	Number of false positives eliminated at the user selected stop dig point	Location of emplaced TOI Prioritized dig list	>40%	>95% Pass
Location Accuracy	Displacement error from ground truth. Radial error	Location of emplaced TOI Estimated location from analysis of EMI data	≤ 25cm	Pass
Qualitative Performance Objectives				
User experience	Acceptable user interfaces and functionality	User poll responses	Positive remarks or constructive criticism. We will internalize and respond to negative feedback, if received.	Positive and constructive remarks were received – presented in their entirety below

7.2 OBJECTIVE: DETECTION OF ALL MUNITIONS OF INTEREST

7.2.1 METRIC

Percent detected of all synthetically seeded TOI.

7.2.2 DATA REQUIREMENT

Required information includes the emplaced TOI and the analyst's dig list.

7.2.3 SUCCESS CRITERIA

All TOI correctly classified (no false negatives).

7.2.4 PERFORMANCE

Success - All TOI were correctly classified, resulting in a probability of detection of 100%.

7.3 OBJECTIVE: REDUCTION OF FALSE POSITIVES

7.3.1 METRIC

Number of false positives eliminated at the user selected stop dig point.

7.3.2 DATA REQUIREMENT

Required documents include the analysts' prioritized dig list.

7.3.3 SUCCESS CRITERIA

Success is declared if the total false positives is less than or equal to 40%.

7.3.4 PERFORMANCE

Success – total false positive rate was 4.7%. In other words, approximately 96% of the clutter were correctly classified as clutter.

7.4 OBJECTIVE: LOCATION ACCURACY

7.4.1 METRIC

Radial error in XY location for emplaced TOI.

7.4.2 DATA REQUIREMENT

To assess this metric, we require emplaced TOI locations and XY locations from the analysts' dig list.

7.4.3 SUCCESS CRITERIA

Success is declared if the XY radial error less or equal to 25cm.

7.4.4 PERFORMANCE

Success – The maximum radial error was 14cm. The average radial error was 3cm.

Note – Although the vertical error is not specifically included in this objective, we report it here because it is related. The maximum vertical error was 18cm and the average vertical error was 4cm.

7.5 OBJECTIVE: USER EXPERIENCE

7.5.1 METRIC

Acceptable user interfaces and functionality.

7.5.2 DATA REQUIREMENT

User poll responses.

7.5.3 SUCCESS CRITERIA

Positive remarks or constructive criticism.

7.5.4 PERFORMANCE

All four project participants provided positive remarks and/or constructive criticism. Their responses are presented in their unedited entirety below.

Summary thoughts regarding comment:

Given the radical change in user experience that UX-Classify offers, the user responses were viewed very favorably. The software was considered easy to use, required minimal training, it loaded without issue on government computers, and it provides unprecedented access for the QA and Regulator into the data processing and decision-making phases of the AGC process. In fact, the ease of use was rated 10 out of 10 by the QA geophysicist and 100 out of 10 by the state regulator.

Because the data set resides in cloud infrastructure instead of local drives or networks, data transfer between parties is realized by changing data access permissions within UX-Classify. As a result, data transfer issues that plaque networked pc-based schemes are eliminated.

Recommendations for providing a revised or big-picture menu for the state regulators was requested by the QA and State regulator participants. We will discuss ideas with them and make changes as appropriate in the coming months. We do not anticipate any technical issues.

The analyst and QC geophysicist requested minor changes to a few specific tools. These recommendations will be discussed and rectified as appropriate. We do not anticipate any significant technical challenges as these minor issues addressed.

Data analyst questionnaire responses:

Name: Alison Paski

Role: Project Geo, Data Analyst

Date: 5/18/2022

1. What comes to mind when you think of UX-Classify?

   Cloud based AGC analysis and project progress software

2. What do you like about UX-Classify?

   The cloud-based data storage and interface. During the analysis process transferring of files between different data storage sites can be time consuming and version control can become an issue. Access to data to multiple analysts as well as other team members in different locations is much easier. Packaging of data deliverables is simplified.

   The Status Summary concept is useful for automated tracking of project task progress.

3. Did you find any aspect difficult to follow? Yes/No. If yes, please explain which one.

   The specific formats and files that are needed for the project. The workflow is generally clear and follows the menus left to right and top to bottom, however specific inputs and If each step is needed are not clear without additional documentation being added.

4. How difficult was the learning curve (scale 1-10 (best)). How can we improve?

   7, with overall process and steps explained in a less than 2-hour demonstration if the user has previous experience with DAGCAP AGC processes. If someone is not familiar with AGC and would be a first-time user of analysis software there are programmatic concepts they would need to learn prior to understanding the structure of the process.

   Documentation is needed, with overview explanation of process, user types/roles and details on the individual tools. Suggest digital training documentation is developed and Help within the application is added. For in app Help something along the line of having a question mark in the corner that can be clicked on that will bring up Help for the tool the user has active.

5. What was your first impression when you entered UX-Classify?

   Is purpose drive software for AGC, not an existing product that has had AGC capabilities added.

6. Within the scope of this cued-focused software, are there any capabilities that we are missing?

   Bringing in additional layers to the Site Map that can be toggled on/off. Currently just the Sensor Info can be toggled. Additional useful information for interpretation are dynamic detection survey data as a background, culture features as lines, points or polygons. Possibly if geotagged photos were included, they could be accessed and tied to the Site Map. Toggling of sources as well as sources that pass QC (ie mask out ones that will not be used). Option for instrument footprint on all instances of Site Map, it is visible on the Measured Data - Survey QC page but not on the Develop Site Library page.

Is it possible to view more data fields associated with a measurement? I am thinking of the Targets gdb and Data gdbs in UX-Analyze and the contents of the H5 file for the raw data. Then later in the process there are several fields in the UX-Analyze Source database that are not visible in UX-Classify.

Some plots that I have referenced in the past are not generated. For example, the SFT shows Response and Response variation plots but not a table view of the data or decay plots. Overlay plots of measurements taken at the same location. Having options to create additional plots at analyst discretion would be useful.

Highlighting all sources associated with the measurement and not just the current source. If there were multiple shots at a single flag possibly have the sources from the other shot identifiable.

Automated way for sources fitting to another flag to be identified and handled.

Automated way to incorporate field notes, this possibly would be on the data acquisition side if they could include a field in the H5 file with their note for the measurement.

7. How would you rate the ease of use?

   7, once the workflow is clear. There are a lot of windows that open and it does take some adjustment to figure out where to look for information however it is not difficult after some practice.

8. Was the audit trail suitable? Yes/No. If no, what information should we add.

   Yes, from a data analysts' perspective don't have any additional suggestions.

   If a user has multiple roles, it is not clear which role they are fulfilling when doing a task, for example I had Project Geo and Data Analyst so both roles were listed for all tasks.

9. Are the user roles and permissions transparent?

   Yes

10. Was the data transfer process clear and efficient?

    The process was efficient but not always clear. Documentation would be helpful for this.

11. Did you find the Status Summary/Data Collection Dashboard useful? Improvements?

    Yes, currently much of this information takes time to organize and summarize. Having it built in with the data storage/analysis/qc/qa site and automated is very helpful and makes it very accessible to the project team.

    Ability to tie this to a field crew daily log that would note workdays/hours of workday would be helpful for project management.

12. Did you find the Status Summary/Geo Unit Dashboard useful? Improvements?

    Yes. Unclear how this would display if there were multiple Geo Units for the site, would like the Site Map to show all Geo Units and a legend with the Status from the table color coded.

Additional explanation Number of TOI found or rename this. Looks like it might be showing the count of best matches to a library item and not the actual TOI found at the site based on intrusive, but there is a blank TOI type with a Count value.

13. Did you find the Status Summary/Weekly Status Dashboard useful? Improvements?

    Not Answered

14. If you could add any feature to UX-Classify, what would it be and why?

    Automated "same as" tool where sources from different flags that fit to the same location with similar features are identified and would be ranked together, for the further flag from the shared source an alternate source would be selected.

15. If you could choose a feature to develop further, what would it be and why?

    Adding of additional layers that can be toggled on/off on the Site Map, and the map being consistent across tools. Having default layers turned on when the Site Map is opened and then the user can change the view as needed. Being able to visualize the flag, "selected flag/source" cued sensor location, other measurement sensor locations, "selected flag" source location(s), other flag source locations, detection survey, culture.

16. Analyst: was the wait time between pages acceptable?

    Some pages take longer to load. It seems to be related to the number of measurements, if there is a day or test type with a smaller number of measurements it loads faster than pages that are bringing up information for the whole Geo Unit. The overall dataset is smaller than we may see for a single site but larger that we typically see for an individual grid.

17. Analyst: was it easy to make data accessible, on a per GeoID basis, for QA and Regulators?

    Yes

18. Analyst: was the workflow (layout and order of menu items) easy to follow? If not, how could it be improved?

    Yes, it was easy to follow however the steps once in a tool were not always clear. Documentation that includes input data types and formats would be helpful.

19. QC Geophysicist: Are you satisfied with the QC tools? If not, please explain.

    N/A

20. QA Geophysicist: Are you satisfied with the QC tools? If not, please explain.

    N/A

21. Third Party (Regulator): Was the level of data access and transparency appropriate? If not, what should we consider adding?

    N/A

QC Geophysicist questionnaire responses:

Name: Cora Blits

Role: QC Geophysicist

Date: 03/02/2022

1. What comes to mind when you think of UX-Classify?

   Cloud-based AGC classification

2. What do you like about UX-Classify?

   Saves times copying large, processed files to/from a SharePoint or FTP site; provides standardized workflow and tools that generate the same classification results and products from multiple processors; dashboards provide a good overview of production and QC results which makes it much easier to relay this information to project managers

3. Did you find any aspect difficult to follow? Yes/No. If yes, please explain which one.

   No, all aspects of the QC process are relatively straightforward to follow once becoming familiar with them

4. How difficult was the learning curve (scale 1-10 (best)). How can we improve?

   7 (with 10 being easiest); basic training materials/documentation would be a huge benefit when getting familiar with the new processing environment

5. What was your first impression when you entered UX-Classify?

   Simplified processing environment with menus following the intended workflow

6. Within the scope of this cued-focused software, are there any capabilities that we are missing?

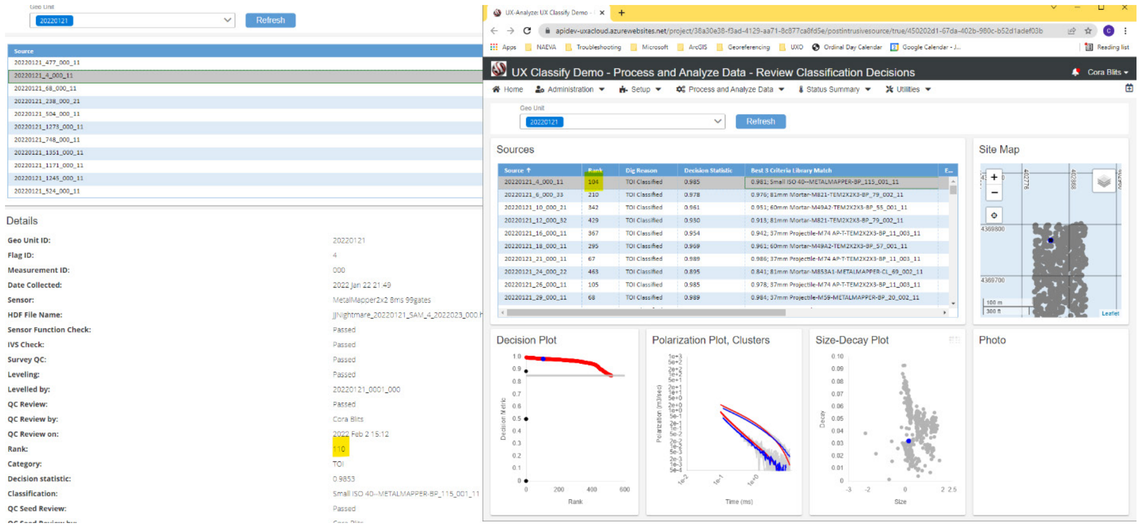
   It would be very useful if there was a way to check the signal amplitude during processing and QC. This is information we regularly use when determining if redo measurements will improve classification results. It would also be quite helpful if there was a way to visualize all six inverted source locations with respect to the instrument footprint, preferably with all flag locations shown as well. When determining whether a redo measurement would be appropriate, we generally look at whether the sources are clustering to a specific location (where we would request a redo measurement be performed) or appear to be widely dispersed (in which case we may not request a redo based on the signal amplitude). It is also useful to review whether the sources are fitting near another flag, in which case a redo would not be required if the fit location was already covered by a measurement associated with the adjacent flag.

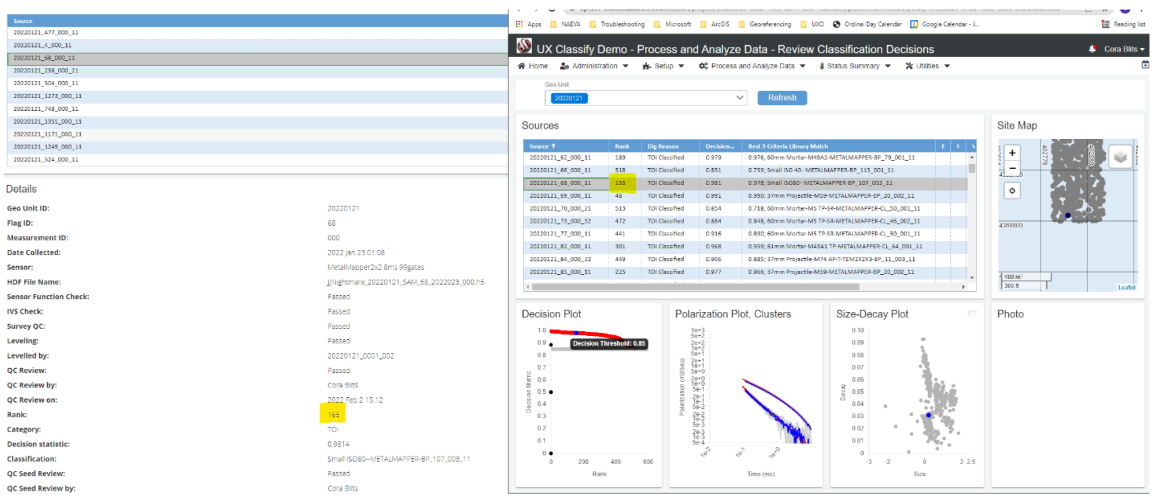
7. How would you rate the ease of use?

   8 (with 10 being easiest); the QC tools were very straightforward to use.

8. Was the audit trail suitable? Yes/No. If no, what information should we add.

   I believe all relevant QC information is being displayed in the audit trail. I also find the QC/QA details displayed on the geo unit dashboard useful. There does appear to be a bug in the Source Audit Log. The Rank does not match what is being shown on the Review Classification Decisions page.





9. Are the user roles and permissions transparent?
   Yes

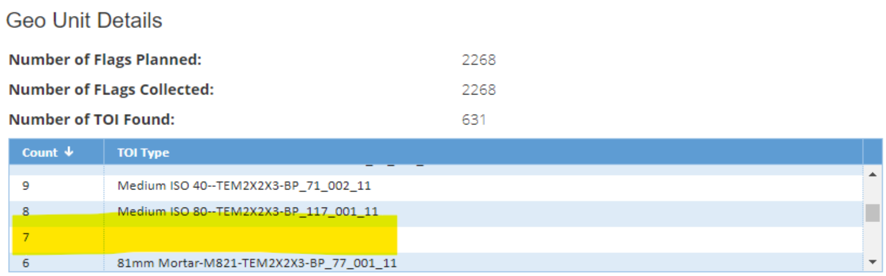
10. Was the data transfer process clear and efficient?
    I initially misunderstood the function of the Release QC Seeds function. The description Tom gave me clarified things, but it would be useful if there was a way to explain this up front

11. Did you find the Status Summary/Data Collection Dashboard useful? Improvements?
    It was very useful. This is information commonly requested by project managers and it is very helpful to have it automatically calculated and available in one place.

12. Did you find the Status Summary/Geo Unit Dashboard useful? Improvements?
    The Geo Unit Details including the QC/QA information is quite useful. Potential improvements listed below.
    a. Is there a way to see a list of flags that have not been collected in geo units where the number of flags collected does not match the number of flags planned? It would also be incredibly useful if there was an option to add comments for uncollected flags (e.g., inaccessible due to brush) and to add uncollectable flags to the dig list.

b. "Number of TOI Found" wording is initially a bit confusing, as this seems to indicate that those are items confirmed as TOI through intrusive investigation.

c. There are 7 TOIs without a type listed. The library items used also changes between different menu items. Under Administration/Library there are 25 items marked as used. Under Status Summary\Library Used Items (TOI List) there are 46 items listed. There are 47 including the entry with no TOI Type under Status Summary\Geo Unit Dashboard.



13. Did you find the Status Summary/Weekly Status Dashboard useful? Improvements?
It was a useful snapshot of weekly progress in different key areas.

14. If you could add any feature to UX-Classify, what would it be and why?
The ability to generate map(s) with source and flag location as detailed in question 6

15. If you could choose a feature to develop further, what would it be and why?
As mentioned in 12, the ability to add uncollectable flags to the dig list. I think it would also benefit the QC process to have an option for the QC Geophysicist to enter comments for both the measured data QC review and the QC seed analysis

16. Analyst: was the wait time between pages acceptable?
N/A

17. Analyst: was it easy to make data accessible, on a per GeoID basis, for QA and Regulators?
N/A

18. Analyst: was the workflow (layout and order of menu items) easy to follow? If not, how could it be improved?
N/A

19. QC Geophysicist: Are you satisfied with the QC tools? If not, please explain.
In general, yes. The QC process would be benefitted by the inclusion of the signal amplitude and source location maps as detailed in question 6, and with the ability to add comments as detailed in question 15. The QC seed analysis is very easy to use.

20. QA Geophysicist: Are you satisfied with the QC tools? If not, please explain.
N/A

21. Third Party (Regulator): Was the level of data access and transparency appropriate? If not, what should we consider adding?
N/A

QA Geophysicist questionnaire responses:

Name: John Jackson

Role: USACE QA Geophysicist

Date: 5/24/2022

1. What comes to mind when you think of UX-Classify?

   Cloud processing and ease of data transfer.

2. What do you like about UX-Classify?
   - Data flow is chronological. Both the processer and the end user can march through the menus in order and have an understanding of flow.
   - QC/QA and Status summary flows provide all the necessary MQO details to understand success of project
   - Ability to follow progress of data analyst and QC is the most transparent I can imagine.
   - Metadata provided for audit trail is transparent and easy to follow
   - Speed of performing processing tasks obviously very quick in cloud
   - Intrusive survey menu is exactly what end users care about but should probably fall under the status summary menu

3. Did you find any aspect difficult to follow? Yes/No. If yes, please explain which one.
   - I think this program has resolved many of the "speed bumps" in normal data flow except one that is not apparent to me-> data gaps in both dynamic and cued surveys. Obviously, this program is currently only meant for cued, but concept remains: the progress menus appear to be based on what is submitted as a geo unit and not "what should be in the data unit." As in, there were 500 original targets but we only collected and processed 450 of them. Would the remaining 50 be identified? (this could be due to field team error or an ROE was revoked in the middle of the project). The synthetic site does not appropriately test this so we will need to work through this on real data.
   - -There should be an "end user menu." Someone like me will want to get in the weeds and march through all of the menu options. But a USACE manager or state regulator will want an obvious bright red menu button that says "start here." Status summary is an attempt at that but still requires some prior knowledge to understand all of the information being presented. I think a general overview menu that gives the most basic of information and then a "go to this menu if you want a more in depth summary on this subject" button.
   - -As far as I can tell, this will force the users to identify geo units either in advance or as part of the dynamic data processing. Personally, I think this is a good thing but in practice, this could be a change in the state of practice and will require some "retooling."
   - -The cluster->size-decay plot was not immediately obvious. Rather than providing the full identified cluster, it provided the items that most looked like the currently selected object. I think either are acceptable depending on need of the analyst at the time, but it should be described so that the user knows what they're looking at.
   - -it appears the can't analyze/unknown were included on the depth plot. It is unclear if this is appropriate, but my suspicion is no and these should be removed and handled separately.

4. How difficult was the learning curve (scale 1-10 (best)). How can we improve?

   It would be good to get an answer from someone that's never used any of this type of software before to get an opinion from the other end of the spectrum, but for someone who was used these types of software packages getting from 0 to 95% required literally zero learning (so I suppose a 10 on this scale?) The last 5% was minimally difficult and was mostly cases of me expecting one thing and it was actually another (cluster analysis) or terminology (simple things like "what is a geo unit dashboard" and "library used items" meaning site specific library. Biggest and easiest improvement would be a nice help menu or users guide describing contents of each menu.

5. What was your first impression when you entered UX-Classify?

   "Please let it open on a government computer, please let it open on a government computer, please let it open on a government computer…yes! It opened on a government computer."

6. Within the scope of this cued-focused software, are there any capabilities that we are missing?

   I was not the analyst so this may be inherent already, but it is unclear if the cued progress list only pulls from the submitted cued files or if you're able to compare to a greater dynamic selections list to know if you collected all of the targets.

   I also would like to make sure the decision logic of "recollects" and "infield additions" are handled appropriately.

7. How would you rate the ease of use?

   Very easy.

8. Was the audit trail suitable? Yes/No. If no, what information should we add.

   Very useful and transparent. Was even able to see when a power-user, back-end administrator went in to fix one of my complaints.

9. Are the user roles and permissions transparent?

   Mostly- I don't think the managers/state regulators can see the full list of who is assigned one and we may want to discuss if they should have the ability to see who has been assigned what permissions.

10. Was the data transfer process clear and efficient?

    From my end, yes. The only issue that popped up was similarly named/numbered QA seeds would overwrite the QC seeds. This will be common in the field and will need to be handled appropriately.

11. Did you find the Status Summary/Data Collection Dashboard useful? Improvements?

    Yes. I would like to add a comparison to the total number of flags expected.

12. Did you find the Status Summary/Geo Unit Dashboard useful? Improvements?

    Yes. Here is the potential for an ability that we may want to have a "DAGCAP conversation" about. Right now the focus is on the QA acceptance of seeds. And UX-Classify mirrors the MQOs on WS#22 in terms of assigning QC acceptance to the other MQOs, but ultimately the QA geophysicist will need to accept all of those metrics. It would be good to add a QA acceptance to the function tests an IVS tests, possibly in a bulk acceptance.

13. Did you find the Status Summary/Weekly Status Dashboard useful? Improvements?

    Not for me. I could see a PM utilizing this to track production. Changing this into a weekly production -vs- overall project production report would be a very useful menu for the PMs.

14. If you could add any feature to UX-Classify, what would it be and why?
    - -See components of previous answers.
    - -dynamic, dynamic, dynamic, dynamic, dynamic
    - -other instruments (hopefully will be helped along by hdf5 v1)
    - -a comparison on size estimate-vs- intrusive results confusion matrix.

15. If you could choose a feature to develop further, what would it be and why?
    - -help menu
    - dynamic, dynamic, dynamic, dynamic, dynamic

16. Analyst: was the wait time between pages acceptable?

    N/A

17. Analyst: was it easy to make data accessible, on a per GeoID basis, for QA and Regulators?

    N/A

18. Analyst: was the workflow (layout and order of menu items) easy to follow? If not, how could it be improved?

    N/A

19. QC Geophysicist: Are you satisfied with the QC tools? If not, please explain.

    N/A

20. QA Geophysicist: Are you satisfied with the QC tools? If not, please explain.
    - -Clearly a step in the right direction in terms of transparency and ease of data flow.
    - -As mentioned earlier, (1) forcing a check of QA-vs-QC numbering or even handling them separately to avoid the issue and (2) a bulk acceptance of the function/QC tests.
    - -(3) the actual selection of validation targets should be done by the QA geophysicist.

21. Third Party (Regulator): Was the level of data access and transparency appropriate? If not, what should we consider adding?

    N/A

State Regulator questionnaire responses:

Name: Jeff Swanson

Role: State Regulatory Authority

Date: 17 May 17, 2022

1. What comes to mind when you think of UX-Classify?

   I view UX-Classify as a tool to put structure, automation, and consistency into the geophysical survey process for munitions cleanup. It provides State regulators the tools to oversee execution of AG projects without having to rely on consultants or Corps geophysicists or bring expertise in house.

2. What do you like about UX-Classify?

   - UX-Classify provides regulators and other stakeholders with visibility into the AGC process and the ability to review data and quality checks throughout the classification process without a steep learning curve or the need to become an AGC data processing expert.
   - Provides the Team powerful tools for collaborating and reviewing AGC results.
   - Transparency provides assurance that quality checks are actually completed and data fully validated.

3. Did you find any aspect difficult to follow? Yes/No. If yes, please explain which one.

   Hard to see the forest for all the trees. This is a great problem for a regulator to have; UX-Classify provides State regulators a virtual library of information (data, analysis, quality checks, classifier results, maps, etc.) but without obvious structure or context it can be overwhelming. Unless you know the details about the AGC survey process it is difficult to navigate and utilize the tools, know what you are looking at, or understand what it means.

