TRAINING MATERIALS

The Application of Advanced Geophysical Classification in Support of Munitions Response Program- An Outreach to Federal, State and Local Regulators and Tribal Governments

ESTCP Project MR-201590-T2

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Department of Navy, NAVFAC-EXWC

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Naval Facilities Engineering Service Center

Distribution Statement A
This document has been cleared for public release
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14. ABSTRACT
The course was designed to teach California’s regulators about the AGC technology, the benefits of the technology, and implementation issues. Course topics included: a history of the Military Munitions Response Program; the development and testing of the AGC technology; an explanation of how the technology works; what are the quality assurance and quality control requirements of the AGC technology; contractor accreditation; and several class exercises. AGC has already been used on some munitions response sites in California, and it is expected to be proposed for use on more projects in the state, particularly for the investigation phase and the remedial action phase.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:
   a. REPORT U
   b. ABSTRACT U
   c. THIS PAGE U

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   UU

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The Application of Advanced Geophysical Classification in Support of the Munitions Response Program:
An Outreach to Federal, State, Local Regulators and Tribal Governments

November 1-2, 2016
California’s Department of Toxic Substances Control
Cypress, CA
<table>
<thead>
<tr>
<th>Time</th>
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<tr>
<td>0830-0900</td>
<td>Welcome &amp; Introduction plus Ice Breaker</td>
<td>John Scandura &amp; Roman Racca</td>
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<td>0900-0950</td>
<td>Purpose- How Did We Get Here...A 30 year Journey</td>
<td>Jim Austreng &amp; Doug Maddox</td>
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<td>0950-0955</td>
<td>Mini-break</td>
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<td>0955-1035</td>
<td>DoD $14B Liability, DERP Goals and Problem with Status Quo</td>
<td>Andy Schwartz</td>
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<td>1035-1045</td>
<td>Break</td>
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<td>1045-1115</td>
<td>ESTCP- Demonstration Program</td>
<td>Bryan Harre</td>
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<td>1115-1215</td>
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<td>1215-1445</td>
<td>The Physics- and 3-D modeling &amp; breaks as needed</td>
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<td>Commercial Application- VSP &amp; Vertical CSM</td>
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<td>1545-1600</td>
<td>Intro To QAPP</td>
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<td>0845-1030</td>
<td>QAPP &amp; breaks as needed</td>
<td>John Jackson</td>
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<td>QAPP Exercise</td>
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<td>1215-1300</td>
<td>Accreditation, Regulatory Perspectives and 3rd Party QA</td>
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<td>Summary</td>
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<td>1600-1800</td>
<td>Final Exam</td>
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</table>
Advanced Geophysical Classification

How we got Here - A 30 year journey

Jim Austreng, P.E.
NAVFAC Engineering and Expeditionary Warfare Center (EXWC)
Environmental Restoration Technology Development (EV31)
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Port Hueneme, CA 93043
(805) 982-1660
Framework

- Interactive, i.e., avoid DBPP (Death By Power Point)
- History of AGC Development
- Understand the physics supporting AGC (does not mean we expect you to be a geophysicist)
- Systematic Planning and UFP-QAPP
- Limitations of AGC
- Quality - The new Paradigm
Key Terminology for AGC

- **Detection Survey or Dynamic Survey**: find where metal exists underground
- **Cued Survey**: Sitting on top of anomaly to collect high SNR AGC data
- **Single-Axis Sensor**: “Traditional” metal detector
- **Multi-Axis Sensor**: “New-Tech” used for classification
- **Electromagnetic Induction (EMI)**: the fundamental basis of the technology
- **Anomaly**: Metallic item that causes a geophysical response
- **Informed Source Selection**: Smart anomaly picking
- **Clutter**: Non-hazardous metal “FRAGments” or other debris
- **Targets of Interest (TOI)**: potentially hazardous anomaly or any other item of interest
- **Classify**: Determine whether “TOI” or “Non-TOI”
- **Validate**: Prove your “classification” worked as expected
- **QC & Validation Seeds**: Key components used to “validate” the AGC process
Historical Events

• 1983 Tierrasanta Accident- not the only one, just very influential
• 1986 Superfund Amendments and Reauthorization Act/DERP
• 1988 Base Realignment And Closure Act (1st Round)
• 1990s Proposed Range Rule and Range Rule Risk Methodology
• 1991 Develop On Site Technology (DOIT) Committee
• 1999 Interstate Technology and Regulatory Council (ITRC) UXO Workgroup
• 2000 EPA & DOD UXO Management Principles
Search for Technical Solutions

• 1991 Develop On-site Innovative Technologies (DOIT Committee)
• 1994 U.S. House of Representatives Subcommittee Hearing
• 1999 Inaugural Session of ITRC UXO Work Group
• 2000 Fort Ord ODDS Study
U.S. House of Representatives Subcommittee Hearing

• Members: DoD, DOI, DOE, EPA and Western Governors’ Association

• DOIT UXO Sub-Committee 1994 – Push for Innovative Technologies, e.g., 3-dimensional imaging
Progress

• 1994-1999
  – Jefferson Proving Ground Technology Demonstration Program, Phase I – IV
Eye Opener

• JPG

Examined state of the art geophysical platforms and their capability to “...detect, classify and remove Unexploded Ordnance (UXO).”

• Phase I included Congressional mandate to test most applicable technologies at five “Live Sites”
  – Results: “The Average $P_D$ [probability of Detection]...was 0.44.”
• $P_D$ Improved through Phase II-III but tradeoff was increase number of false positives

• Phase IV (1996) focused on demonstrating discrimination capabilities
  – Early days of what is now Advanced Geophysical Classification
Analog
The Answer?
Correctly Processed
1999 ITRC UXO Workgroup

- First UXO Report: December 2000 with emphasis of demonstrating digital technologies and pursuing those with discrimination capabilities.
Transmittal Memorandum,
William Schneider, Jr.,

October 24, 2003
“The Task Force found that technology can be of dramatic help in each problem area. The current cleanup problem is massive in scale but there is a clear opportunity to save tens of billions of dollars in the total cleanup process by the use of more modern technology”

Appendix J, page 2
“We then “process the daylights” out of this data with powerful digitally implemented algorithms and data processing routines”
Survey of Munitions Response Technologies

Prepared by:

The Environmental Security Technology Certification Program (ESTCP)
The Interstate Technology & Regulatory Council (ITRC)
The Strategic Environmental Research and Development Program (SERDP)

June 2006

The publication of this document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency. Mention of specific product names or vendors does not constitute an endorsement by any of the authoring organizations.
Sensors of Choice

Typical Electromagnetic Induction Sensor

Transmit Coil

Primary Field

Induced Dipole

Secondary (Induced) Field

Wheeled EMI System
Photo courtesy of US Army

Geometrics G-858 Portable Cesium Magnetometer/Gradiometer
Photo courtesy of Geometrics

Earth’s Field
We Learned

• Dipole Modeling

• Detection Curves

• Geophysical Prove Outs
But