   I think this can be easily addressed with a "big picture" project summary dashboard and series of basic process flow diagrams illustrating the data/process steps and decision points.

4. How difficult was the learning curve (scale 1-10 (best)). How can we improve?

   Relative to the current option, where you must learn Oasis and become a UXO geophysicist, its 100+ on a 10-point scale.

   UX-Classify learning curve is hard for me to judge as I have watched the program evolve, but I would say it shouldn't be too bad to learn. It would be highly dependent one the users background in AGC and munitions field work. I think it would be difficult for someone relatively new to munitions cleanup to use without training, but once someone walks them through everything quick to learn and use.

   For State regulators, I think the learning curve and overall usability can be significantly improved with "big picture" dashboards and process illustrations (see #3) to provide context.

5. What was your first impression when you entered UX-Classify?

   At first a bit lost and overwhelmed, took some time to understand what I was looking at. Then I became very impressed by the tools and their layout and transparency. I can see UX-Classify as a valuable tool for regulatory oversight.

6. Within the scope of this cued-focused software, are there any capabilities that we are missing?

   With the addition of the dig verification and validation tools, not that I'm aware of.

7. How would you rate the ease of use?

   As State regulator, ease of use is good. It's mostly just click and review.

8. Was the audit trail suitable? Yes/No. If no, what information should we add.

   Yes, very powerful information.

9. Are the user roles and permissions transparent?

   Yes, this is a great feature of the system.

10. Was the data transfer process clear and efficient?

    N/A

11. Did you find the Status Summary/Data Collection Dashboard useful? Improvements?

    Yes. Possible improvements: 1) tag for which Geo Unit data belongs to know link to other dashboard; 2) an overall project summary stats card, and a map of locations collected.

12. Did you find the Status Summary/Geo Unit Dashboard useful? Improvements?

    Yes, but with only one unit hard to really judge.

13. Did you find the Status Summary/Weekly Status Dashboard useful? Improvements?

    No, but I'm not in a PM role. Possible improvements: Add cumulative project/geo unit totals along with weekly production numbers.

14. If you could add any feature to UX-Classify, what would it be and why?

    - See #3 above.
    - Support for dynamic AGC surveys.

15. If you could choose a feature to develop further, what would it be and why?

    Top level project status and summary dashboard to sit on top of tools.

16. Analyst: was the wait time between pages acceptable?

    N/A

17. Analyst: was it easy to make data accessible, on a per GeoID basis, for QA and Regulators?

    N/A

18. Analyst: was the workflow (layout and order of menu items) easy to follow? If not, how could it be improved?

    N/A

19. QC Geophysicist: Are you satisfied with the QC tools? If not, please explain.

    N/A

20. QA Geophysicist: Are you satisfied with the QC tools? If not, please explain.

    N/A

21. Third Party (Regulator): Was the level of data access and transparency appropriate? If not, what should we consider adding?

    Yes, overall UX-Classify provides great data access and transparency.

8.0 COST ASSESSMENT

We propose to develop expected costs of using this technology.

Table 5. Demonstration Time and Costs

Cost Element	Tracked Item	Unit	Preparing / Learning	Demonstration
Data Analyst Labor	Labor hours	Total hours	8	24
Data QC Labor	Labor hours	Total hours	3	6
QA Labor	Labor hours	Total hours	3	9
Regulator Labor	Labor hours	Total hours	2	6
Azure Storage Costs	Network Storage Costs	US Dollar	0	$90
Azure Processing Costs	Network Processing Costs	US Dollar	0	$950

The detailed description of each cost element follows.

Data Analyst Labor - number of labor hours spent by the data analyst in support of this demonstration.

Data QC Labor - number of labor hours spent by the QC geophysicist in support of this demonstration.

QA Labor - number of labor hours spent by the governments' QA geophysicist in support of this demonstration.

Regulator Labor - number of labor hours required by the governments' oversight regulator in support of this demonstration.

Azure Storage Costs - costs associated with provisioning and storing the data on Microsoft's Azure Cloud. The reported costs represent raw costs billed to AcornSI by Microsoft Azure during the three-month demonstration.

Azure Processing Costs - costs associated with numerical computations and data processing using Microsoft's Azure Cloud. The reported costs represent raw costs billed to AcornSI by Microsoft Azure during the three-month demonstration.

9.0 SCHEDULE OF ACTIVITIES

The demonstration was executed during the early months of 2022.

Phase	**CY 2022**				
	January	**February**	**March**	**April**	**May**
1. Project provisioning	■				
2. Generation of data	■				
3. Distribution of data and user training	■				
4. Data QC and analysis		■	■		
5. QA geophysicist review			■	■	■
6. Regulator review				■	■
7. Assessment and documentation					■

10.0 MANAGEMENT AND STAFFING

Dean Keiswetter and Tom Furuya, AcornSI, planned and managed this demonstration. Their oversight included provisioning the software in Microsoft Azure, providing technical support and training to third party analysts and government participants as required, assembling the qualitative responses, and writing the report.

Alison Paski, NAEVA, was the data analyst. At the time of the demonstration, she was an experienced data analyst with UX-Analyze desktop (Oasis montaj), but only vaguely familiar with UX-Classify. As a result, her experience and learning curve are representative of other industry data analysts. She received the data from the government and proceeded to process the data using only the tools in UX-Classify.

Cora Blits, NAEVA, was the QC Geophysicist. At the time of the demonstration, she was an experienced data analyst with UX-Analyze desktop (Oasis montaj), but only vaguely familiar with UX-Classify so her experience and learning curve were representative of other industry data analysts. Once the data were loaded into the Cloud project, she performed all QC functions as required by the AGC QAPP.

John Jackson, EDQW, served as the QA Geophysicist. At the time of the demonstration, he was an experienced data analyst with UX-Analyze desktop (Oasis montaj), but only vaguely familiar with UX-Classify. In addition to performing the QA functions as dictated in the AGC QAPP, he used DoD's UX-Simulator to generate MM2x2 data and score the final product.

Jeff Swanson, State of Colorado, served as the Regulator. Jeff is an experienced regulator, including projects that include AGC, and fully versed in the AGC QAPP requirements. He is also aware of the inherent limitations and restrictions of the networked PC solutions and current-day technologies. As such, he was uniquely positioned to evaluate the considerable capabilities and structure embodied within UX-Classify.

11.0 REFERENCES

DENIX, https://www.denix.osd.mil/mmrp/advanced-geophysical-classification-accreditation-and-other-tools/

Department of Defense Quality System Requirements for Advanced Geophysical Classification (DoD SR), Version 2.0, December 2018.

EM 200-1-15, Environmental Quality Technical Guidance for Military Munitions Response Actions, October 30, 2018.

Uniform Federal Policy for Quality Assurance Project Plans, Munitions Response QAPP Toolkit, Module 1, December 2018.

APPENDIX A HEALTH AND SAFETY PLAN

This demonstration is a software assessment and evaluation effort. All work will be in local offices setting. There is not travel or data acquisition planned. As such, no Health and Safety Plan is required.

APPENDIX B POINTS OF CONTACT

POINT OF CONTACT Name	ORGANIZATION Address	Phone Fax E-mail	Role in Project
Dean Keiswetter	AcornSI	919-454-4774 dkeiswetter@acornsi.com	PI
Tom Furuya	AcornSI	919-539-8098 tfuruya@acornsi.com	CO-PI, UX-Classify
Alison Paski	NAEVA	434-978-3187 apaski@naevageophysics.com	Data Analyst
Cora Blits	NAEVA	434-978-3187 cblitx@naevageophysics.com	QC Geophysicist
John Jackson	EDQW	916-557-6614 john.m.jackson@usace.arm.mil	QA Geophysicist Data Generator
Jeff Swanson	State of Colorado	720-988-3859 Jeffrey.swanson@state.co.us	Regulator

APPENDIX C DYNAMIC PROCESSING FLOW DESIGN: TASK REPORT

SUMMARY

In partial support to MR 201713, the focus of this task was to design a data processing scheme for dynamic EMI data that leverage the unique capabilities of UX-Classify.

TECHNOLOGY DESCRIPTION

The work detailed in this report advanced the usefulness of the UX-Classify algorithm by designing a workflow for processing AGC EMI data collected while the sensor was in motion across the site (viz., dynamic mode).

UX-Classify is an EMI data classification software suite designed to facilitate transparent program flow, efficient processing, and excellent classification results. It leverages classification technology and lessons learned from the UX-Analyze desktop routines that are embedded into Seequent's Oasis montaj and were developed for networked personal computers.

Unlike UX-Analyze Desktop, that uses Oasis montaj libraries, databases, and views, the UX-Classify software was developed from scratch. It does not rely on any third party, high-level libraries. UX-Classify leverages Microsoft's Azure, which is a cloud computing service created by Microsoft for building, testing, deploying, and managing applications and services through Microsoft-managed data centers.

The top-level graphical user interface (GUI) of UX-Classify is shown in Figure 16. The menus at the top of the figure provide all the tools required to read, check quality metrics, process, and analyze EMI data. The application is accessed via a web browser (Figure 17) and utilizes Microsoft Azure authentication tools for user security and login.

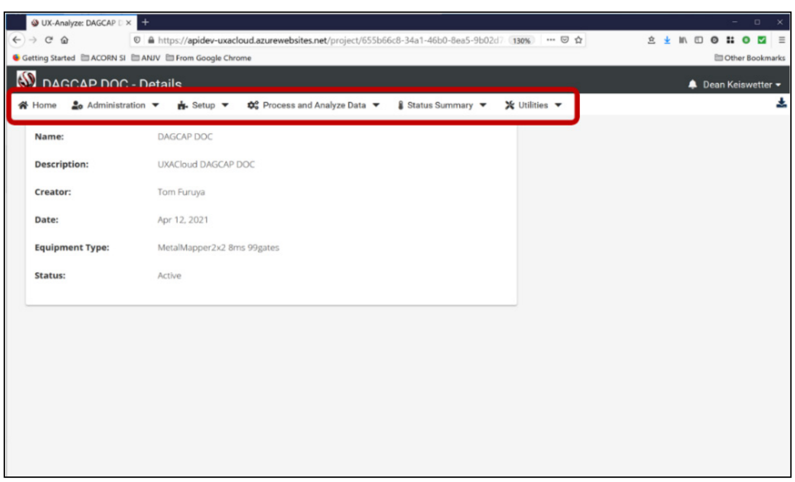


Figure 16. Screen Snapshot of the UX-Classify (Cued) Top Level Page.

All technical tasks are bundled within the six menus inside the red box; Administration, Setup, Process and Analyze Data, Status Summary, and Utilities. These top-level menus remain unchanged after designing the Dynamic workflow.

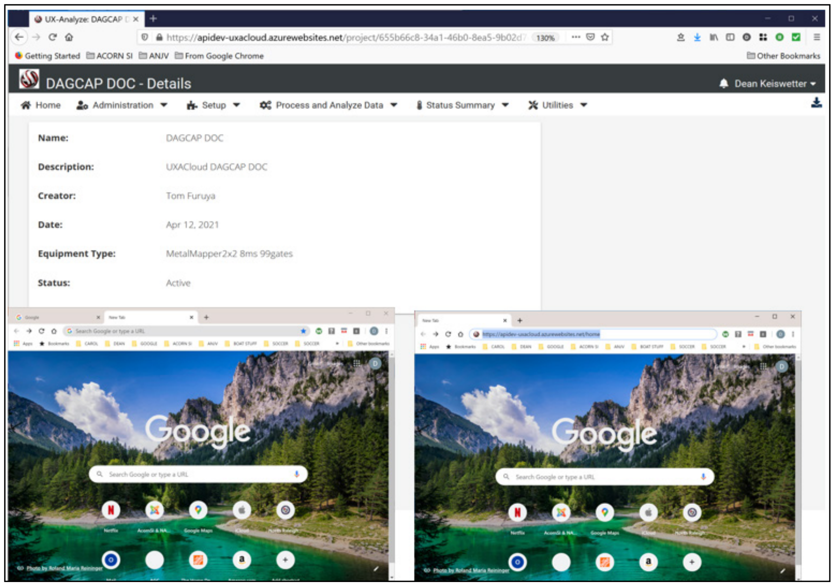


Figure 17. UX-Classify Is an Online Application that Leverages Microsoft Azure Security Measures and Authentication Protocols.

Local computer security compliance issues are mitigated because no software is installed locally.

The UX-Classify software was validated for processing cued data by EDQW during April of 2021. After notifying DAGCAP that UX-Classify was ready for a technical assessment, DAGCAP personnel generated a MM2x2 data set using UX-Simulator. It was a blind test in that the analysts were not aware of the number or type of munitions or the number and/or size of clutter objects. In addition to the complete dynamic data, the analysts received a full suite of QC data, including (1) instrument verification strip data, (2) background measurements (repeated), (3) background reconnaissance data, and (4) sensor function tests. The data were processed using the standard processing flow embedded into UX-Classify. Results of the DAGCAP assessment were positive and UX-Classify v1.0 passed DAGCAP's technical assessment (Figure 18).

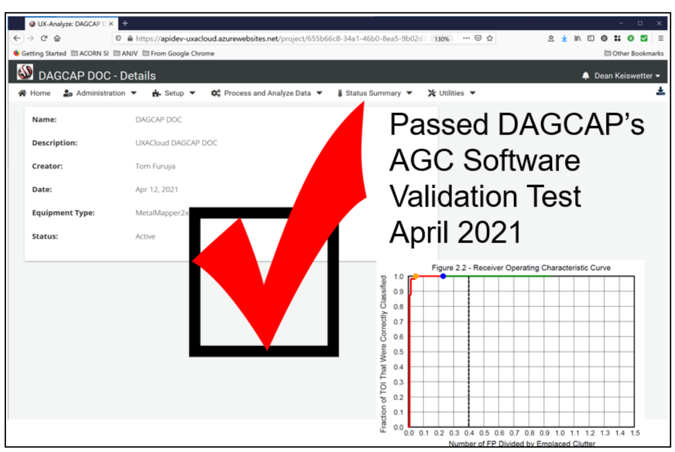


Figure 18. UX-Classify Passed the DAGCAP Validation Test with Flying Colors in April 2021 and Was Shown, As Part of the Validation Effort, to Produce Polarizations and Decisions Identical to UX-Analyze Desktop that Is Embedded into Oasis Montaj.

The focus of this work is to enhance UX-Classify by designing a dynamic workflow that leverages as much of the cued application as possible and maintains the inherent advantages of working in the Cloud.

The design resulted in changes to two of the six high level menus (Figure 19). Additional details of the specific changes are described at a submenu level in Section 2.2 Development.

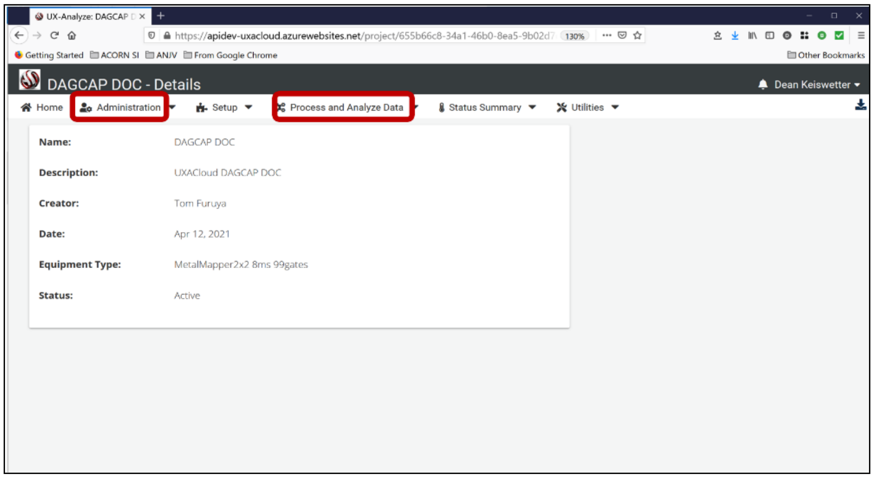


Figure 19. Screen Snapshot of UX-Classify – Desktop.

All functionality is accessed via the Home, Administration, Setup, Process and Analyze Data, Status Summary, and Utility menus. To accommodate dynamic data, modifications were designed for the Administration and Process and Analyze Data menus.

DEVELOPMENT

a) Administration Menu: The Administration menu is used to establish key aspects of the work environment. Two of the four submenus required changes (Figure 20, Figure 21, Figure 22).

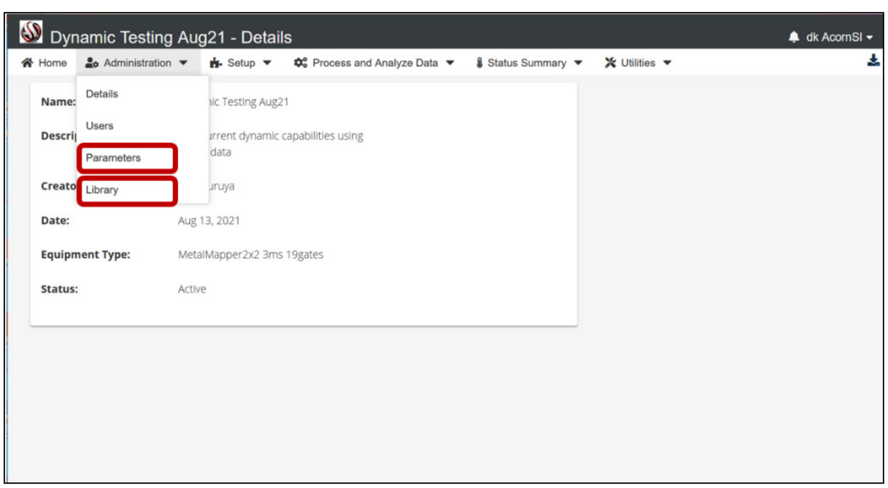


Figure 20. Administration Menu: To Accommodate Dynamic Data, the Parameters and Library Submenus Required Modification.

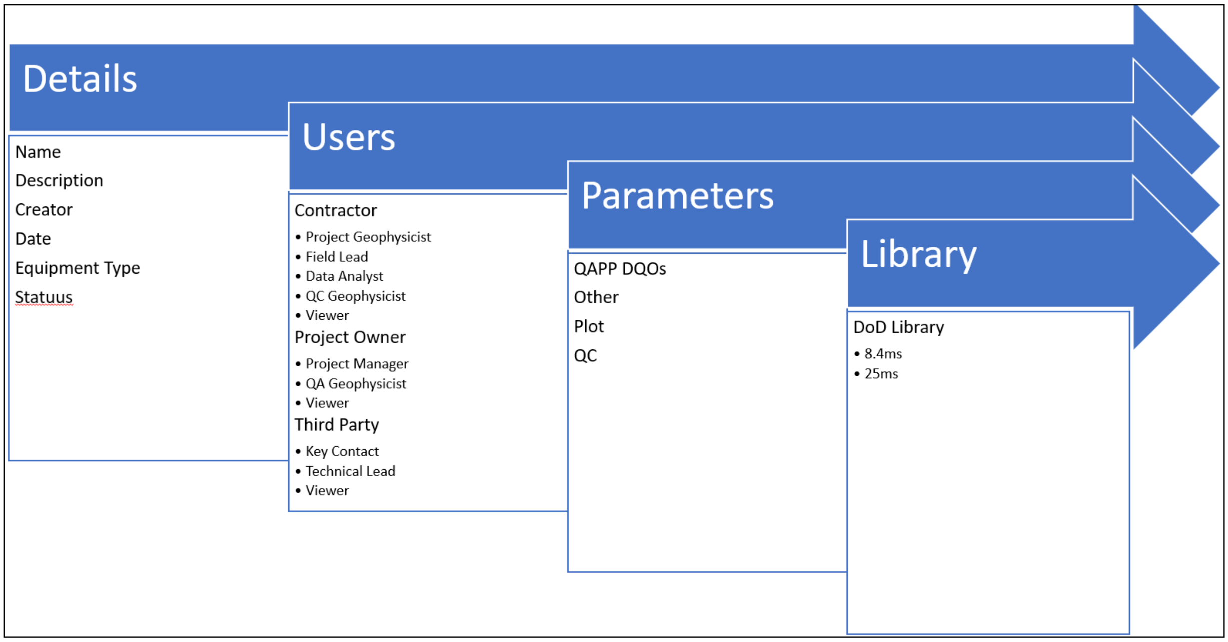


Figure 21. Administration Menu: UX-Classify (Cued) Submenus and Major Functions.

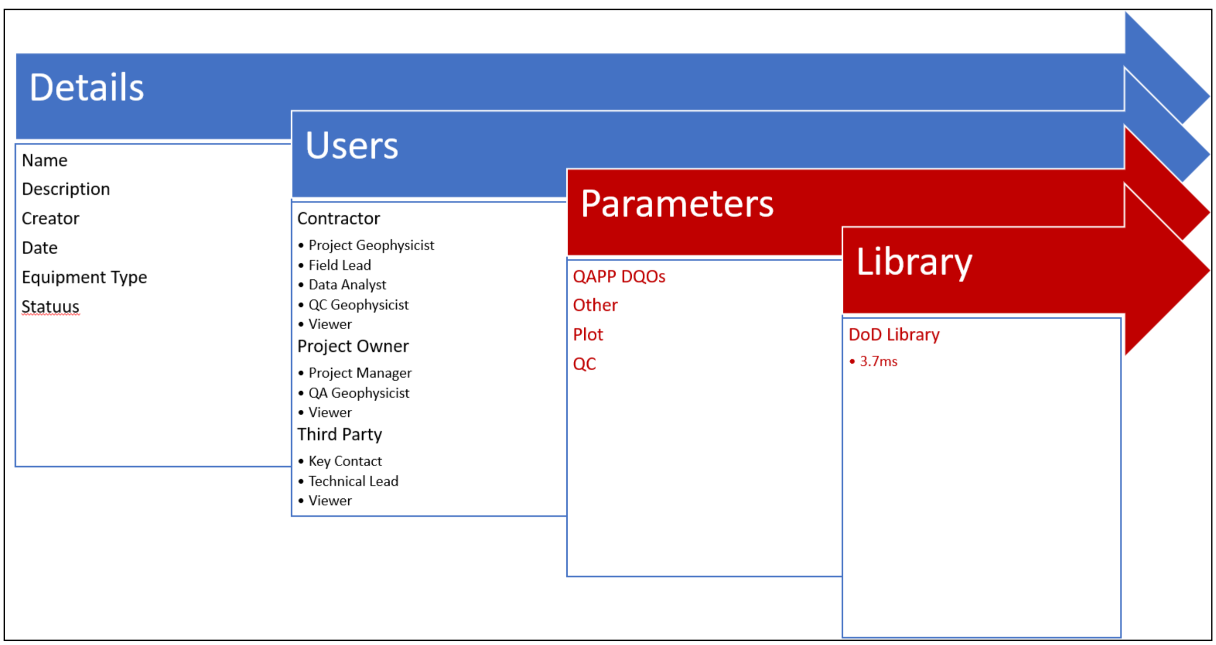


Figure 22. Administration Menu: UX-Classify (Dynamic) Submenus and Major Functions.

The submenus in red identify modified behavior.

The Details submenu presents high level project information and has not user input or interaction. The users tab lists all users and defines their role. User roles include Contractor, Contractor QC, Project Owner (USACE or the client providing funding), and the Special Interest Group (viz., State Regulators or ancillary third-party oversight). These two submenus are unchanged by the dynamic workflow.

The Parameters submenu is used to store project specific information, metrics, and thresholds related to processing parameters, plotting settings, or QC evaluations. The QAPP portion of this tool leverages the language and values established by the AGC QAPP as detailed in Worksheet 22. This section required updating for dynamic parameters (Figure 23).

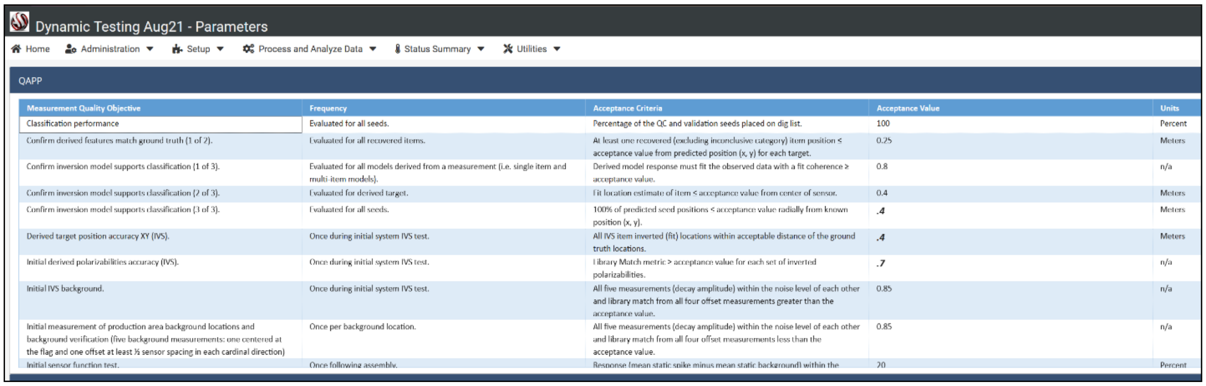


Figure 23. Screen Print Showing Some of the Parameters for Dynamic Processing.

This section was updated to comply with all the values and settings described in AGC-QAPP Worksheet 22.

The Library submenu provides access to the DoD's TOI Signature Library and was included in the upgrade design. In this case, the upgrade required is not related to functionality of the tool, but rather the information that the tool stores (Figure 24). Because dynamic data are acquired while the sensor is moving, the transmit pulse must be shorter than that used for cued collections to minimize down track smearing.

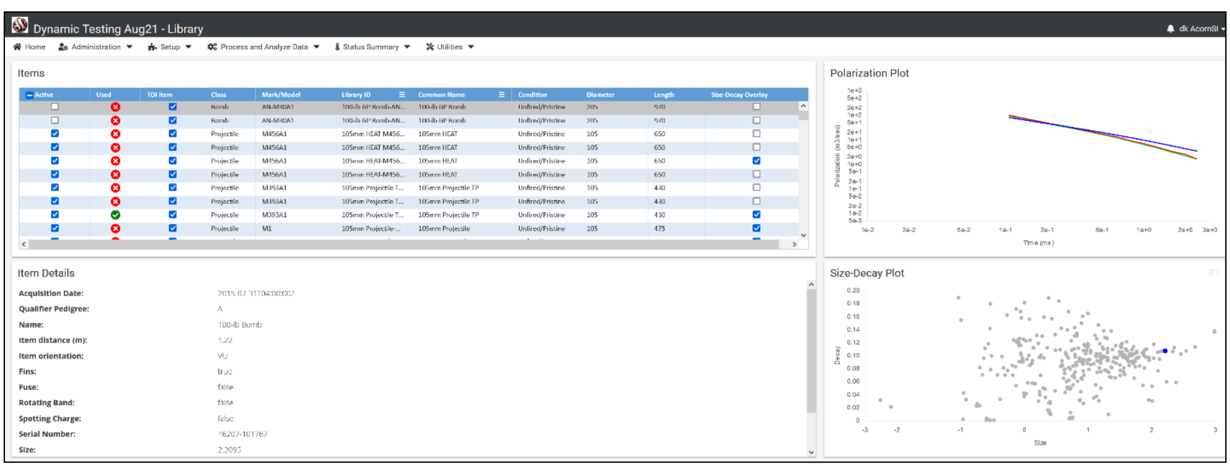


Figure 24. Screen Display for the 3.0 Millisecond EMI Library that Was Required to Process Dynamic Data.

b) **Process and Analyze Data menu:** The Process and Analyze menu represents the heart of the data processing scheme. All the technical tasks related to data preparation, background subtraction, inversion, classification, and documentation are housed within this menu. As such, this is where most of the design focused. Three of the ten submenus required changes (Figure 25, Figure 26, Figure 27).

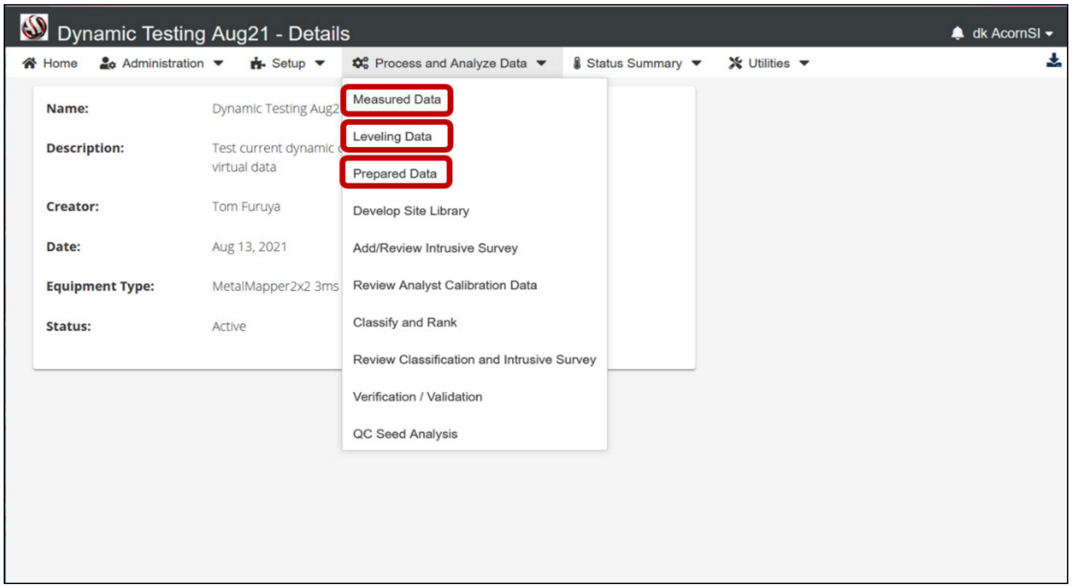


Figure 25. Process and Analyze Menu: To Accommodate Dynamic Data, the Measured Data, Leveling Data, and Prepared Data Submenu Required Modification.

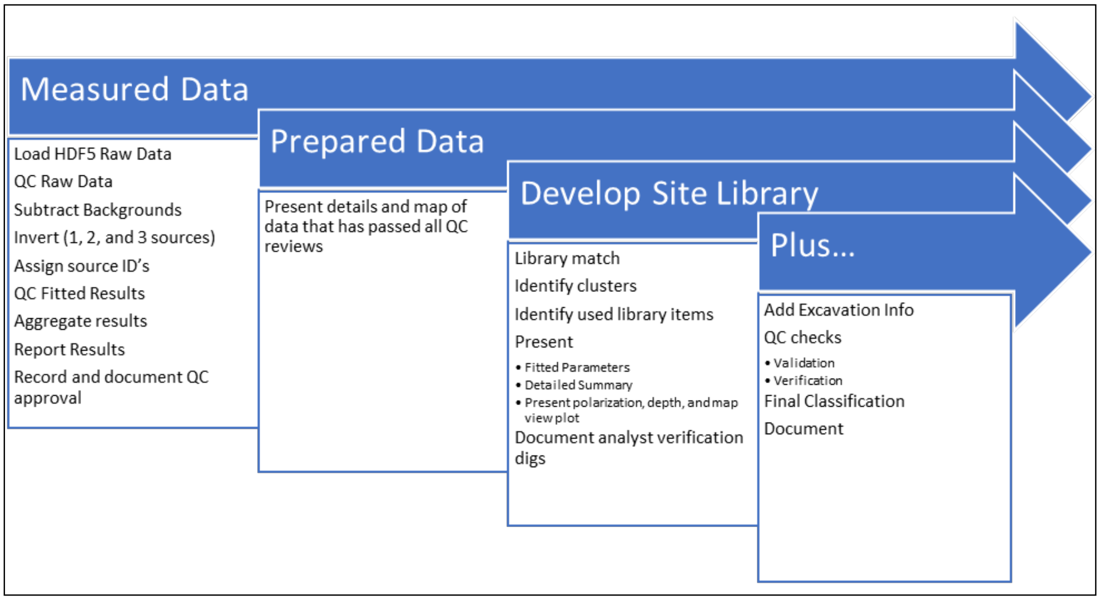


Figure 26. Process and Analyze Menu: UX-Classify (Cued) Submenus and Major Functions.

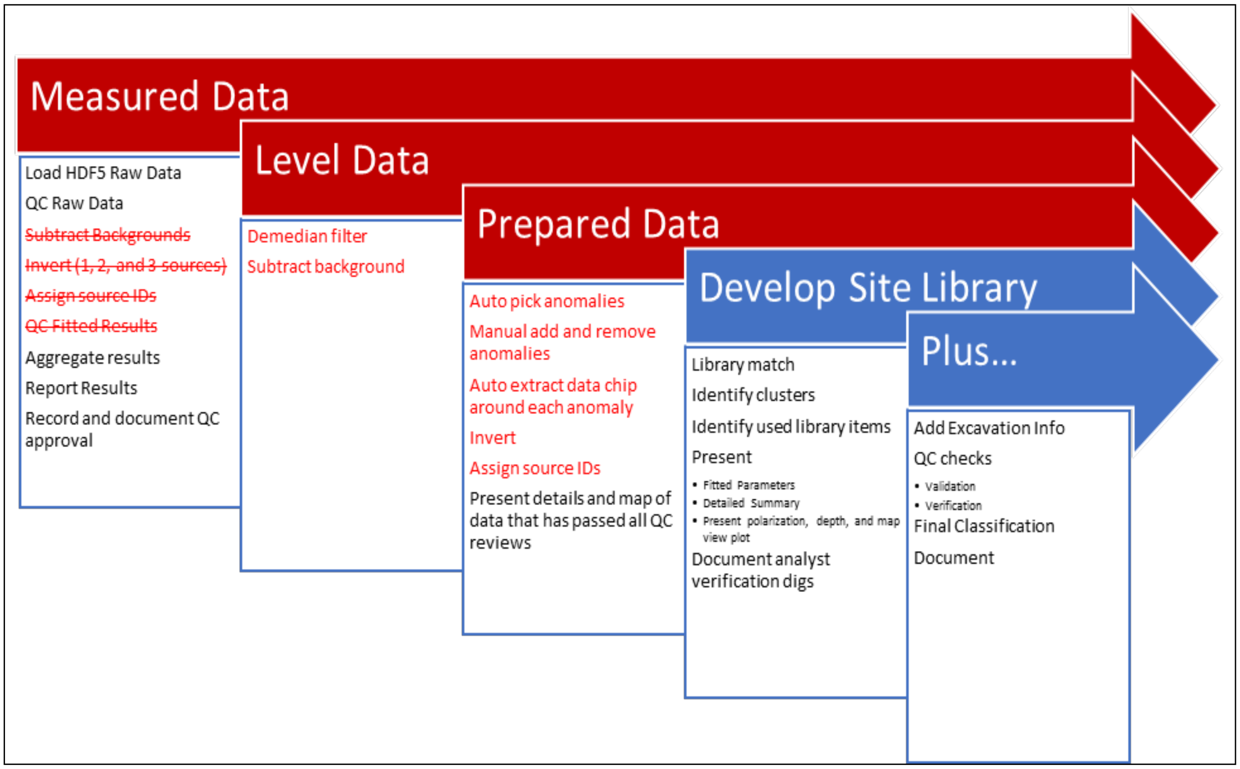


Figure 27. Process and Analyze Menu: Setup Menu: UX-Classify (Dynamic) Submenus and Major Functions.

The submenus in red identify modified behavior. Functions in ~~strikeout~~ format were removed, otherwise the capability was added.

The Measured Data submenu provides the means to upload HDF5-formatted data, performs QC checks on the incoming data streams and stores the data on a temporal basis (Figure 28, Figure 29). It also provides the means for the QC geophysicist to manually evaluate data completeness and quality and stores the assessment result. If the data pass the manual QC, they are allowed to be processed by downstream functions. If the data do not pass the manual QC, they are quarantined and not allowed to be further processed. Like the cued application, the Measured Data provides summary statistics regarding the number and type of data collected each day. A site map was added to this GUI, along with a satellite image underlayment.

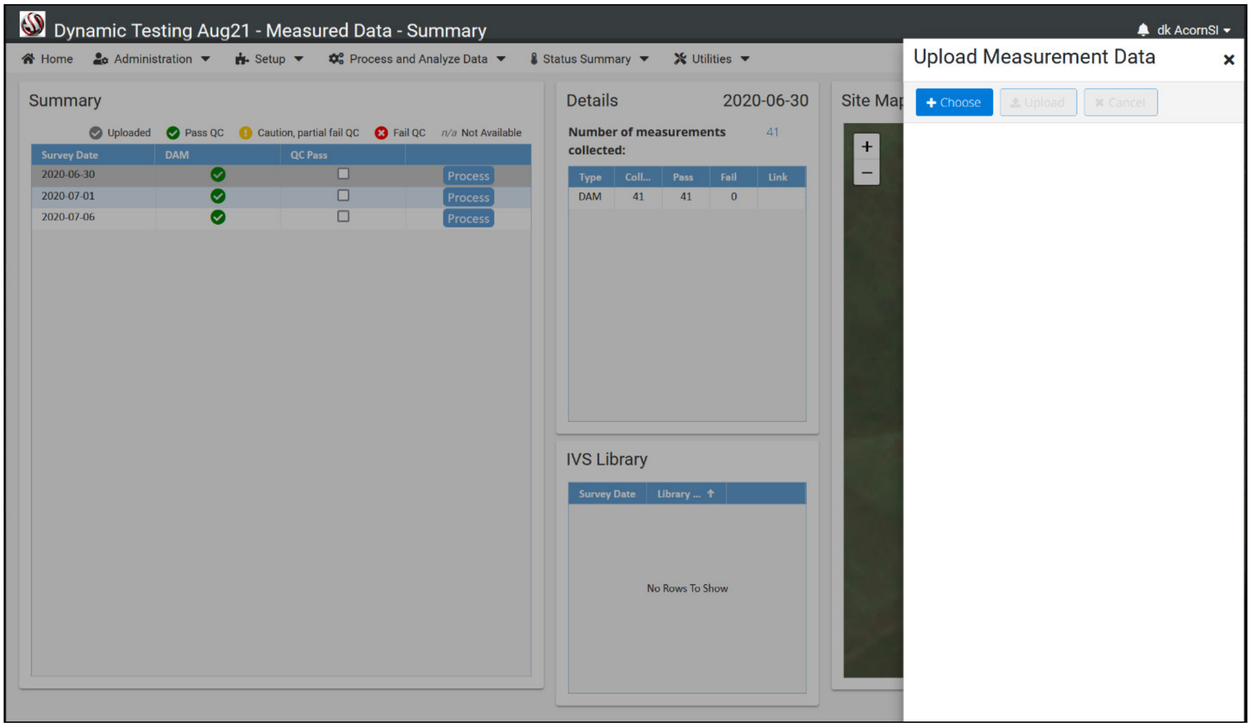


Figure 28. Measured Data GUI Showing the Tool Designed to Select User-specified Files on their Local Machine for Uploading to the Cloud Environment.

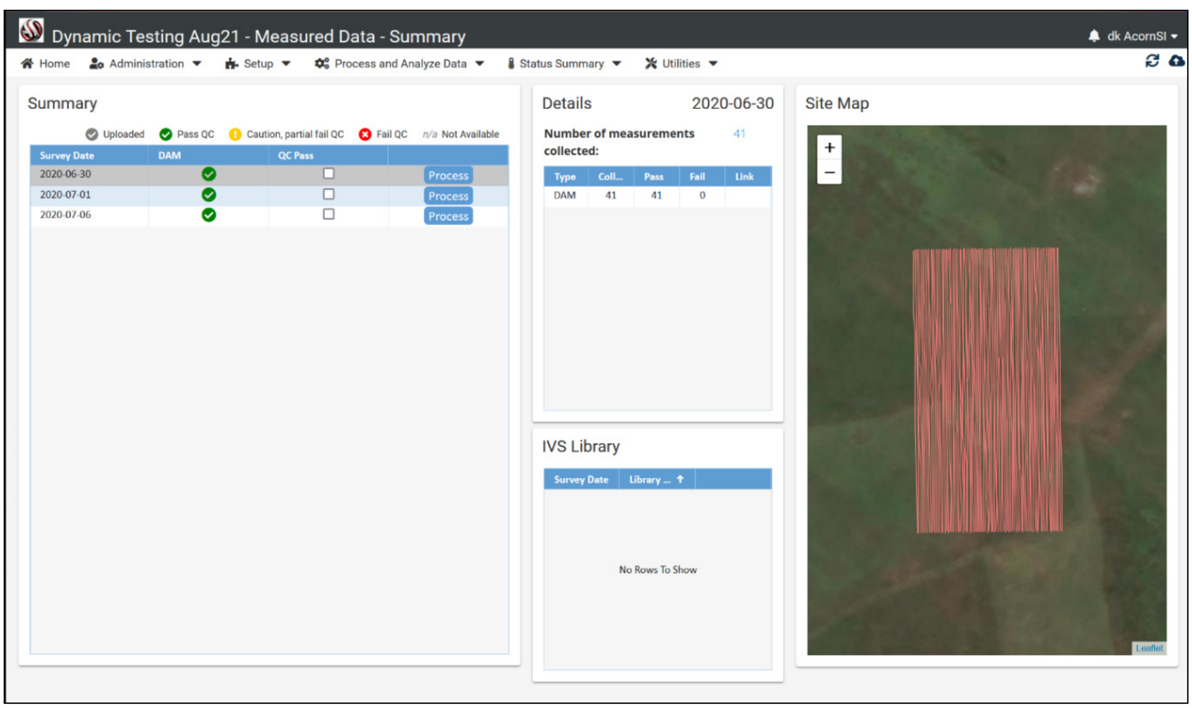


Figure 29. Screen Snapshot of the Measured Data GUI.

This page displays all data uploaded to the system and provides the means to evaluate sensor data quality, record the action of the QC geophysicist, and display data spatially.

Downstream functions were also designed to allow users to list individual data files acquired each day with the intent of downloading or deleting specific files (Figure 30, Figure 31).

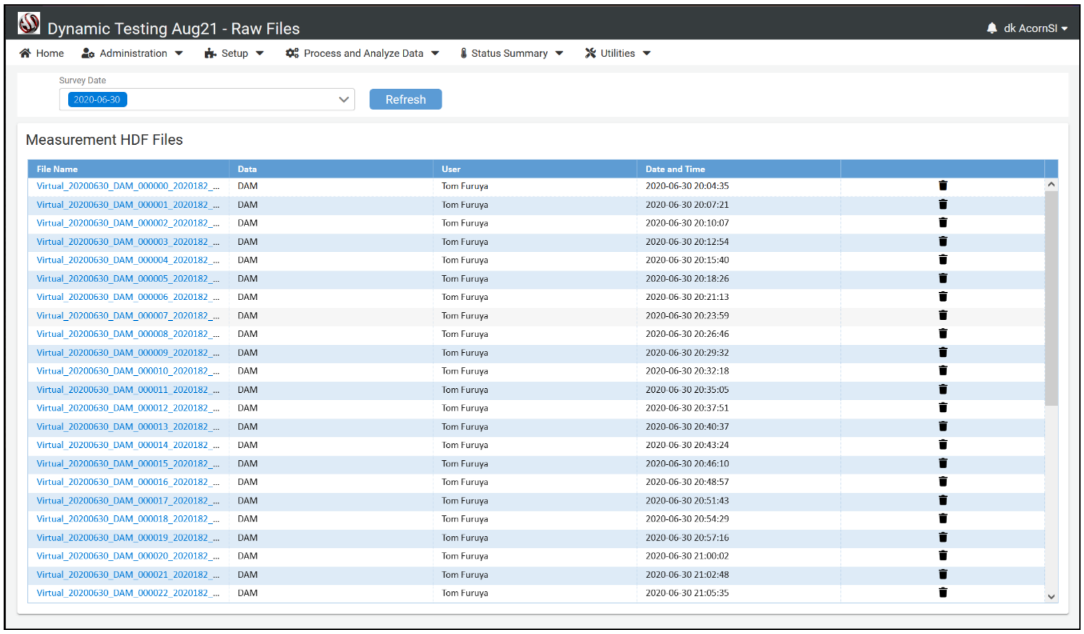


Figure 30. A List of All Data Collected for a Given Day Is Easily Created from the Measured Data GUI.

Individual files can be deleted by clicking on the trash symbol.

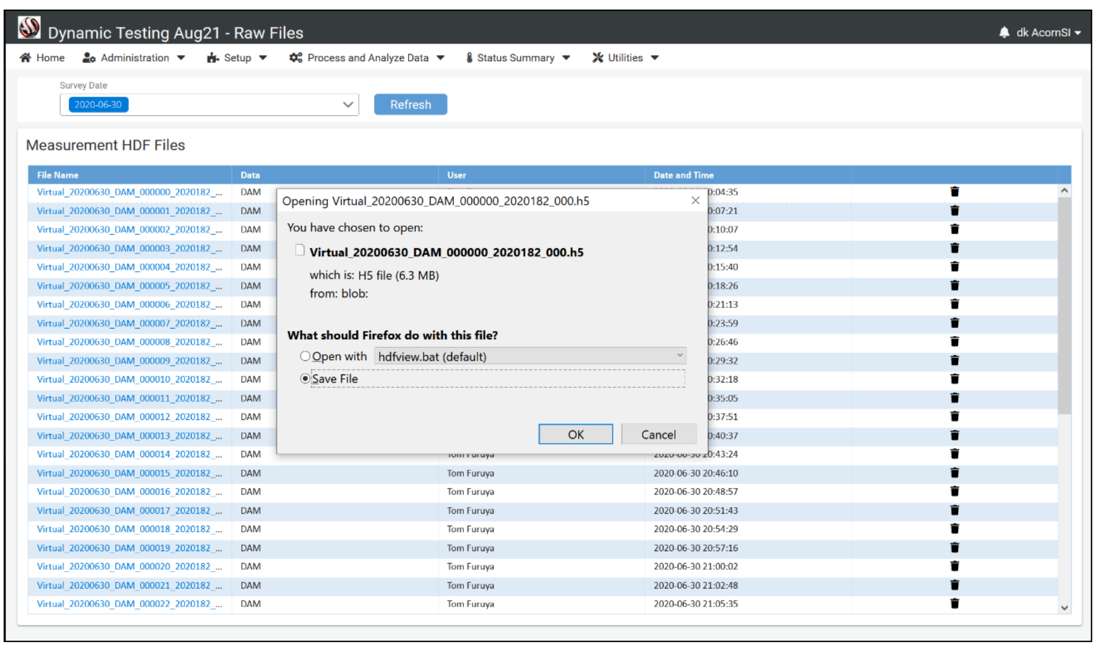


Figure 31. A List of All Data Collected for a Given Day Is Easily Created from the Measured Data GUI.

Individual files can be opened by clicking on the filename.

The Leveling Dynamic Data submenu provides the means to remove background signals and accentuate anomaly signatures by utilizing a demedian filter. Users first select data they want to include in the processing run (Figure 32) and set the filter parameter (Figure 33).

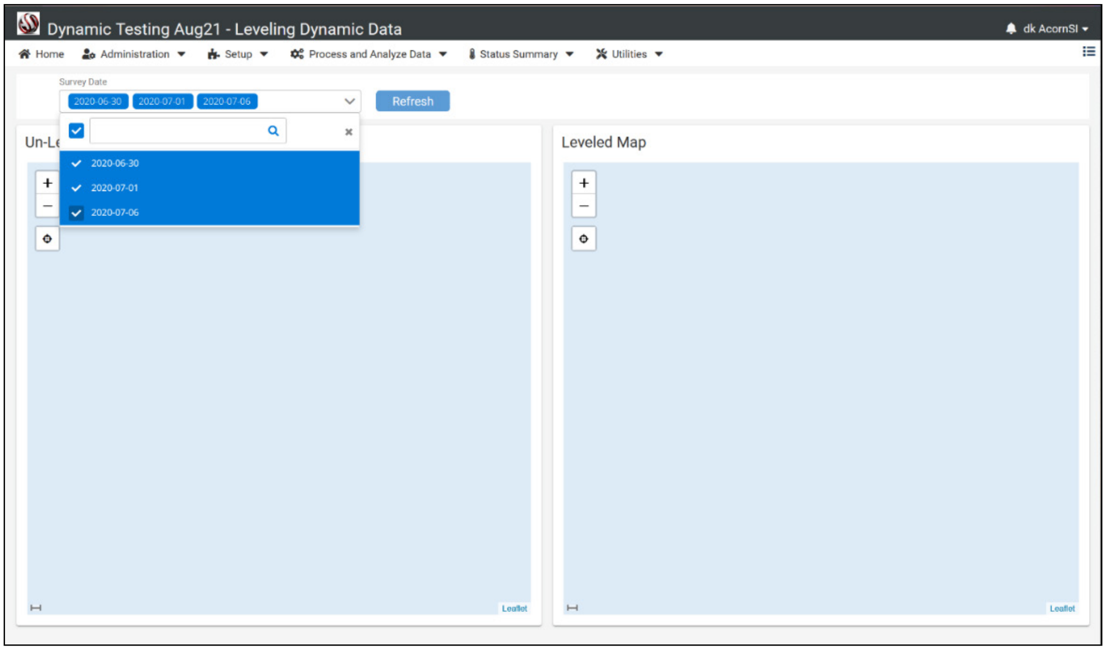


Figure 32. Leveling Dynamic Data GUI: The User Selects Data for Processing by Selecting the Day the Data Was Acquired.

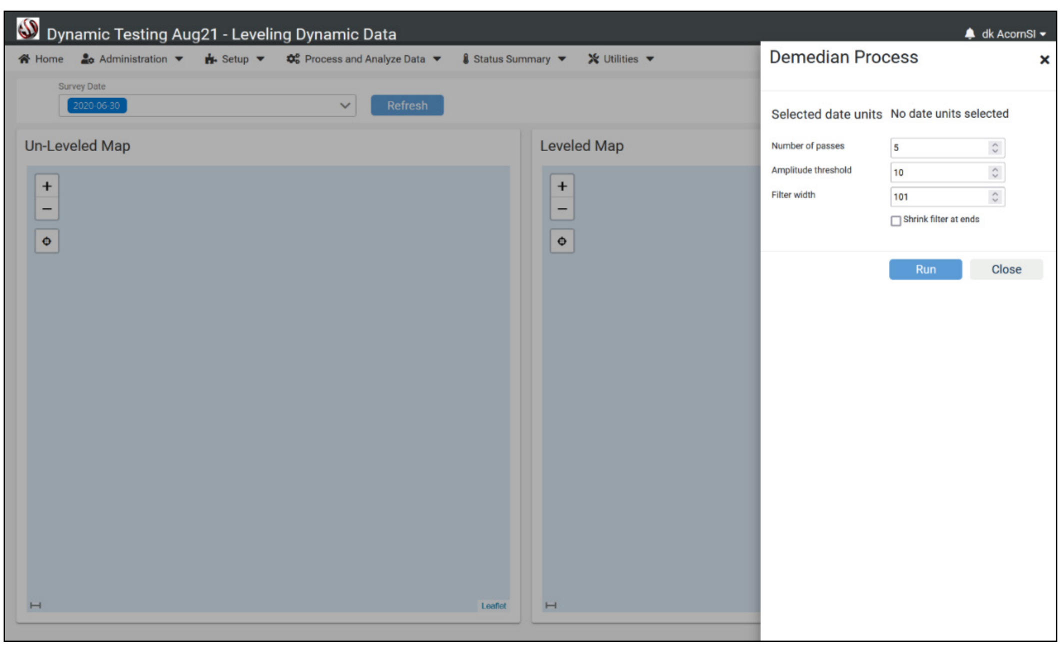


Figure 33. Parameters for the Demedian Filter Are Exposed by Hitting the Icon in the Upper Right-hand Corner of the Leveling Dynamic Data Menu.

Upon submittal, the GUI display the data before (left) and after (right) application of the filter so that the analyst can evaluate and change filter parameters if desired (Figure 34).

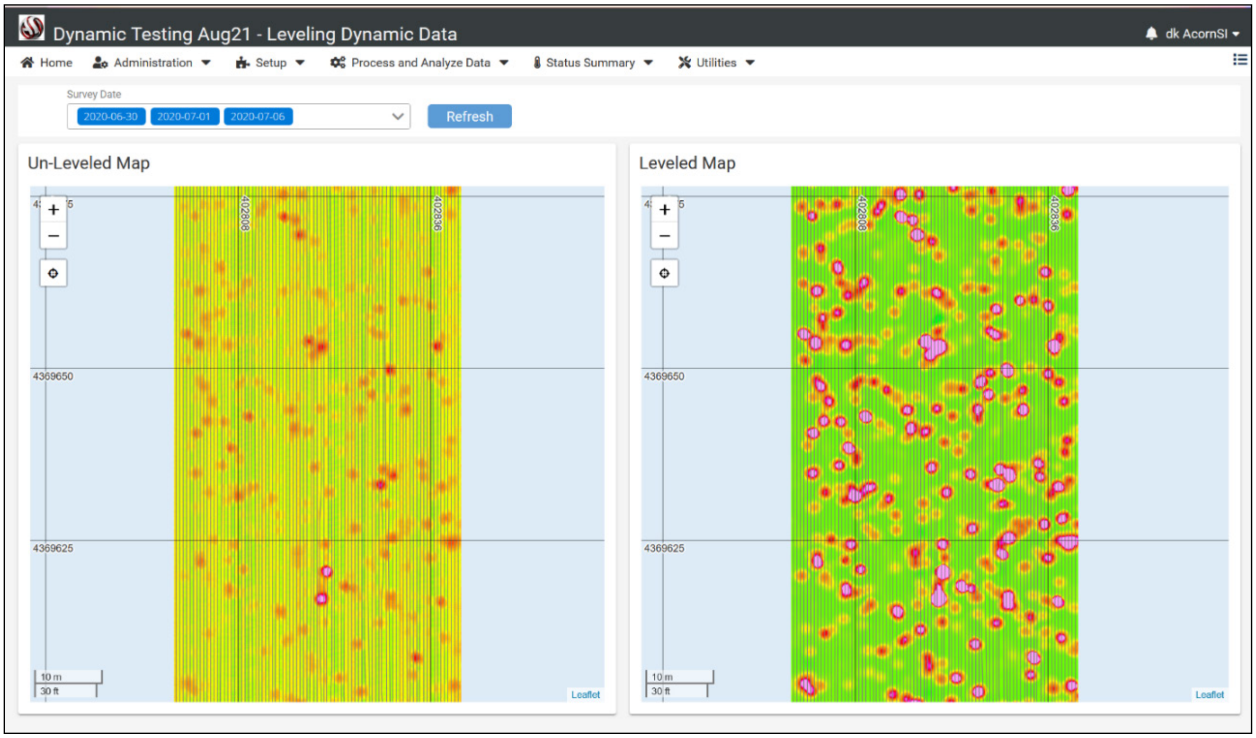


Figure 34. Leveling Data GUI: Before (Left) and After (Right) Application of a Demedian Filter.

The Prepared Data submenu was heavily modified (Figure 27) to include additional functionality necessary for dynamic data processing. The new functionality includes:

a. auto-picking anomalies,

b. manual edits (add and remove) to selected anomalies,

c. auto extract data chips around anomalies and store in an easily accessible structure,

d. 1-, 2-, and 3-source data inversions,

e. assignment of source ID’s,

f. storage of polarizations, and

g. graphical layout changes to accommodate visualization of data (Figure 35).

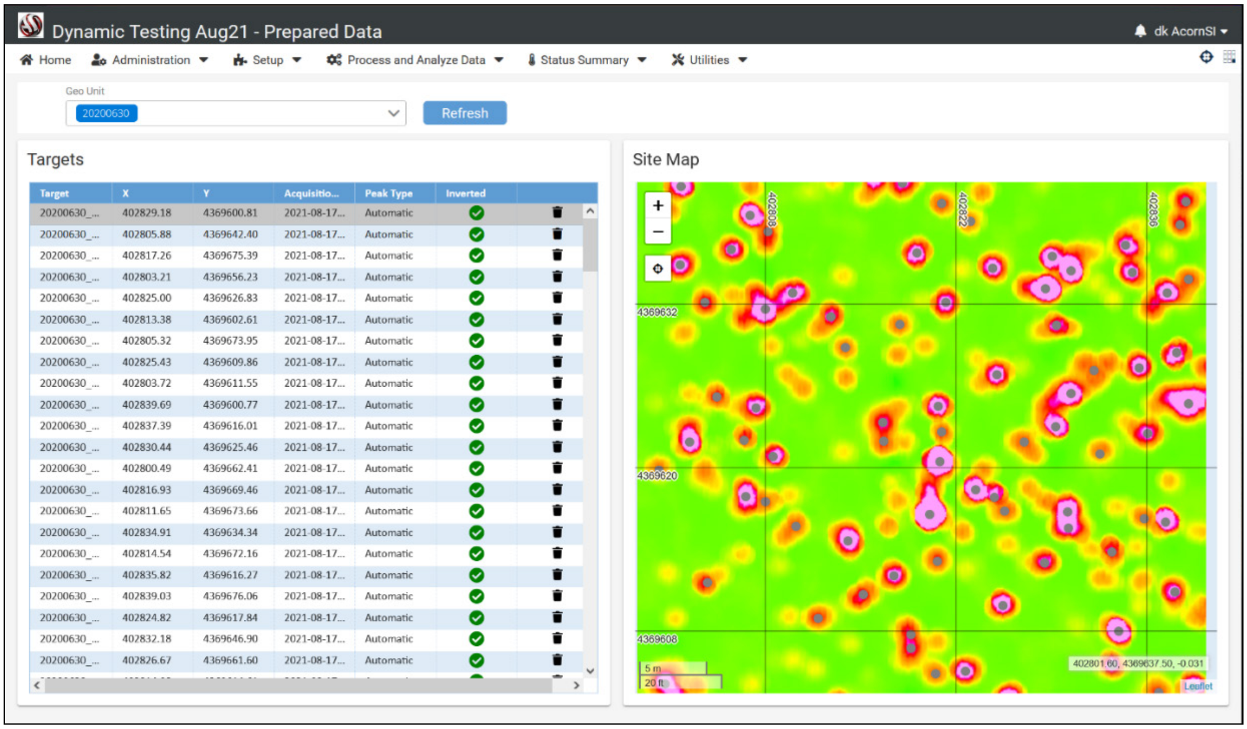


Figure 35. The Design of the Prepared Data GUI Was Heavily Modified to Include Automatic Anomaly Detection, Manual Anomaly Edits (Add and Delete), and 1-, 2-, and 3-Source Inversions.

Figure 36 and Figure 37 show screen images of the Prepared Data GUI that highlight the auto pick anomaly tool and the icon that runs inversions. Individual anomalies can be deleted by clicking on the appropriate trash can or added by holding down the Ctrl key while clicking on the map.

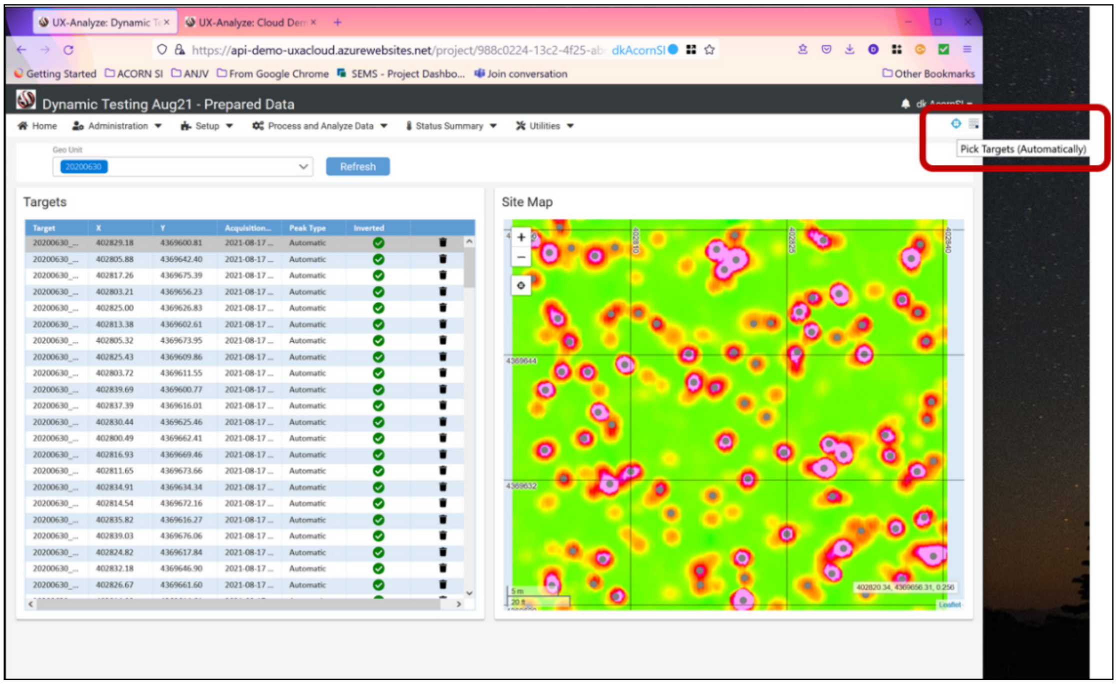


Figure 36. Prepared Data GUI Highlighting the Auto Pick Tool (Red).

Anomaly detections are manually added by holding down control key while clicking on the map and deleted by clicking on trash icon.

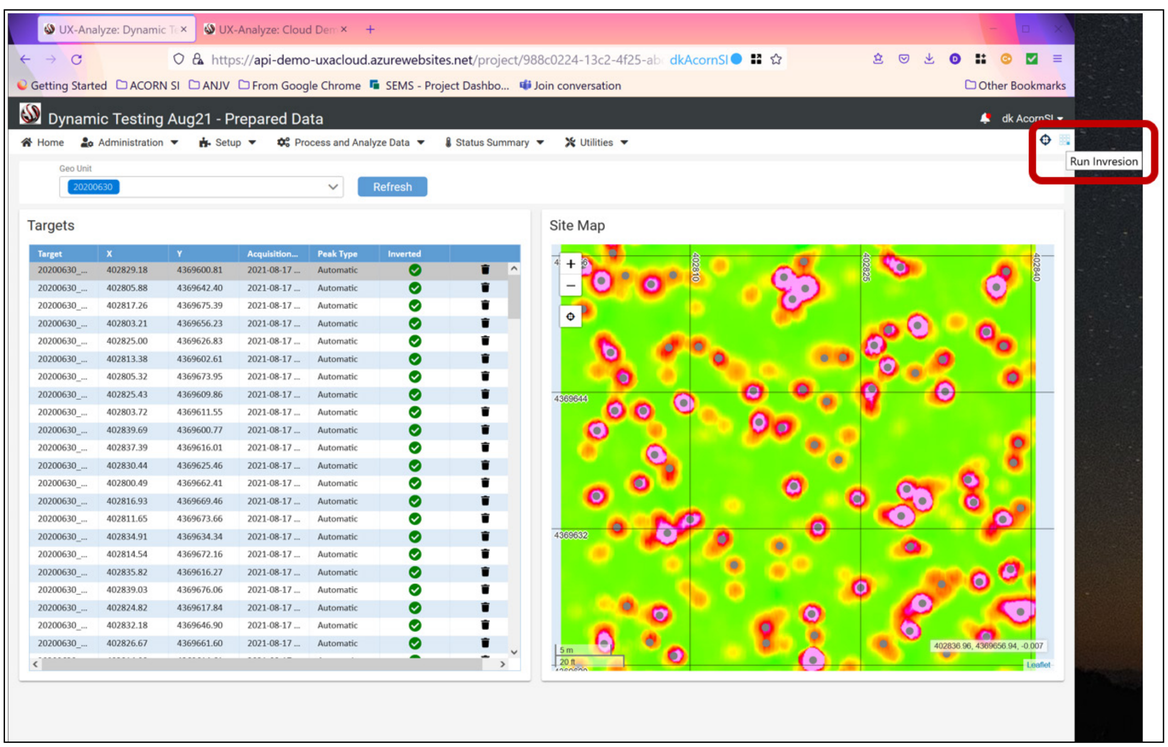


Figure 37. Prepared Data GUI Highlighting the Inversion Icon (Red).

Once polarizations are derived, the processing flow is like that used for cued data. The principal difference is the signature library utilized for classification purposes.

The Develop Site Library, shown in Figure 38, presents all information required to evaluate sources, look for clusters, and confirm that the site-specific library is suitable for the data set being processed.

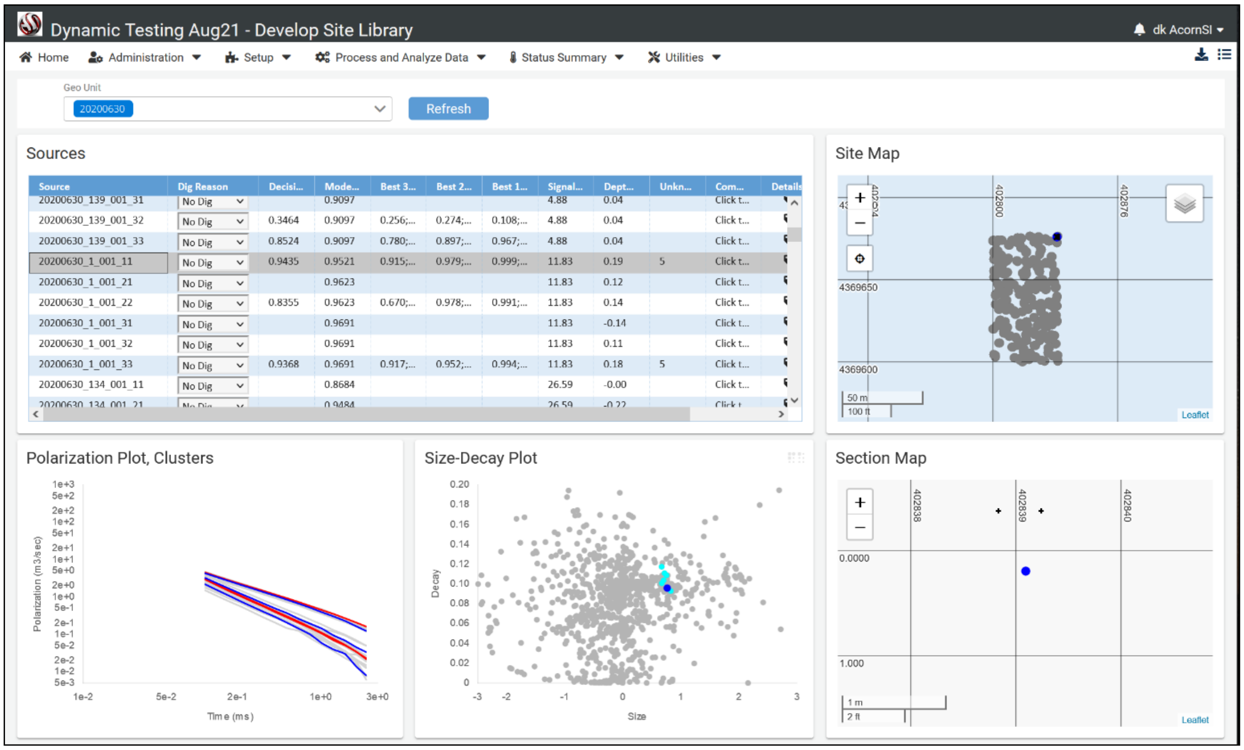


Figure 38. Develop Site Library: Once Leveled and Culled, Dynamic Data for Each Anomaly Are Inverted and Classified Using the TOI Library Discussed Earlier.

In addition to building structure to capture the reasons for follow-up, the GUI provides the means to download the complete dig list (Figure 39) or inspect individual polarization plots (Figure 40).

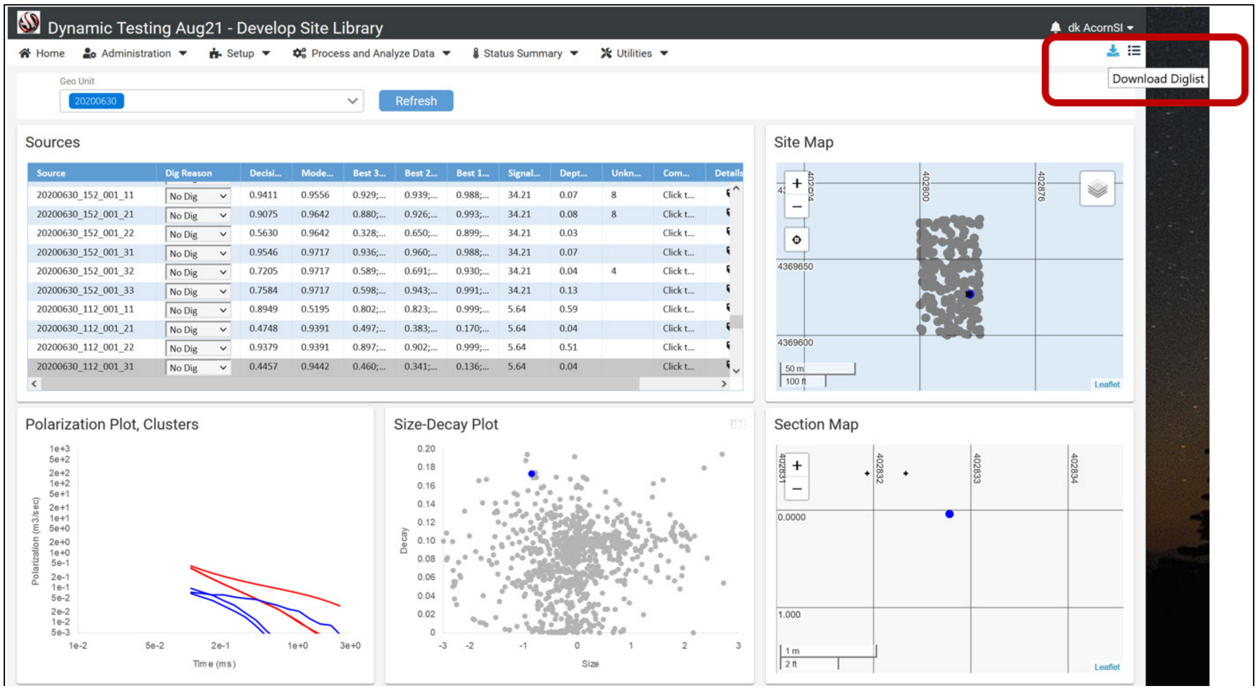


Figure 39. Develop Site Library Highlighting the Download dig List Icon (Red).

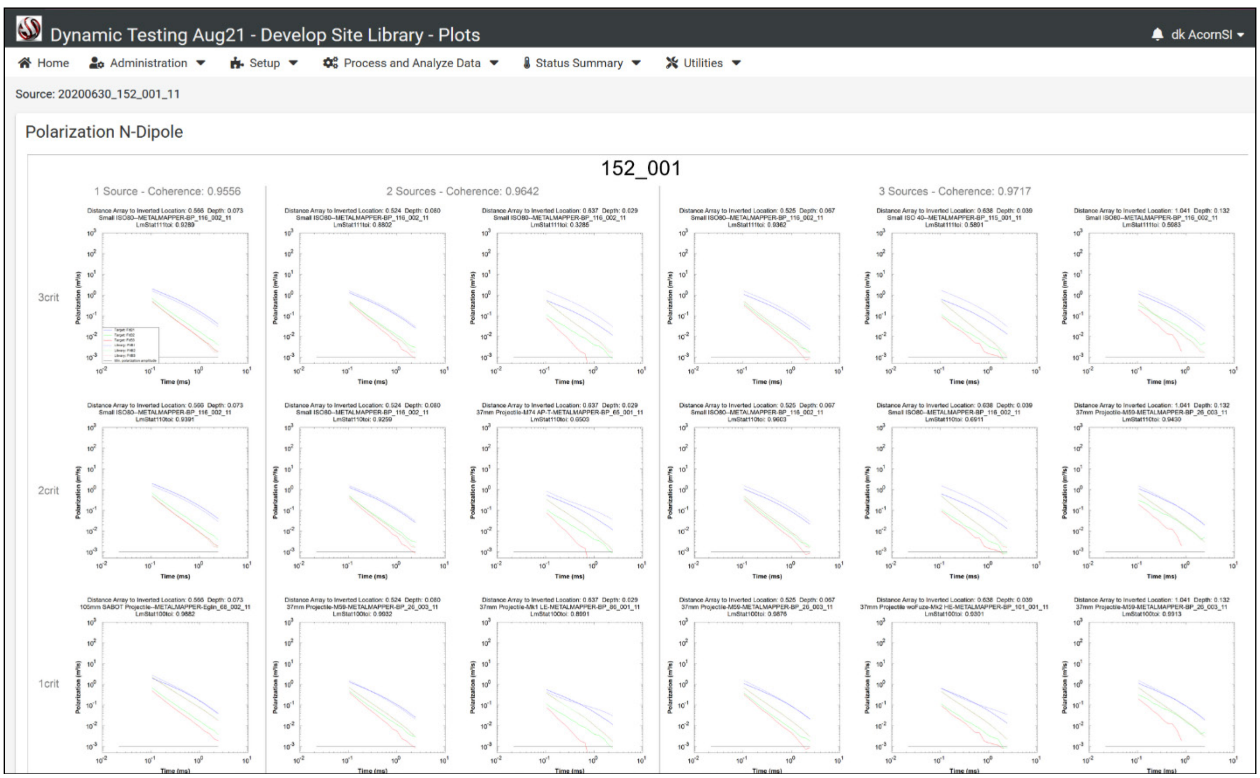


Figure 40. Example of 1-, 2-, and 3-source Polarizations with Library Matches that Were Derived from a Single Anomaly.

ADVANTAGES AND LIMITATIONS

The advantages of this technology are the result of a unique project management approach, strict adherence to the AGC QAPP, and the revolutionary achievements of Cloud technology. Specific advantages include:

1) No local software installations required
2) Institutionalized QC measures
3) Systematic firewalls
4) Robust and user-friendly monitoring of project activities
5) Transparent and efficient data transfer
6) Solution for the entire project delivery team

A limitation of this technology is that it requires an active internet connection.

Alternate technologies are software solutions designed for networked PC. Table 1 compares the two technologies for key attributes.

Table 6. Comparison of Key Attributes for PC- and Cloud-based AGC Processing Schemes.

Attribute	PC Based	Cloud Based
Security	compartmentalized	uniform
Communication	compartmentalized	transparent
Version control & activity logging	compartmentalized	automated
IT requirements	Local	Internet
Processing speed	Local and limited	On demand
Cost basis	Per system and infrastructure	Per use

DATA PRODUCTS

UX-Classify generates lots of information regarding anomaly lists, fitted location, polarization plots. The addition of dynamic data processing does not change or modify the standard plots.

One aspect that is new, however, is a result of the dynamic data processing itself. Dynamic data can either be inverted and classified or used to direct subsequent investigations. If the data are used to make classification decisions, the data product is a standard classification dig list (Figure 41). If the data do not support final classification, the anomaly or fitted locations is generated (Figure 42).

UXA_GEO_ID	UXA_FLAG_ID	UXA_TARGET_ID	UXA_FIT_X	UXA_FIT_Y	UXA_Fit_BGS	UXA_FIT_COH	UXA_SIG_AMPLITUDE	UXA_Decision_Statistic	UXA_Size_Predicted	UXA_UXOTYPE
20210512	2	20210512_2_001_22	402811.3985	4369632.426	0.420069707	0.999887672	11.75663238	0.999072698	Large	105mm Projectile-M84-TEM2X2X3-BP_22_001_11
20210512	19	20210512_19_001_11	402829.6966	4369652.449	0.203162718	0.999558624	10.93263743	0.998370756	Medium	60mm Mortar-M49A2-TEM2X2X3-BP_57_001_11
20210512	4	20210512_4_001_32	402814.3349	4369621.482	0.473465719	0.99977023	5.262508614	0.997569101	Large	105mm HEAT-M456A1-TEM2X2X3-BP_99_001_11
20210512	3	20210512_3_001_21	402834.4677	4369642.58	0.494971111	0.999761826	5.92723132	0.996877757	Large	105mm Projectile-M84-TEM2X2X3-BP_22_001_11
20210512	14	20210512_14_001_22	402821.8201	4369640.901	0.58131359	0.999176129	3.378859553	0.994626705	Large	105mm Projectile-M84-TEM2X2X3-BP_22_001_11
20210512	47	20210512_47_001_11	402831.4886	4369616.21	0.116254871	0.998487166	5.238773276	0.994187119	Small	Small ISO80--METALMAPPER-BP_107_003_11
20210512	24	20210512_24_001_21	402813.5518	4369614.513	0.284913272	0.999252477	4.396027354	0.993984414	Medium	60mm Mortar-M49A2-TEM2X2X3-BP_57_001_11
20210512	21	20210512_21_001_21	402809.1098	4369634.645	0.281949863	0.99954219	5.362388685	0.993788945	Medium	60mm Mortar-M720 HE-METALMAPPER-CL_10_001_11
20210512	10	20210512_10_001_11	402823.2018	4369618.279	0.254115315	0.999729286	9.414491569	0.993712024	Medium	60mm Mortar-M720 HE-METALMAPPER-CL_10_001_11
20210512	1	20210512_1_001_21	402807.2861	4369620.659	0.410976184	0.999921204	9.410654844	0.99320242	Large	105mm Projectile-M84-TEM2X2X3-BP_22_001_11
20210512	79	20210512_79_001_21	402809.7653	4369627.783	0.108537612	0.999459671	5.889507345	0.992618114	Small	Small ISO80--METALMAPPER-BP_107_003_11

Figure 41. Example Data Product for Classification Dig List.

Target ID:	Easting (U	Northing (	Cued
SW-1	438803.4	3743907	1
SW-2	438785.4	3743897	1
SW-3	438790.7	3743923	1
SW-4	438782.9	3743921	1
SW-5	438812	3743916	1
SW-6	438781.2	3743906	1
SW-7	438778.6	3743910	1
SW-8	438813.2	3743901	1
SW-9	438784.7	3743923	1
SW-10	438798.1	3743900	1

Figure 42. Example Data Product for Detection-only List for Further Action.

IMPLEMENTATION ISSUES

In compliance with this task, we designed a dynamic data processing flow that seamlessly integrates with, and leverages, the UX-Classify (cued) application. The high-level design was summarized during in-progress briefings in June 2020 and May 2021.

During the 2021 meeting, we indicated that due to the complexity of the workflow, the design included many options and variables. As a result, and in partnership with ESTCP, AcornSI has been contributing internal resources to incrementally implement the design so that subsequent plans could become evident. As a result of this collaboration, the basic framework has been implemented, as evident by the graphics presented in this report.

There are no known technical implementation issues that will prevent this technology from working.

APPENDIX D UX-SIMULATOR: TASK REPORT

SUMMARY

The UX-Simulator program described in this technical brief is designed to generate realistic EMI data for use in training and testing data analysts. It allows users to generate dynamic and static EMI data for performance testing and advanced analyst training.

The UX-Simulator program was named 'Virtual Site' during proposal and development stages.

The work detailed in this report advanced the usefulness of the UX-Simulator algorithm by building advanced failure modes that allow trainers and testers to evaluate analyst performance and quality-control measures more thoroughly.

TECHNOLOGY DESCRIPTION

The UX-Simulator program is a stand-alone software suite designed to generate MM2x2 data for testing and training of analysts. The program collects user preferences via a graphical user interface, stores that information into site configuration files that can be accessed later, adds appropriately colored noise, generates dynamic and cued EMI data collections, and scores the data analysts' classification decisions (Figure 43). Note that the data analyst processes the data and makes the classification decision using separate software. The UX-Simulator creates the EMI data and evaluates their decisions, it is not used to process and classify EMI data.

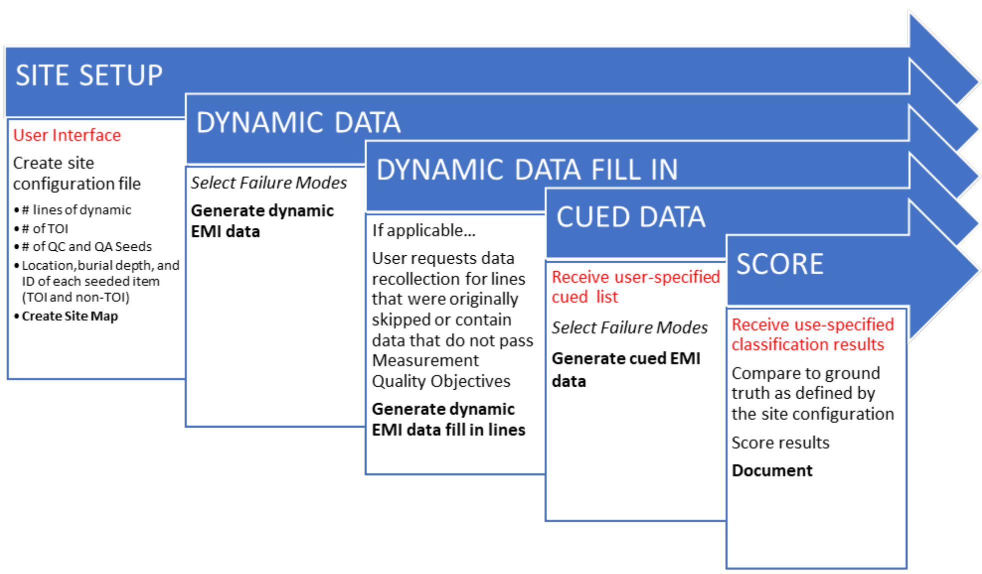


Figure 43. Schematic Showing General Project Flow and Organization of the UX-Simulator Program.

Each major element represents a separate page of the application.

DEVELOPMENT

In this section, we present an overview of the complete software package. In section 3.0, we focus on the failure modes and list and describe each mode individually.

The Site Setup page of the application (Figure 44) allows the user to define and create the size of the synthetic site and the number, type, inclination, and burial depth of Target of Interest (TOI) sources as well as non-TOI sources. The nature and number of the embedded QC Seeds, which are included as aids to the data analysts, is also included.

The available types of TOI are presented to the user in the TOI box window. The number and types of TOI are hardwired, as of this writing. The user adds munitions types by selecting the desired munitions item from the list and adding them to the site by selecting the middle "Add" button. Once added, the user defines the number of items that are to be included and sets limits regarding allowable burial depths and orientations.

Once happy with the site design, the user creates the digital site by hitting the Construct Site box.

The algorithms randomly place the desired TOI and non-TOI throught the site, constrained by the TOI-specifie burial depth constraints. A spatial map is automatically generated (bottom right hand side of Figure 44) and can be accessed using the Site Map tab.

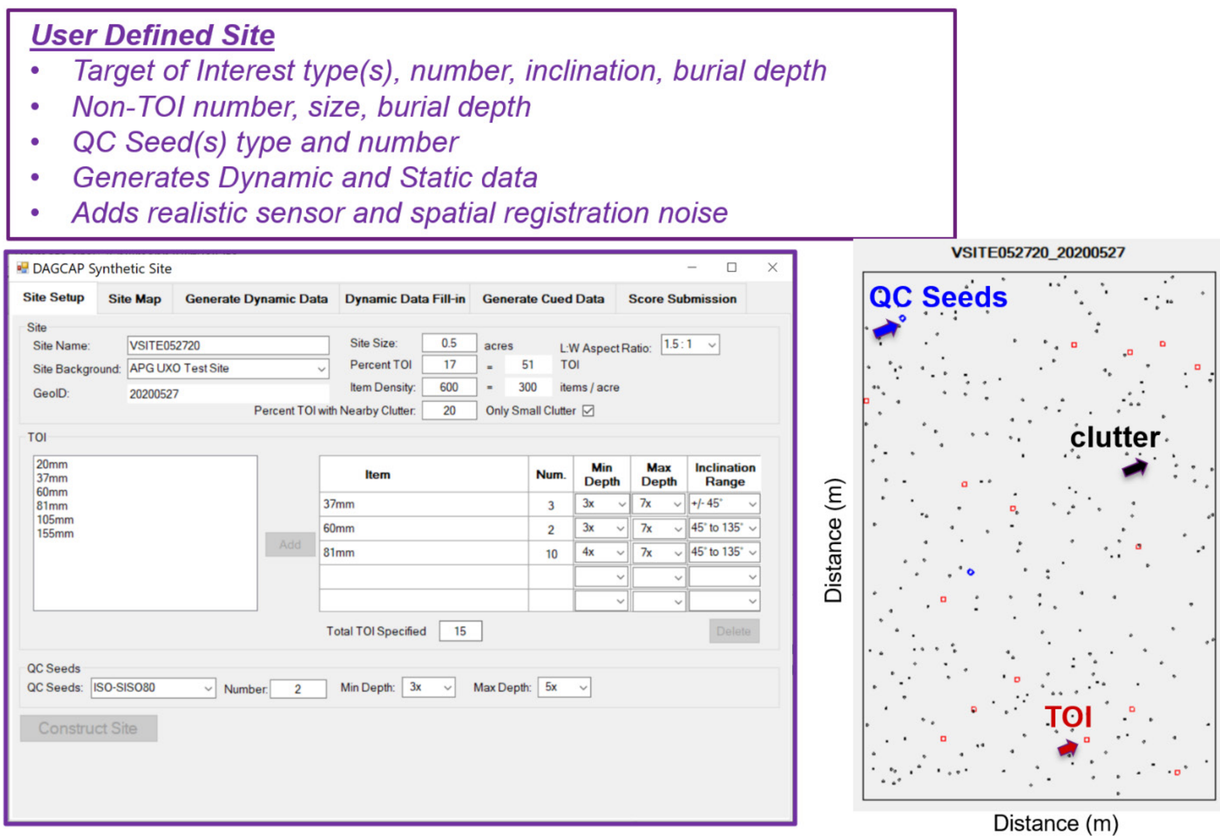


Figure 44. Graphical User Interface for Site Setup.

The Generate Dynamic Data page of the application (Figure 45) allows the user to load a previously generated site and to provide user-specific information used to define direction of dynamic survey, speed, and line spacing of the dynamic survey.

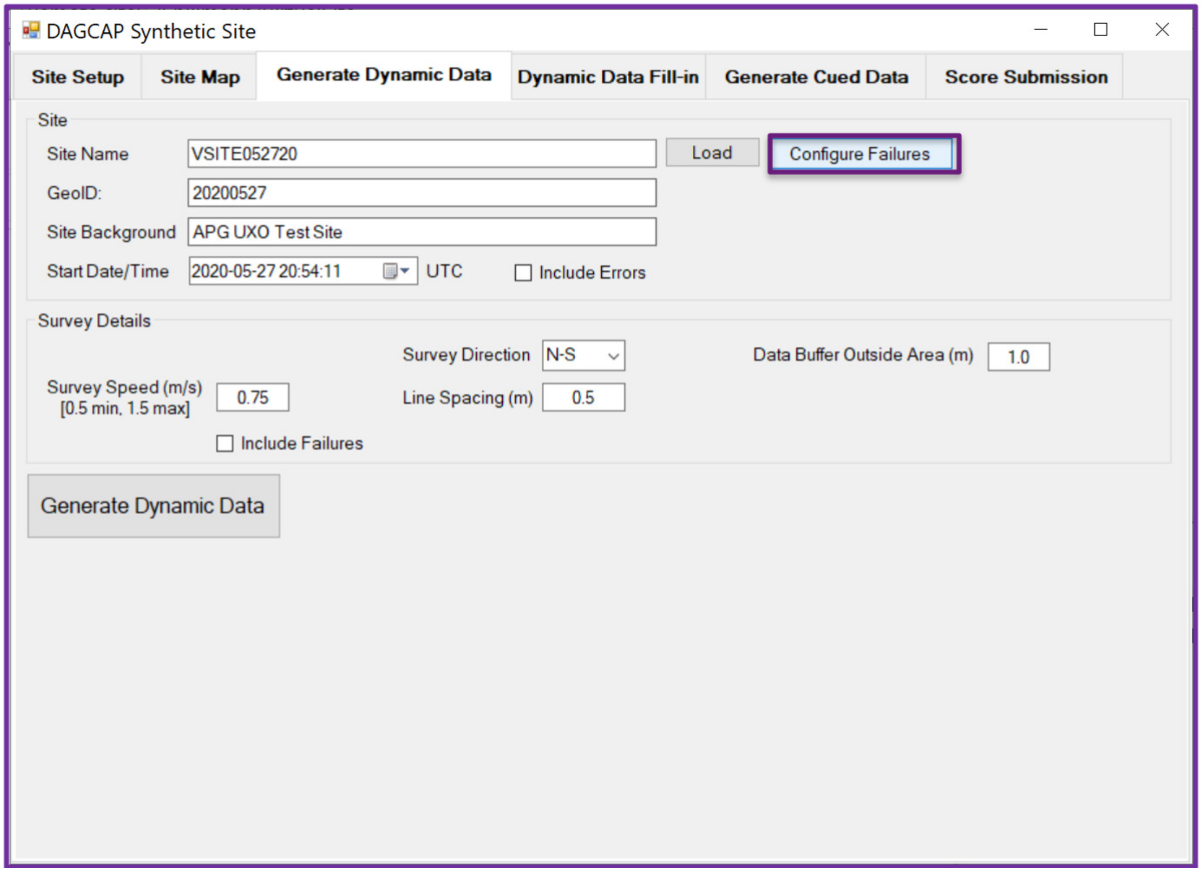


Figure 45. The Generate Dynamic Data Page Presents Options for Surveying, Site Nomenclature, and Failure Configuration.

The Generate Dynamic Data page also provide the means to impart data collection and EMI system failures. If the user wants to add failures, the Configure Failures button is selected, which then offers the two additional menus shown in Figure 46.

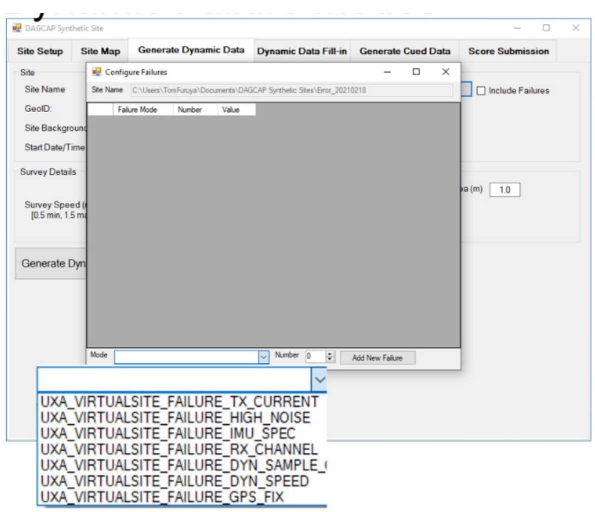


Figure 46. GUI Used to Offer Various Failure Modes During Dynamic Data Generation.

Once the site is configured as desired and the Construct Site button is depressed, the algorthm generates HDF5-formated (version 0) dynamic data. One file is created for each measurement as the synthetic sensor is traversed across the site along the planned transects (Figure 47).

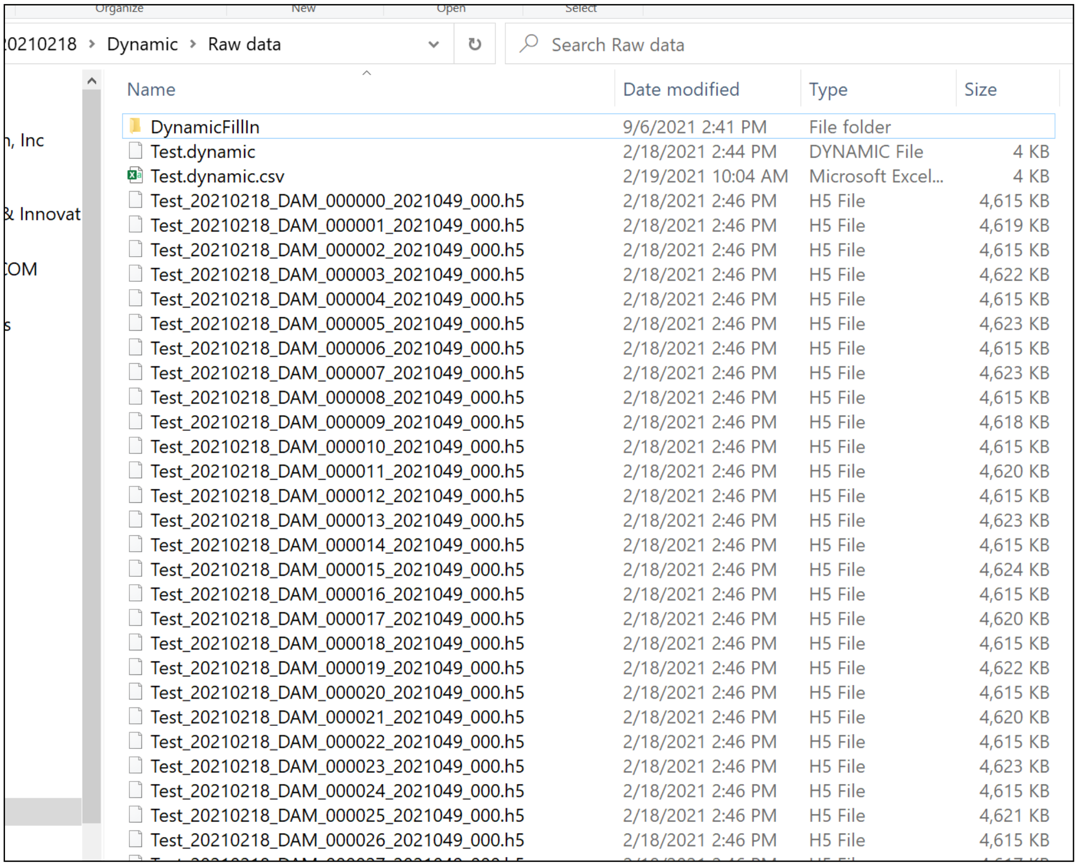


Figure 47. Screen Snapshot Showing a Folder of HDF5-formatted Dynamic Data Files.

The user must process the dynamic data using third party data analysis software, such as UX-Analzye (Figure 48). As the data are checked for quality and processed, the analyst must identify any and all data that does not conform to the data quality objectives.

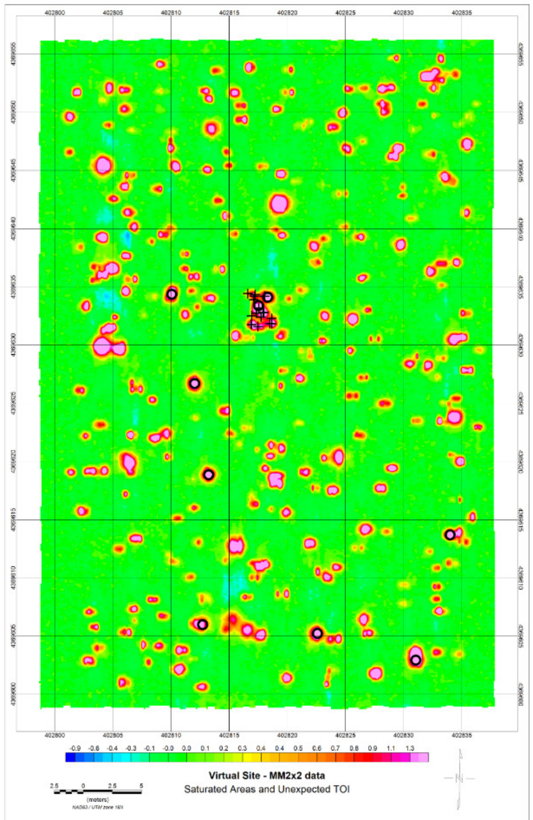


Figure 48. False Color Map of Example Data.

In this figure, background response is shown using green colors and anomalous responses are identified by yellows, oranges, and red colors. The circles identify a select few of the emplaced objects. These data were processed using UX-Analyze and used to identify all data that does not conform to the project's data quality objectives.

The UX-Simulator provides the means for users to request additional data to replace the non-conforming data via the Dynamic Data Fill-in tab. While not explicitly shown here, the process involves using a pre-defined comma-separated form for requesting data to replace the non-conforming data.

Once the analyst receives all dynamic data and confirms that it passes the project's data quality objectives, the analyst processes the dynamic data and produces a list UTM locations where they would like Cued Data to be collected.

The Generate Cued Data tab (Figure 49) is used to read the user defined list of desired cued measurements. If additional failures are desired, the user selects the Configure Failures button and chooses from the list of desired failure modes. Multiple failure modes can be selected during generation of the dynamic or cued data.

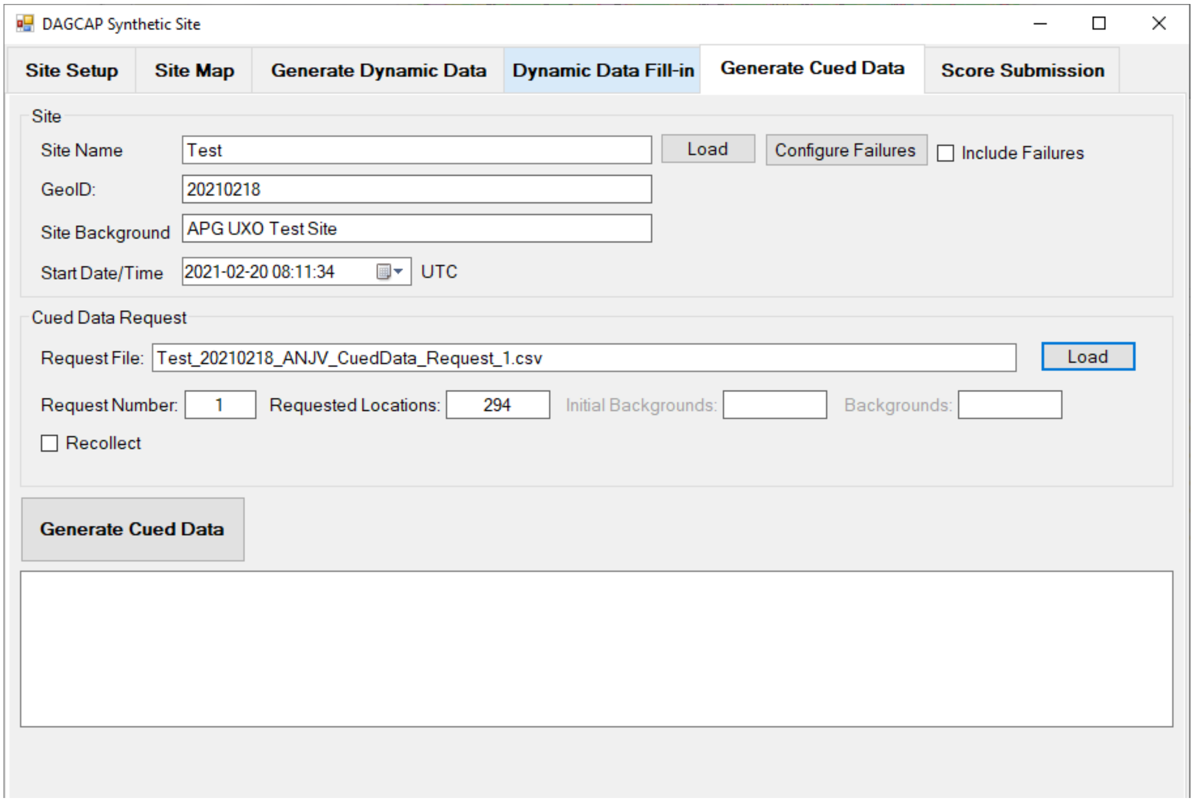


Figure 49. The Generate Cued Data GUI Is Used to Read the List of User-defined Locations at Which Cued Data Are Desired and Define Data Failures, if Any, to Create.

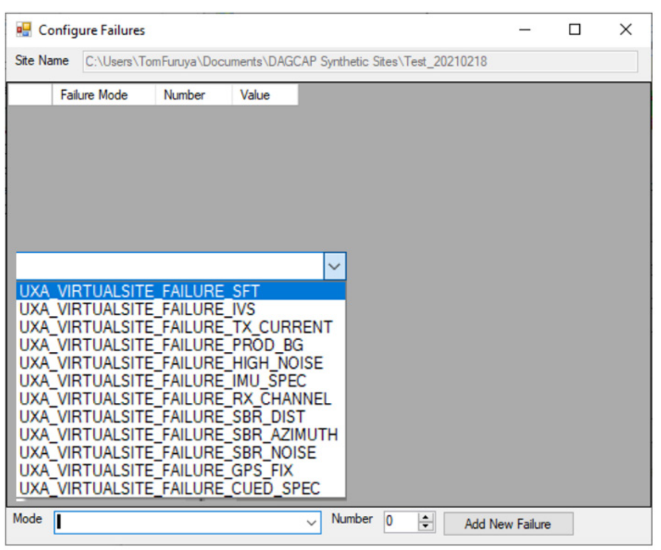


Figure 50. GUI Used to Offer Various Failure Modes During Cued Data Generation.

After setting all parameters as desired, cued data are generated by selecting the Generate Cued Data button. Similar to the dynamic data case, all generated data are created in HDF5 format and stored in an appropriately-labeled folder. In this case, however, each HDF5 file contains only single measurement over the desired XY location according the the user-defined cued data request form.

The final step is for the analyst to process the cued data, again using third party software, and submit a classification dig list for scoring. The Score Submission tab is setup to receive classification results in the same structured comma-separated-value format that was used by ESTCP's Large Scale Classification demonstrations. The analyst's scores are then scored and performance result materials automatically generated.

Concise development history:

- 2018 Dr. Herb Nelson, ESTCP, designed and developed the top-level user interface and scoring routines in Visual Basic.
- 2019 Drs. Tom Bell and Bruce Barrow, Leidos employees, contributed noise models via algorithms written in the Interactive Data Language (IDL).
- 2019 AcornSI created the application structure, converted the noise models to C, and added EMI routines.
- 2020 - 2021 AcornSI designed and integrated enhanced failure modes and code abstraction.

Minimum Hardware:

* Dual core 64bit processor

* 4GB RAM

* 20GB of storage (depends on HDF5 files created and size of sites)

Recommended Hardware:

* Quad core 64 bit processor

* 8+ GB RAM

* 128GB SSD

Software Requirements:

* Microsoft Windows 64-bit OS

* .NET Framework 4.5

ADVANTAGES AND LIMITATIONS

This technology provides a means to efficiently and cost effectively generate realistic EMI data that can be used to train and test data analysts. Advantages of the approach include:

1. It can be used multiple times, each time generating its own data and ground truth
2. User defined site conditions
    a. Target of Interest (type(s), number, inclination, burial depth)
    b. Non-TOI (number, size, burial depth)
    c. QC Seed(s) (type and number)
3. Generates Dynamic and Static data for the user-defined site scenario
4. Adds realistic sensor and spatial registration noise
5. Incorporates common failure modes for both dynamic and cued data collections

There are few, if any, inherent limitations of the technology given continued development. As of the end of this development program in 2020, however, current limitations of the technology include:

1. Limited sensor configurations. At the time of development, the only AGC sensor on the market was Geometrics MM2x2 cart-mounted sensor. Because of this, the codes described here contain hard coded logic to generate data for the MM2x2 AGC sensor configuration.
2. Limited data formats. At the time of development of this application, HDF5 (v0) was the being developed. As a result, data generated by this application writes HDF5 (v0) formatted data files.
3. PC environment. This application was designed to be deployed and utilized on PC computers. Additional development work is required to transition the routines to a Cloud based deployment environment if desired.

The alternative to synthesizing EMI data is to collect empirical data using controlled tests. While empirical tests are required during early stages of research, acquiring empirical data that demonstrates various failure modes for multiple source scenarios, is prohibitively expensive in terms of both money and time.

DYNAMIC DATA COLLECTION

Under this program, we developed several failure modes that are all-to-often observed while collecting broadband EMI data with AGC sensors. Each failure mode is described separately below.

a. Transmit Current

Description: AGC sensors are powered by batteries. Sensor manufacturers specify the operational window for the systems' current. If the observed current is outside of these limits, the acquired data does not conform to MQO's and should not be used to make a classification decision.

Specific Failure: Sometimes the battery is not fully charged, and the voltage drops across all transmitters. A voltage drop for only one transmitter, as shown below, indicated a problem with that particular transmitter circuit.

Required Action: The data should be identified by the analyst and recollected.

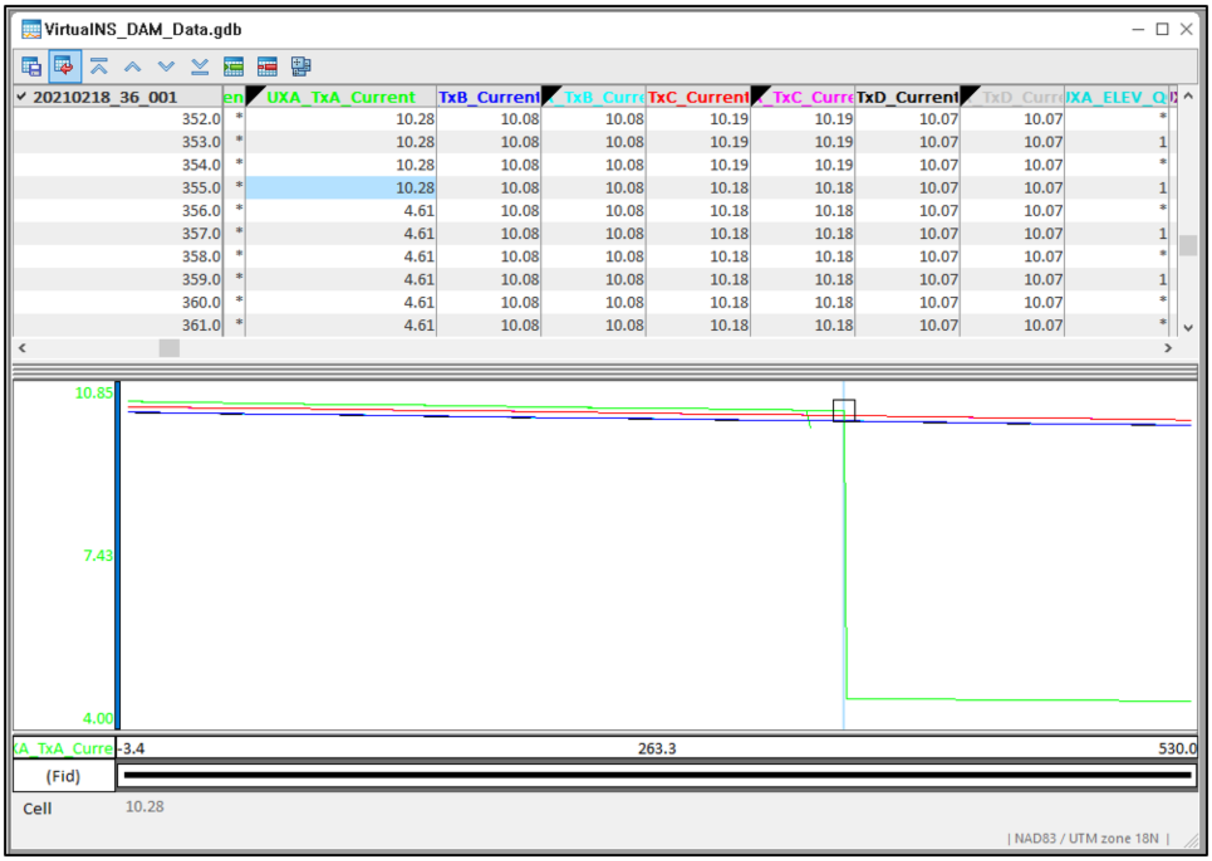


Figure 51. Oasis Montaj Database Showing a Voltage Drop for One Transmitter.

b. High Noise

Description: Successful classification requires signal to noise ratio (SNR) of five or greater. If the sensor is receiving competing signals from an external or internal source, the SNR may not be high enough to support a classification decision.

Specific Failure: Received signal is dominated by white or colored noise, depending on the noise source.

Required Action: The data should be identified by the analyst and recollected.

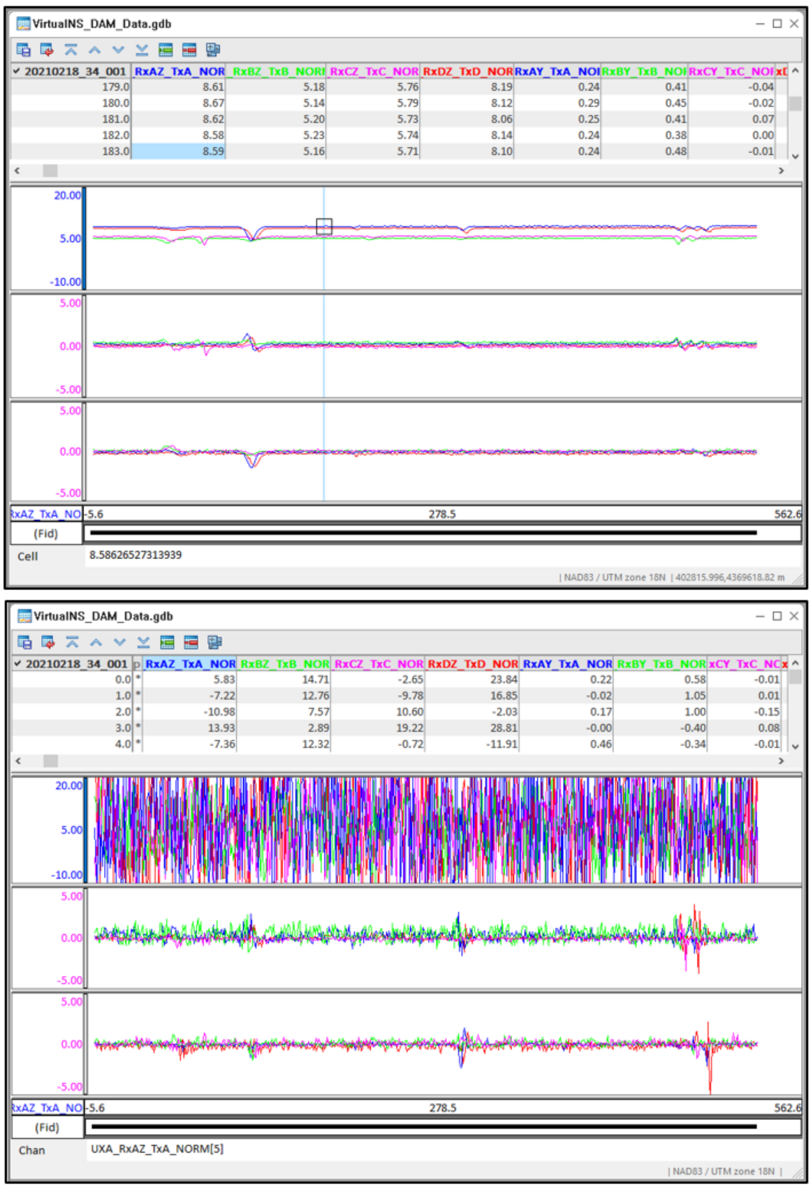


Figure 52. Oasis Montaj Databases Showing Data with Acceptable SNR's (Top) and Unacceptable (Bottom).

c. Inertial Navigation Sensor

Description: Accurate sensor orientation data is required for successful classification decisions. This information is often measured using an integrated Inertial Navigation Sensor. If the INS stops operating within specifications, the EMI data should not be used for classification decisions.

Specific Failure: The INS roll, pitch, and yaw values are constant, indicating an INS problem.

Required Action: The data should be identified by the analyst and recollected.

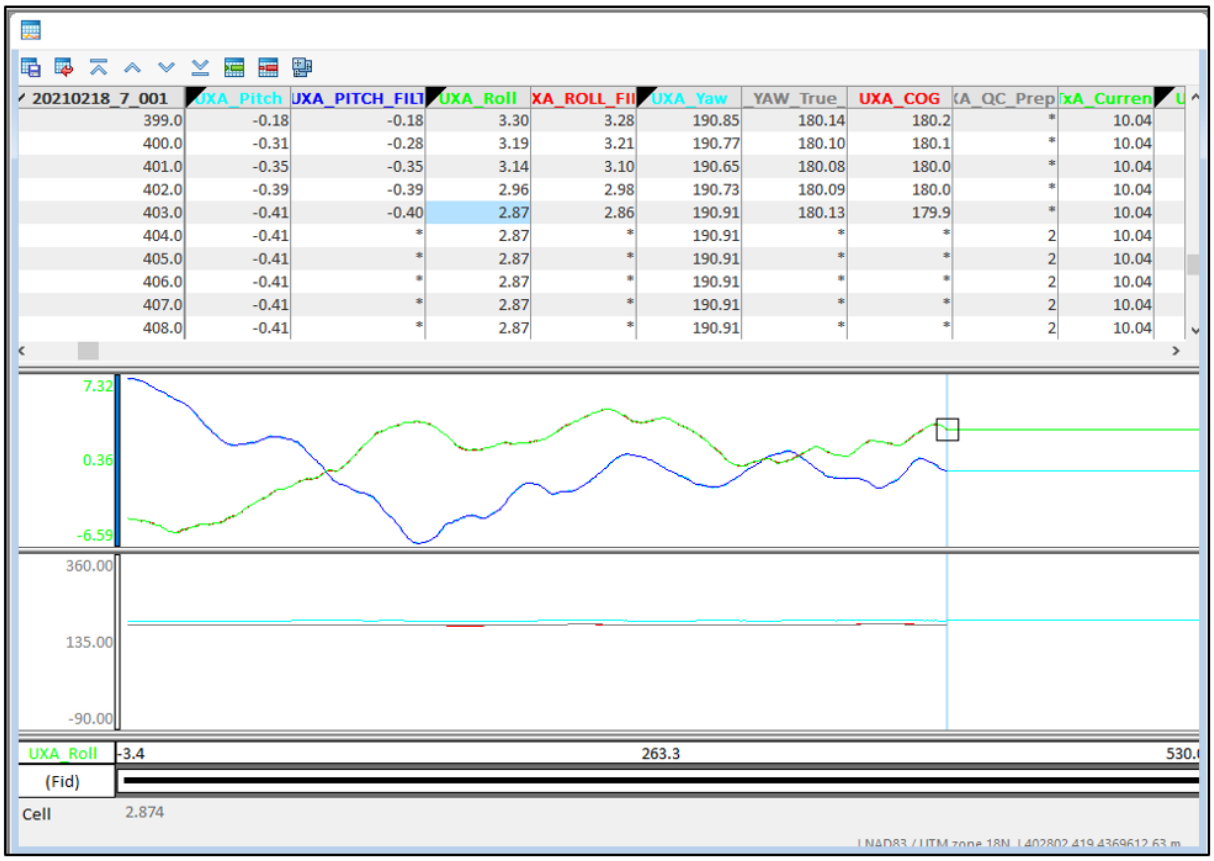


Figure 53. Oasis Montaj Database Showing Non-changing INS Roll, Pitch, and Yaw (Heading) Values.

d. Receiver

Description: AGC sensors are nominally comprised of multiple transmitters and multiple receivers. All the transmitters and receivers need to function properly in order for the sensor data to be optimal.

Specific Failure: One of the receivers is not responding.

Required Action: The data should be identified by the analyst and recollected.

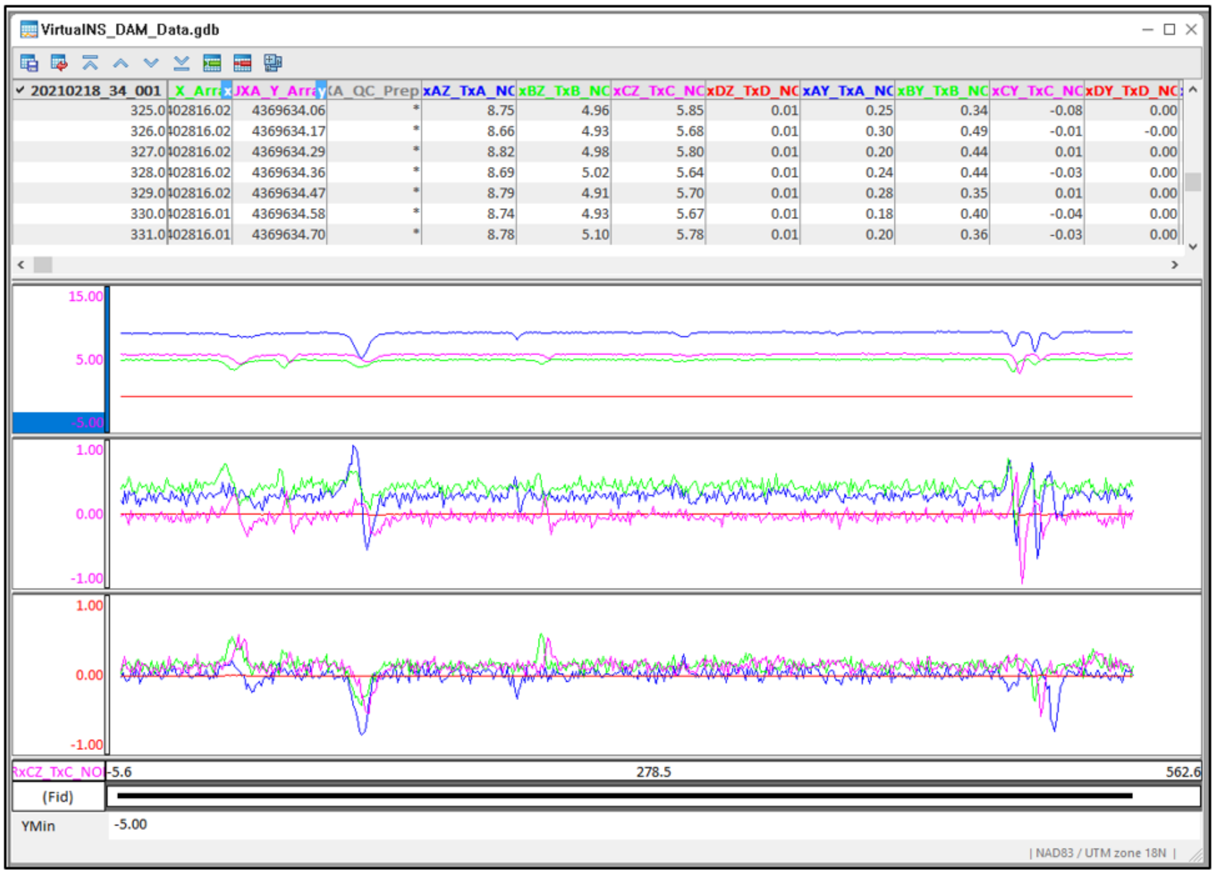


Figure 54. Oasis Montaj Database Showing an Example of a Failed (Flatlined) Receiver.

e. Down track Sample Density

Description: When used to survey an area, AGC sensors are typically set to acquire data at a constant rate while they are moved about spatially. When working properly and transported at a roughly uniform speed, the distance between successive samples should be fairly constant.

Specific Failure: A distinct and abrupt change in measured X and Y values indicates non uniform spatial sampling.

Required Action: The data should be identified by the analyst and recollected.

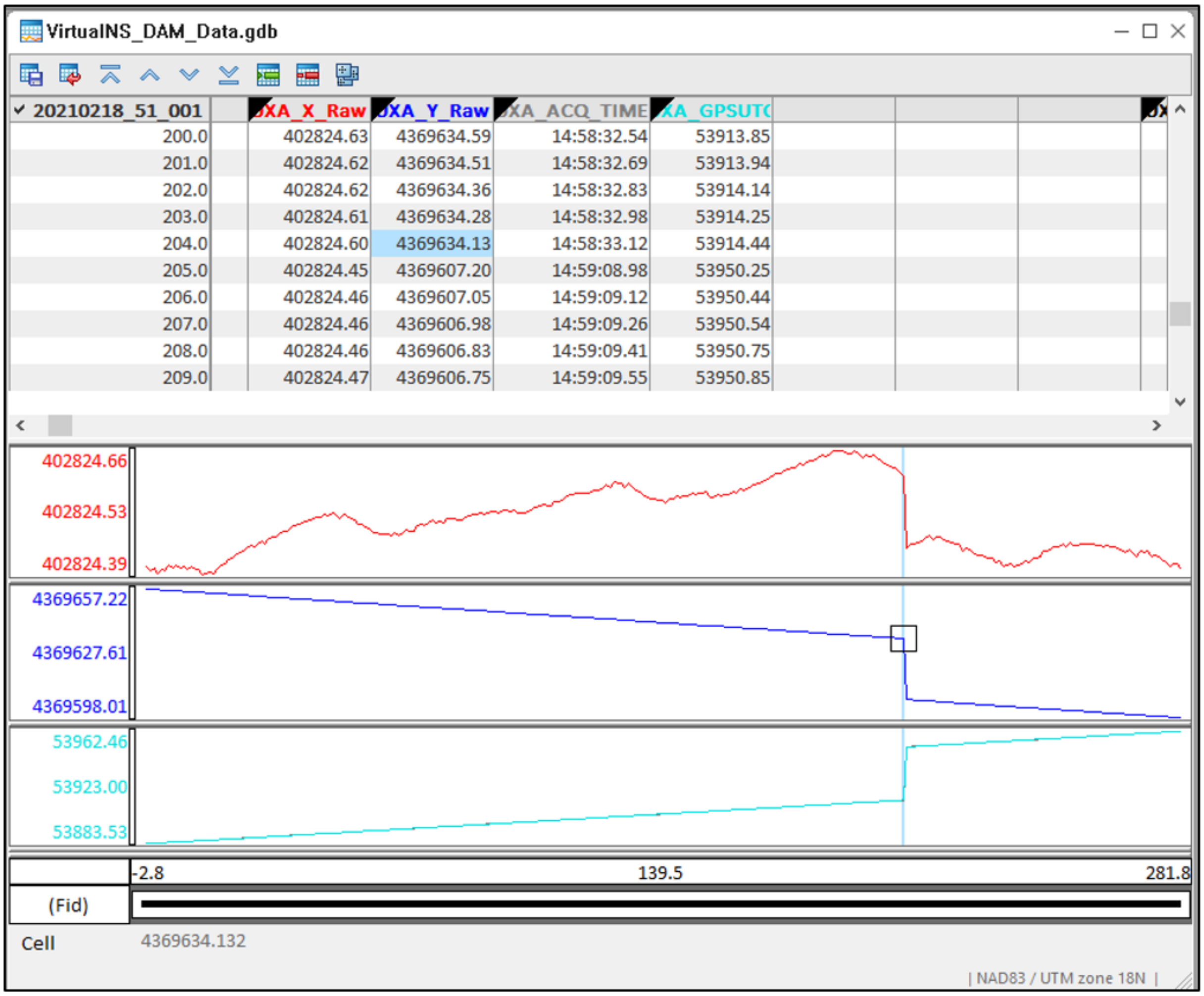


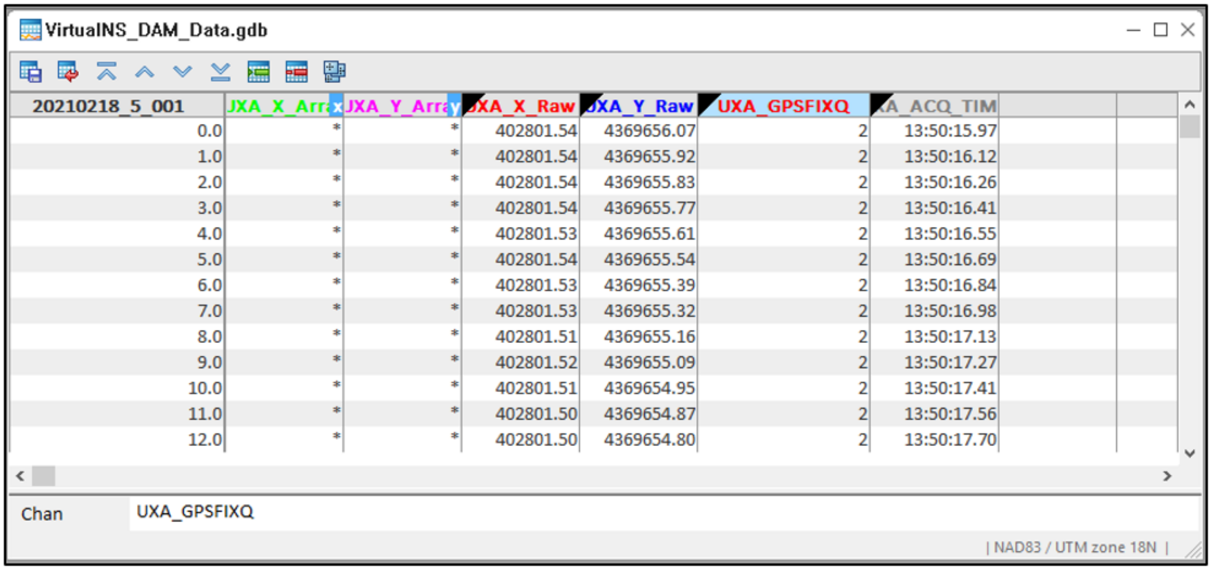
Figure 55. Oasis Montaj Database Showing a Distinct and Abrupt Change in the Measured X and Y Coordinates, which Indicates Non-uniform Spatial Sampling.

f. GPS

Description: Accurate spatial registration data are required for successful AGC decisions. When using GPS for spatial registration, a GPS Fix Quality of 4, which denotes RTK precision (centimeter precision), is required

Specific Failure: The GPS fix quality for this dataset is 2, which denotes differentially correct but not RTK, instead of 4.

Required Action: The data should be identified by the analyst and recollected.



20210218_5_001	JXA_X_Arra	JXA_Y_Arra	XA_X_Raw	XA_Y_Raw	UXA_GPSFIXQ	A_ACQ_TIM
0.0	*	*	402801.54	4369656.07	2	13:50:15.97
1.0	*	*	402801.54	4369655.92	2	13:50:16.12
2.0	*	*	402801.54	4369655.83	2	13:50:16.26
3.0	*	*	402801.54	4369655.77	2	13:50:16.41
4.0	*	*	402801.53	4369655.61	2	13:50:16.55
5.0	*	*	402801.54	4369655.54	2	13:50:16.69
6.0	*	*	402801.53	4369655.39	2	13:50:16.84
7.0	*	*	402801.53	4369655.32	2	13:50:16.98
8.0	*	*	402801.51	4369655.16	2	13:50:17.13
9.0	*	*	402801.52	4369655.09	2	13:50:17.27
10.0	*	*	402801.51	4369654.95	2	13:50:17.41
11.0	*	*	402801.50	4369654.87	2	13:50:17.56
12.0	*	*	402801.50	4369654.80	2	13:50:17.70

Figure 56. Oasis Montaj Database Showing a GPS Fix Value of 2.

CUED DATA COLLECTION

a. Sensor Function Test

Description: AGC sensors are relative and not absolute sensors. One measure of performance is the instruments' response to a standard object. The Sensor Function Test measures the sensor's response to a standard object over time to confirm and document sensor functionality.

Specific Failure: The Sensor Function Test results for one collection, indicated by the red marker below, are not within MQO.

Required Action: The data should be identified by the analyst and recollected.

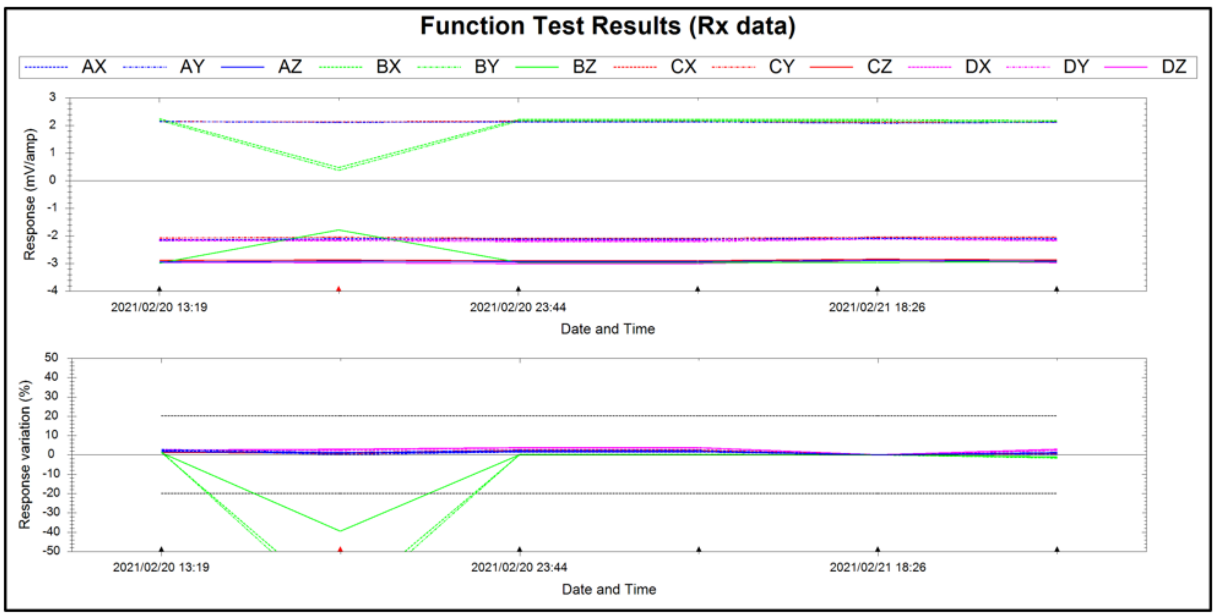


Figure 57. Oasis Montaj Database Showing Sensor Function Test Results for a Short Period of Time.

b. Instrument Verification Strip

Description: AGC sensors are tested multiple times per day over test objects to document system performance and consistency.

Specific Failure: The inverted polarizabilities, location, and estimated depth for these IVS data do not match the expected values.

Required Action: The data should be identified by the analyst and recollected.

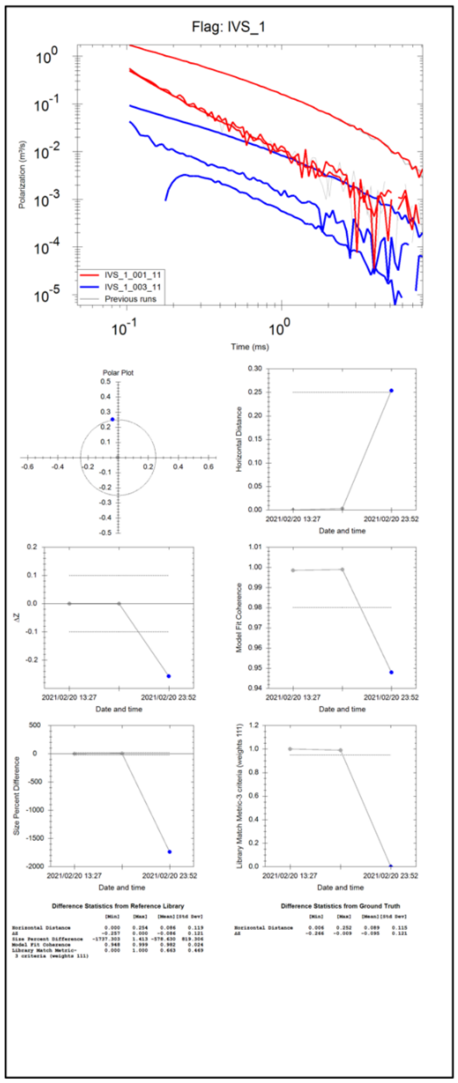


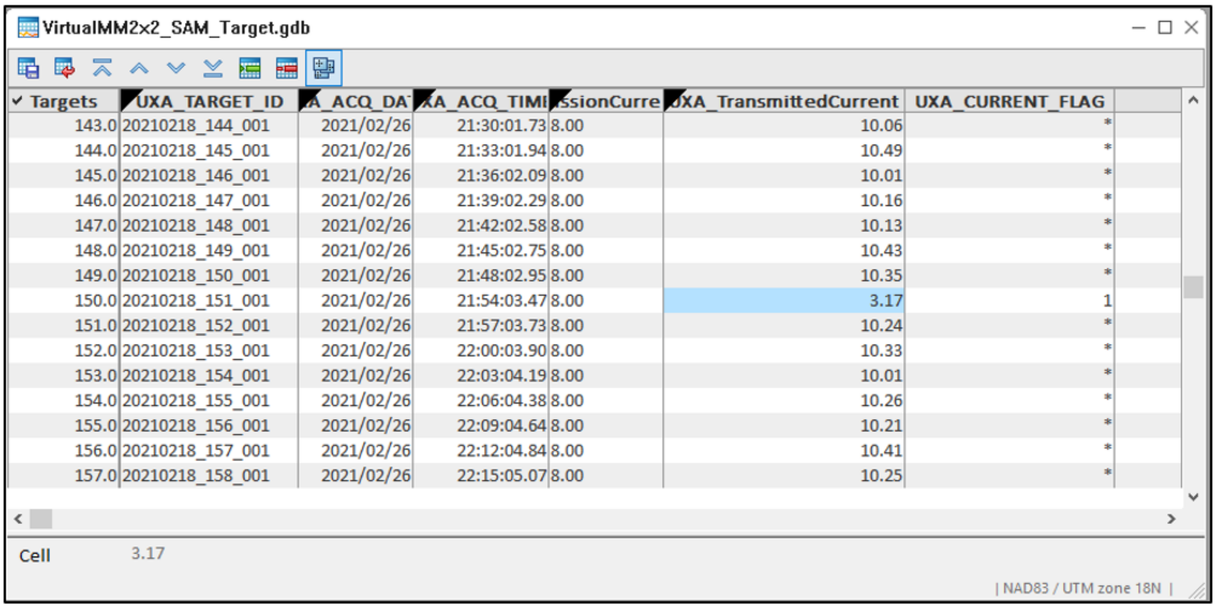
Figure 58. UX-Analyze IVS Report for a Single IVS Object Identified Non-conforming Data.

c. Transmit Current

Description: AGC sensors are powered by batteries. Sensor manufacturers specify the operational window for the systems' current. If the observed current is outside of these limits, the acquired data does not conform to MQO's and should not be used to make a classification decision.

Specific Failure: The recorded transmit current for one of the cued data collections is below the MQO.

Required Action: The non-conforming data should be identified by the analyst and recollected.


VirtualMM2x2_SAM_Target.gdb

Targets	UXA_TARGET_ID	A_ACQ_DA	XA_ACQ_TIMI	ssionCurre	XA_TransmittedCurrent	UXA_CURRENT_FLAG
143.0	20210218_144_001	2021/02/26	21:30:01.73	8.00	10.06	*
144.0	20210218_145_001	2021/02/26	21:33:01.94	8.00	10.49	*
145.0	20210218_146_001	2021/02/26	21:36:02.09	8.00	10.01	*
146.0	20210218_147_001	2021/02/26	21:39:02.29	8.00	10.16	*
147.0	20210218_148_001	2021/02/26	21:42:02.58	8.00	10.13	*
148.0	20210218_149_001	2021/02/26	21:45:02.75	8.00	10.43	*
149.0	20210218_150_001	2021/02/26	21:48:02.95	8.00	10.35	*
150.0	20210218_151_001	2021/02/26	21:54:03.47	8.00	3.17	1
151.0	20210218_152_001	2021/02/26	21:57:03.73	8.00	10.24	*
152.0	20210218_153_001	2021/02/26	22:00:03.90	8.00	10.33	*
153.0	20210218_154_001	2021/02/26	22:03:04.19	8.00	10.01	*
154.0	20210218_155_001	2021/02/26	22:06:04.38	8.00	10.26	*
155.0	20210218_156_001	2021/02/26	22:09:04.64	8.00	10.21	*
156.0	20210218_157_001	2021/02/26	22:12:04.84	8.00	10.41	*
157.0	20210218_158_001	2021/02/26	22:15:05.07	8.00	10.25	*

Cell 3.17

| NAD83 / UTM zone 18N |

Figure 59. Oasis Montaj Database Showing Transmitter Current for Several Cued Data Collection.

One of the collections reports a transmitter current of 3.17, which is not within the sensors MQO's.

d. Production Background Measurement

Description: Standard protocol requires that the cueing AGC sensor collect data at areas known to be free of metallic sources. This background data is later used during processing to remove sensor and geologic contributions. To be useful, the data collected at these fixed locations should not change.

Specific Failure: This plot overlays multiple measurements collected at a fixed XY location. One of the measurements produces a much larger response, and therefore needs to be reviewed.

Required Action: The non-conforming data should be identified by the analyst and recollected. This failure, left unmitigated, will affect all data that needs to use this background reading.

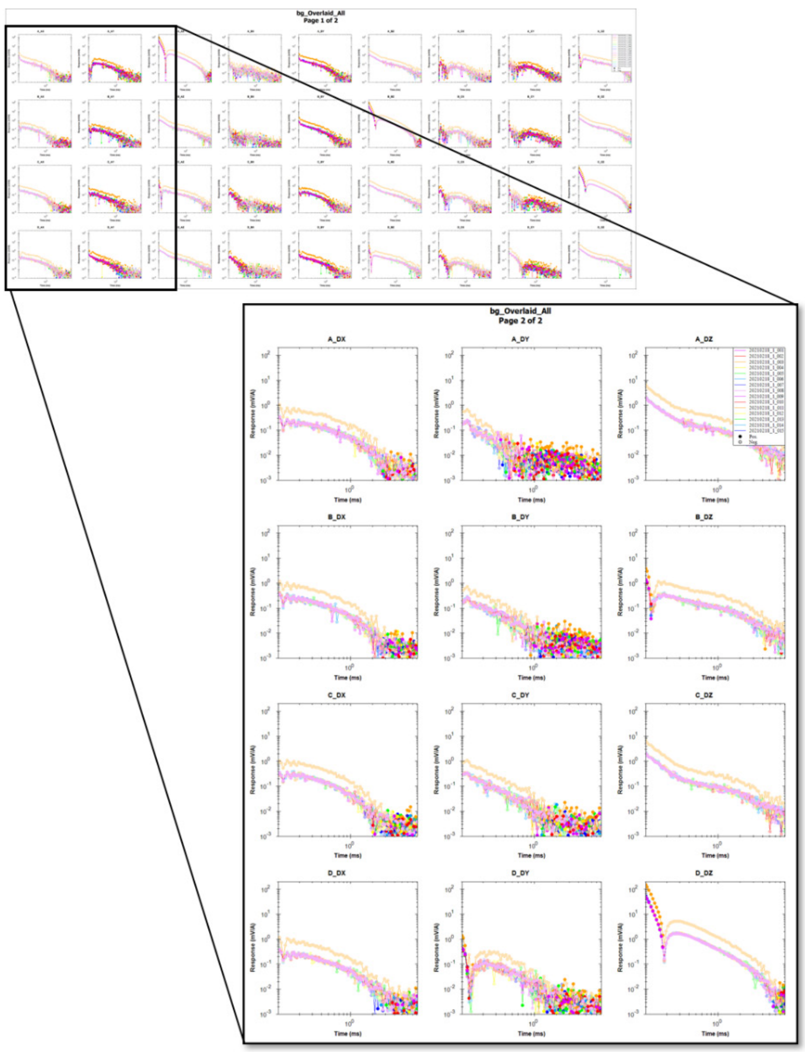


Figure 60. UX-Analyze Background Report Showing and Overlay of Successive Measurements Collected at a Single, Fixed XY Location.

e. High Noise

Description: AGC sensors required high SNR data. If high noise is observed in the measured EMI data, the sensor and or environment settings may not be conducive to collecting classification data.

Specific Failure: The measured response is highly variable and bounces, as a function of time gate, from negative to positive responses.

Required Action: The non-conforming data should be identified by the analyst and recollected.

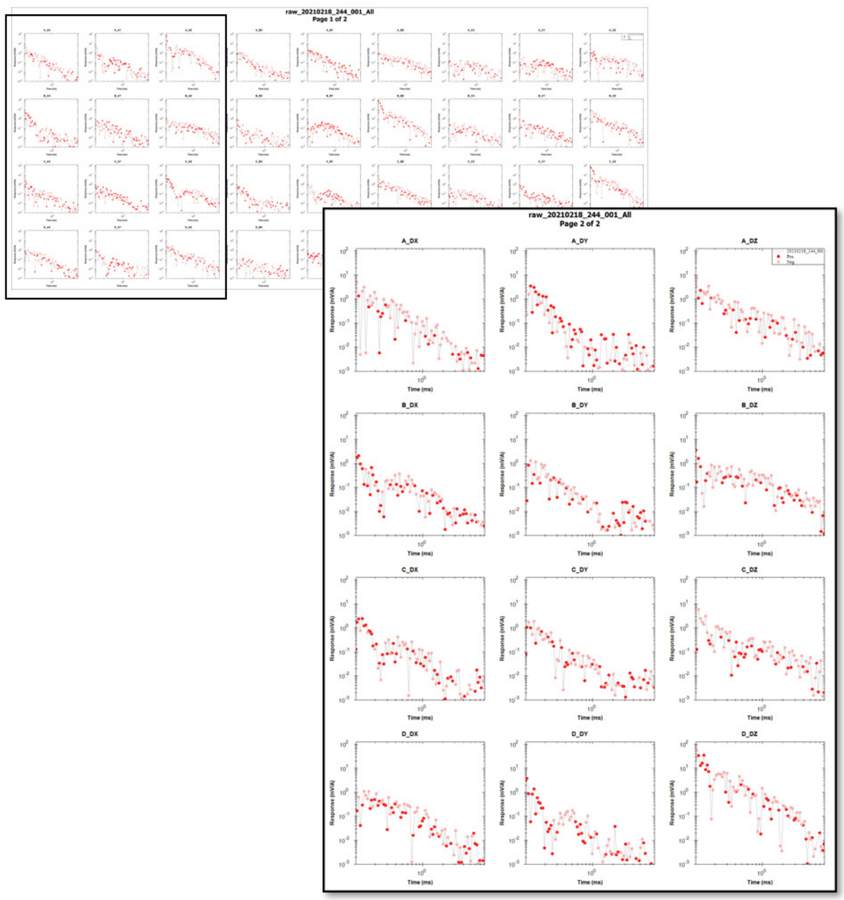


Figure 61. Oasis Montaj Plot of the Measure Transients.

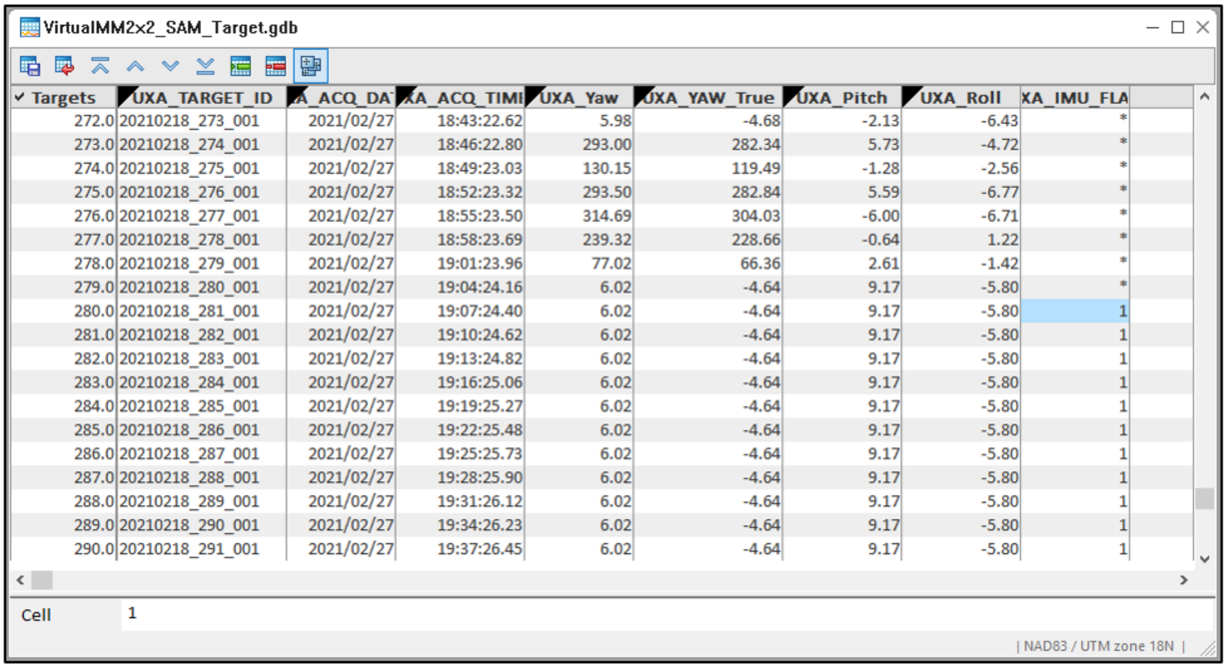
In this case, the transients show high variability and bounce between negative and positive values.

f. Inertial Measurement Unit

Description: Accurate and timely sensor orientation data are required for successful classification.

Specific Failure: The INS roll, pitch, and yaw (heading) have flatlined to a constant value.

Required Action: The non-conforming data need to be identified and recollected.



Targets	UXA_TARGET_ID	A_ACQ_DA	XA_ACQ_TIMI	UXA_Yaw	UXA_YAW_True	UXA_Pitch	UXA_Roll	XA_IMU_FLA
272.0	20210218_273_001	2021/02/27	18:43:22.62	5.98	-4.68	-2.13	-6.43	*
273.0	20210218_274_001	2021/02/27	18:46:22.80	293.00	282.34	5.73	-4.72	*
274.0	20210218_275_001	2021/02/27	18:49:23.03	130.15	119.49	-1.28	-2.56	*
275.0	20210218_276_001	2021/02/27	18:52:23.32	293.50	282.84	5.59	-6.77	*
276.0	20210218_277_001	2021/02/27	18:55:23.50	314.69	304.03	-6.00	-6.71	*
277.0	20210218_278_001	2021/02/27	18:58:23.69	239.32	228.66	-0.64	1.22	*
278.0	20210218_279_001	2021/02/27	19:01:23.96	77.02	66.36	2.61	-1.42	*
279.0	20210218_280_001	2021/02/27	19:04:24.16	6.02	-4.64	9.17	-5.80	*
280.0	20210218_281_001	2021/02/27	19:07:24.40	6.02	-4.64	9.17	-5.80	1
281.0	20210218_282_001	2021/02/27	19:10:24.62	6.02	-4.64	9.17	-5.80	1
282.0	20210218_283_001	2021/02/27	19:13:24.82	6.02	-4.64	9.17	-5.80	1
283.0	20210218_284_001	2021/02/27	19:16:25.06	6.02	-4.64	9.17	-5.80	1
284.0	20210218_285_001	2021/02/27	19:19:25.27	6.02	-4.64	9.17	-5.80	1
285.0	20210218_286_001	2021/02/27	19:22:25.48	6.02	-4.64	9.17	-5.80	1
286.0	20210218_287_001	2021/02/27	19:25:25.73	6.02	-4.64	9.17	-5.80	1
287.0	20210218_288_001	2021/02/27	19:28:25.90	6.02	-4.64	9.17	-5.80	1
288.0	20210218_289_001	2021/02/27	19:31:26.12	6.02	-4.64	9.17	-5.80	1
289.0	20210218_290_001	2021/02/27	19:34:26.23	6.02	-4.64	9.17	-5.80	1
290.0	20210218_291_001	2021/02/27	19:37:26.45	6.02	-4.64	9.17	-5.80	1

Figure 62. Oasis Montaj Database Showing Non-conforming INS Data (Roll, Pitch, and Yaw).

g. Receiver

Description: AGC sensors utilize multiple receivers. All of these receivers need to be functioning correctly for optimal classification performance.

Specific Failure: Once of the receivers, in this case receiver A, is not responding correctly.

Required Action: All non-conforming data must be identified and recollected.

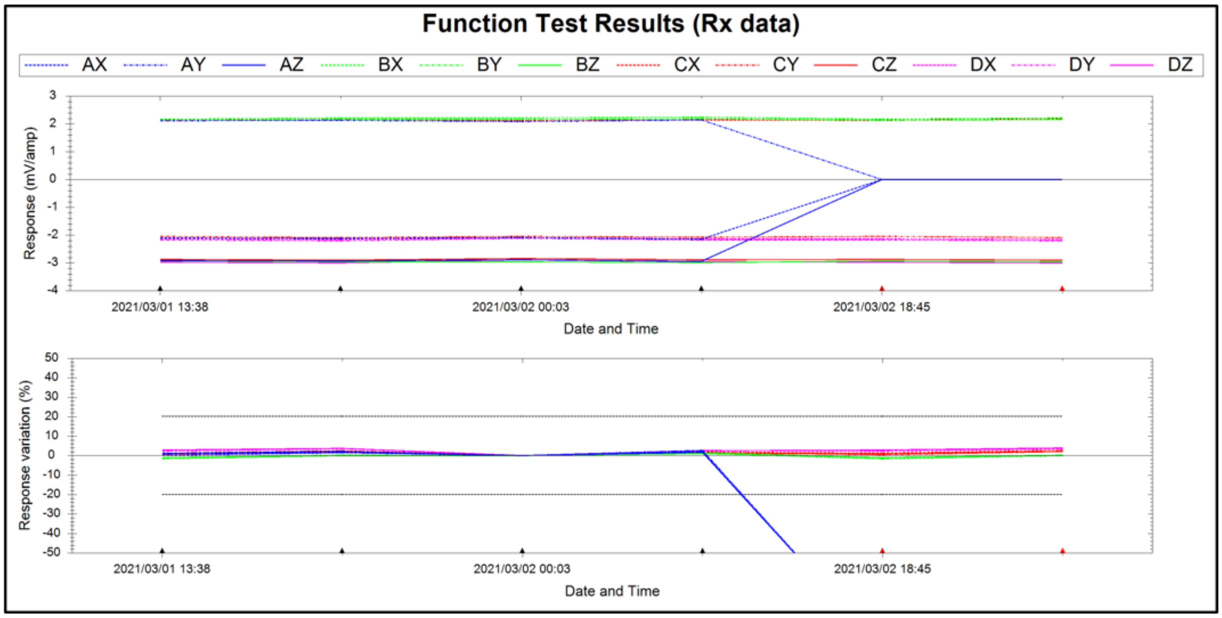


Figure 63. Oasis Montaj Database Showing a Non-responsive Receive Coil.

h. Static Background Reconnaissance

Description: Before background locations are utilized, they must be shown to be free of nearby metallic sources. The means for showing the absence of metal is to collect multiple data samples about a central location and compare the response to each other, as well as a synthetic TOI source.

Specific Failure: Multiple failure modes are shown below.

Required Action: All non-conforming data must be identified and recollected.

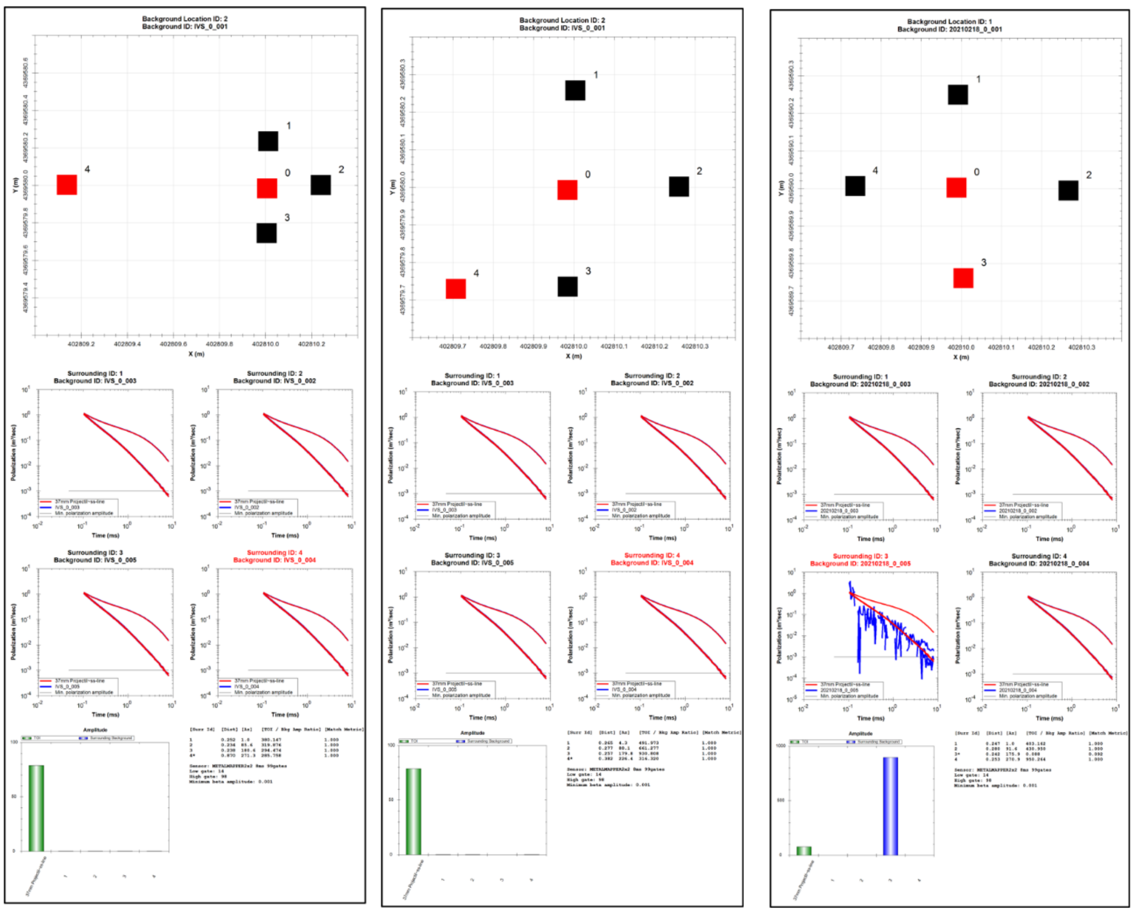


Figure 64. UX-Analyze Reports for Three Non-conforming SBR Measurements.

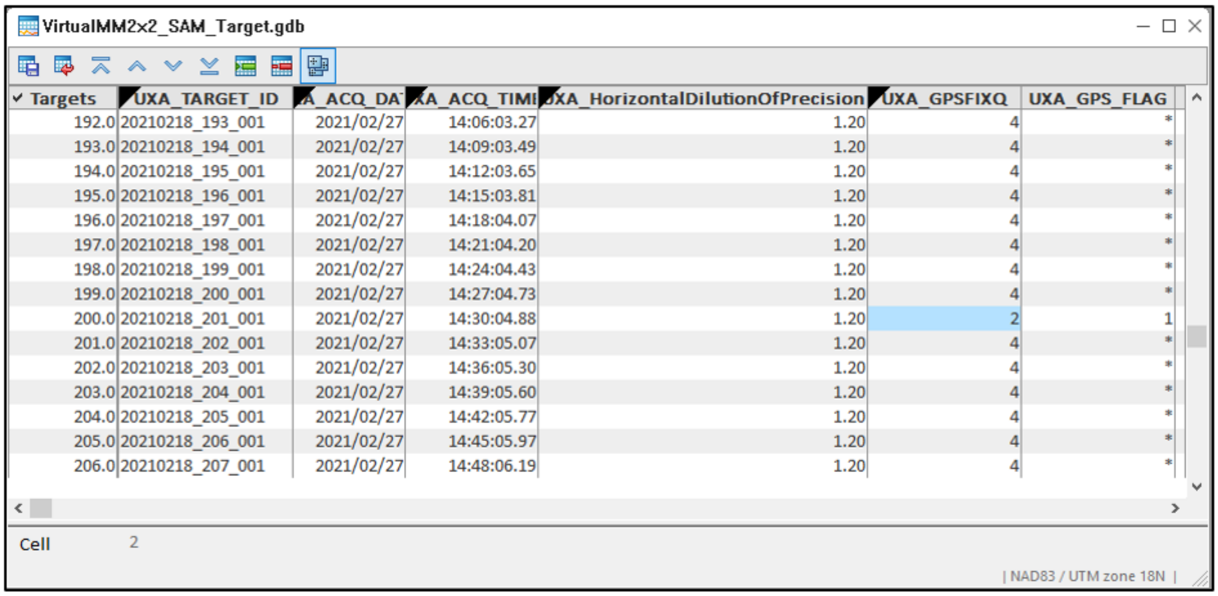
Non-conformance due to distance between measurements (left), inadequate azimuthal sampling (center), and high noise (right).

i. GPS

Description: Accurate spatial registration data are required for successful AGC decisions. When using GPS for spatial registration, a GPS Fix Quality of 4, which denotes RTK precision (centimeter precision), is required

Specific Failure: The GPS fix quality for one of the cued measurements is 2, which denotes differentially correct but not RTK.

Required Action: The non-conforming data should be identified by the analyst and recollected.


VirtualMM2x2_SAM_Target.gdb

Targets	UXA_TARGET_ID	A_ACQ_DA	XA_ACQ_TIMI	XA_HorizontalDilutionOfPrecision	UXA_GPSFIXQ	UXA_GPS_FLAG
192.0	20210218_193_001	2021/02/27	14:06:03.27	1.20	4	*
193.0	20210218_194_001	2021/02/27	14:09:03.49	1.20	4	*
194.0	20210218_195_001	2021/02/27	14:12:03.65	1.20	4	*
195.0	20210218_196_001	2021/02/27	14:15:03.81	1.20	4	*
196.0	20210218_197_001	2021/02/27	14:18:04.07	1.20	4	*
197.0	20210218_198_001	2021/02/27	14:21:04.20	1.20	4	*
198.0	20210218_199_001	2021/02/27	14:24:04.43	1.20	4	*
199.0	20210218_200_001	2021/02/27	14:27:04.73	1.20	4	*
200.0	20210218_201_001	2021/02/27	14:30:04.88	1.20	2	1
201.0	20210218_202_001	2021/02/27	14:33:05.07	1.20	4	*
202.0	20210218_203_001	2021/02/27	14:36:05.30	1.20	4	*
203.0	20210218_204_001	2021/02/27	14:39:05.60	1.20	4	*
204.0	20210218_205_001	2021/02/27	14:42:05.77	1.20	4	*
205.0	20210218_206_001	2021/02/27	14:45:05.97	1.20	4	*
206.0	20210218_207_001	2021/02/27	14:48:06.19	1.20	4	*

Cell 2

| NAD83 / UTM zone 18N |

Figure 65. Oasis Montaj Database Showing GPS Fix Values for Several Cued Data Collections.

One of the measurements reports a GPS fix quality of 2, which does not conform to the data quality required.

j. Cued Location Request

Description: For cued AGC collections, the XY location for the measurement is derived from an alternate survey or data source. If the subsequent cued collections are collected in the wrong spatial location, it will not be able to be used to characterize the source of original anomalous signal.

Specific Failure: Two cued collections, identified by the red + symbol below, were collected too far from the desired location to be within MQO's.

Required Action: The non-conforming data should be identified by the analyst and recollected.

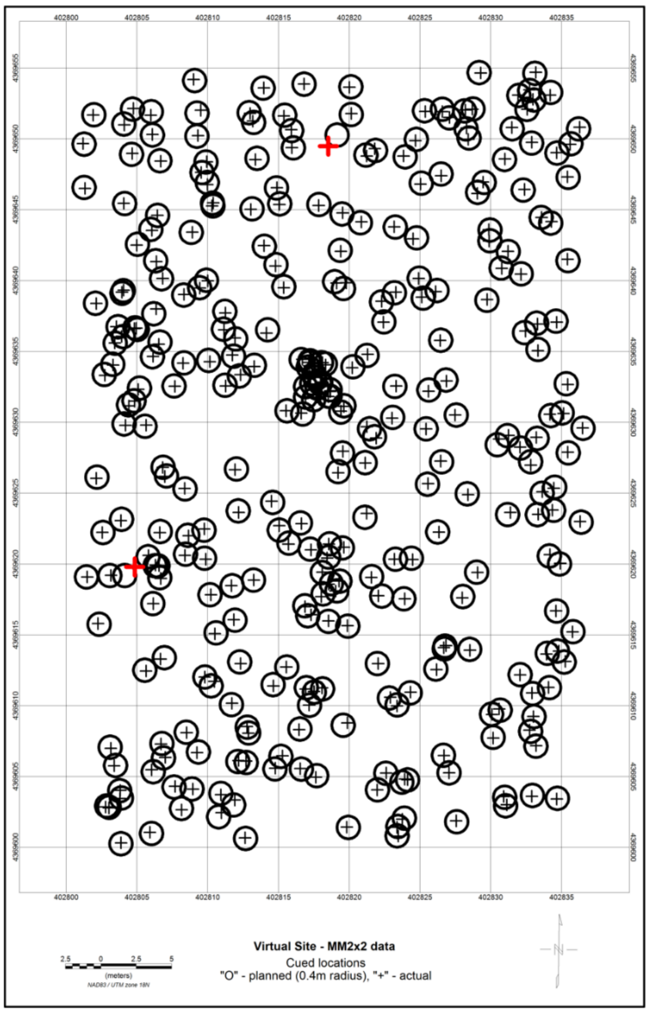


Figure 66. Oasis Montaj Image Showing the Location of Planned Cued Measurements (circle) and Actual (+).

The red + symbols identify cued measurements that were not collected close enough to the planned location.

k. Saturated Response Area (SRA)

Description: The AGC method can break down and systematically fail if the number of metallic sources within the sensors' view is large. In these cases, the spatial response is often saturated, such that individual anomalies cannot be readily identified.

Specific Failure: An SRA was created in the center of this synthetic site. This relatively small SRA contains two TOI and multiple non-TOI.

Required Action: For classification to be successful, metallic sources within the SRA must be removed and the area resurveyed. At a minimum, SRA's need to be identified and remediated accordingly, with proper QC and validation checks.

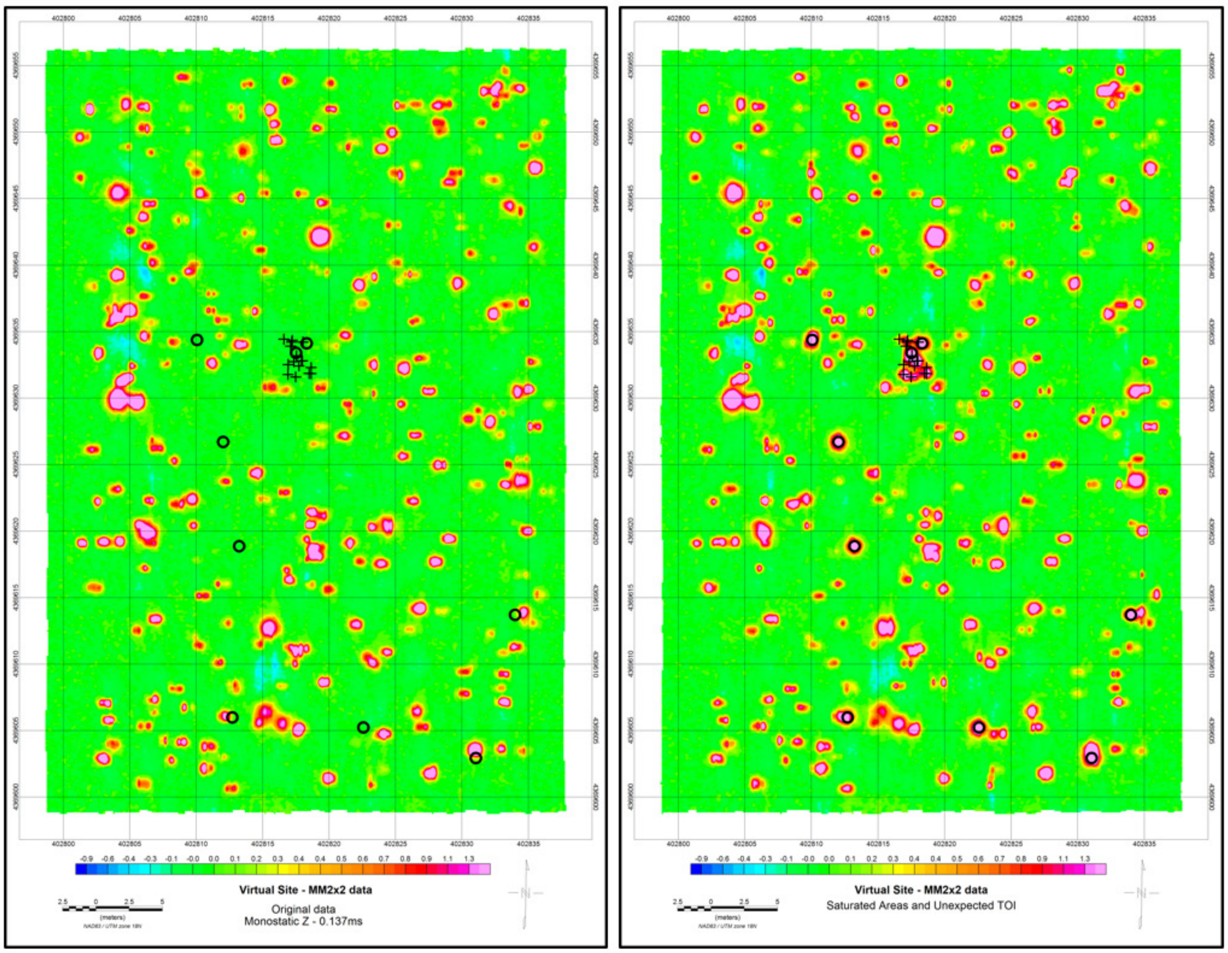


Figure 67. Oasis Montaj False Color Plots of a Synthetic Data Set Before (Left) and After (Right) Adding a Saturated Response Area, Which Is Defined Here As an Area That Is Difficult to Identify Source Locations from the Amplitude Response.

IMPLEMENTATION ISSUES

The UX-Simulator program (executable) was initially delivered to the US Government in 2019, for use in testing and benchmarking classification performance as part of the DoD Advanced Geophysical Classification Accreditation Program (DAGCAP). This enhanced version, which includes the additional failure modes, was delivered to the US Government in April 2021.

Implementation of the entire process requires coordination between the tester and the analyst. A typical interaction sequence is presented in Figure 68.

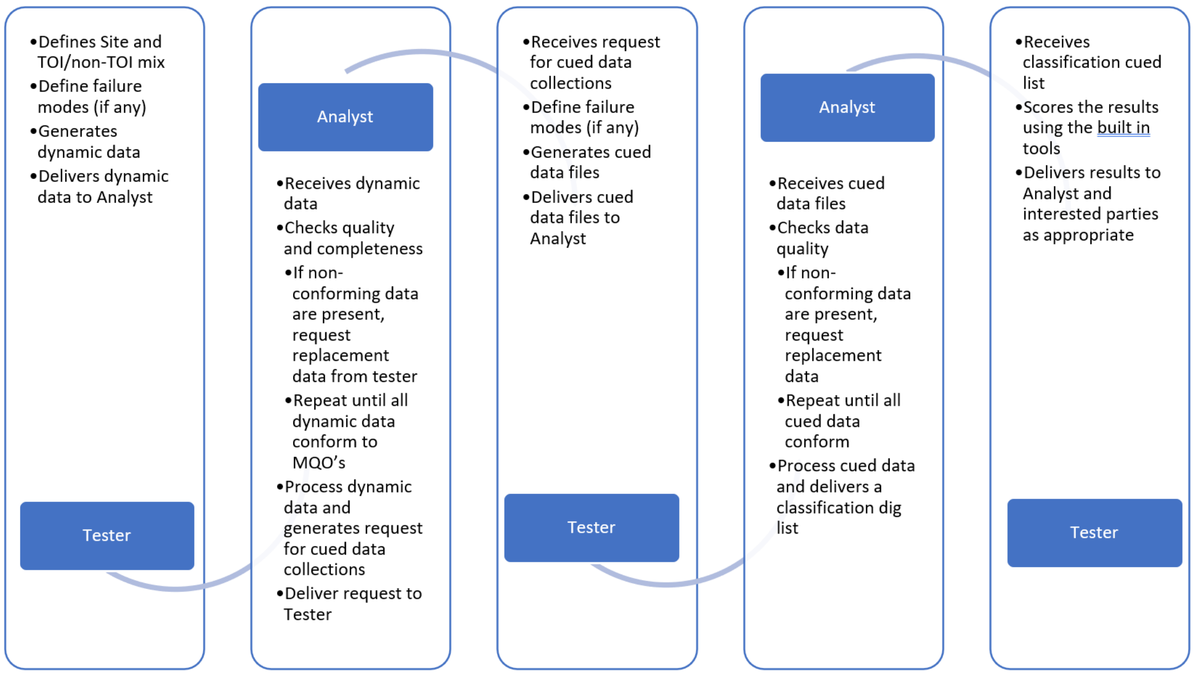


Figure 68. Flow Chart Detailing a Typical Interaction Sequence Between the Tester and the Analyst (the Individual Being Tested).

The analyst must be able to run computer programs, qualitatively check the inputs, and qualitatively check the generated data and reports. The analysts must have access to third party EMI data classification software and be trained in its use.

To facilitate development and early integration by government and DAGCAP personnel, the UX-Simulator application was written for personal computers. To facilitate ease of use of government computers going forward, however, we recommend converting it to a Cloud application so that no local software installations are required. Additional software modifications will be required to accommodate data format changes associated with HDF5 versioning and/or ancillary sensor configurations, if desired.

APPENDIX E ROOT CAUSE ANALYSIS – COINCIDENT SOURCE LOGIC

As stated in Section 7, two dig lists were submitted for scoring while completing this demonstration. The initial dig list resulted in what was reported as a detection failure (Figure 69, Table 7). By looking into the online UX-Classify database, the government determined that the source was correctly classified and located, but it had been omitted from the dig list.

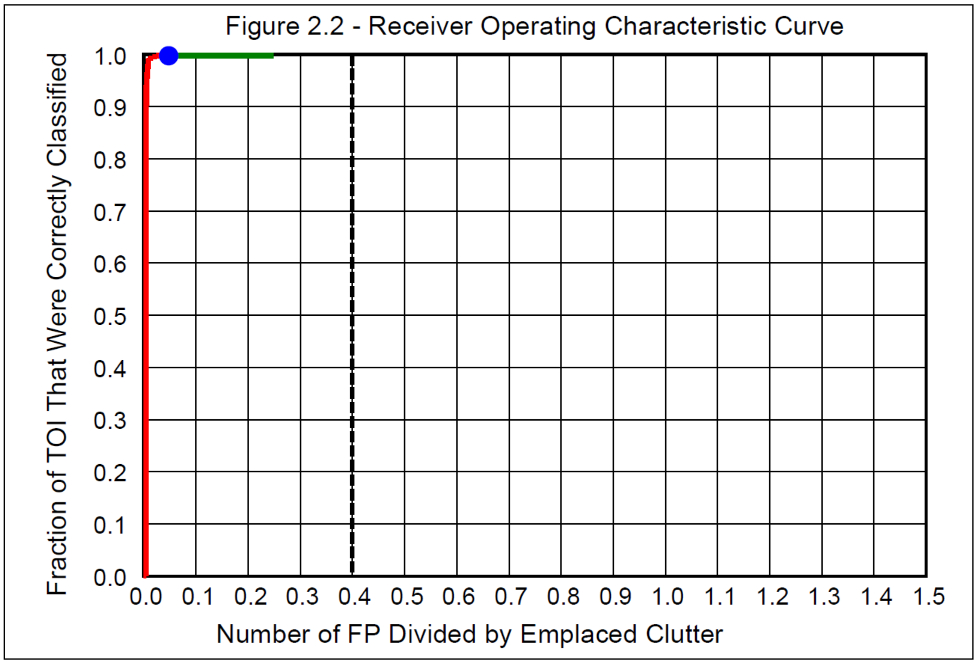


Figure 69. ROC Curve from Our Initial Dig List Submittal.

Table 7. Missed TOI from the Initial Dig List Submittal.

Item	ID	Easting (m)	Northing (m)	Depth (m)	Scoring
395	105mm	402,884.01	4,369,625.78	0.620	Not Detected

The EMI-based decision process involves generating multiple possible solutions that explain the measured data to varying degrees. Because the UX-Classify solver generates solutions assuming a single source, two sources, and three sources, for example, six possible solutions are generated for each inverted data chip. This process is automatically performed in an attempt to accurately determine if one, two, or three distinct pieces of metal are present within the sensor's footprint. After the possible sources are generated, decision logic is used to determine which one, or which ones, need to be reported as TOI so that their XY locaton is recorded.

Upon investigation, AcornSI realized that the TOI in question was left off the dig list due to faulty decision logic associated with a nearby sources. In this case, four sources in close proximity were assigned to a particular cluster for digging (e.g., within 25cm of the cluster's center, Figure 70). The southernmost source (colored blue) within the cluster was the subject TOI. The northernmost source was a Cannot Analyze. During part of the classification process, UX-Classify places Cannot Analyze sources at the top of the dig list, above the Type 1 TOI category. As part of the decision process, the faulty decision logic selected the highest ranked anomaly for digging within the cluster and reported its XY location. In other words, the Cannot Analyze source's location was selected for excavation because its rank was higher than that of the TOI, even though the TOI had a much higher decision metric. In addition, the distance from the Cannot Analyze source to the TOI was greater than that allowed for a decision – so the scoring software believed the TOI was not detected.

After adjusting the relevant decision logic to prioritize decision metric values within excavation clusters instead of rank, the reported XY location for this cluster was moved to that of the TOI – which resulted in a successful classification. Section 7 above reports on the second scoring submittion that was generated after correcting the logic error.

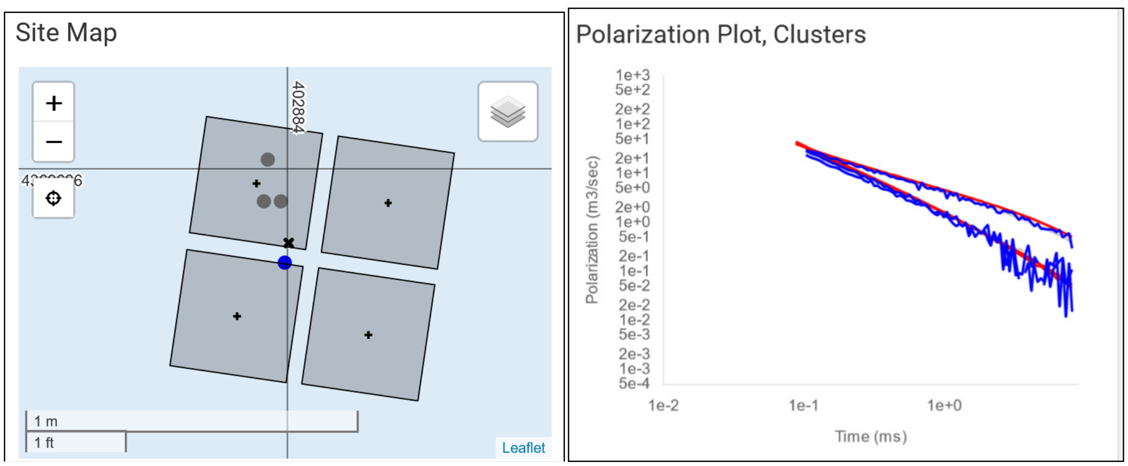


Figure 70. Left - Schematic Showing the Cluster of Sources Associated with the Non-Reported, or Missed, TOI. The Blue Dot Represents the Location of the Subject TOI. The Polarizations and Library Match for this Source Are Shown on the Right.

The library match details include a match metric of 0.995 and a match type of a 105mm projectile.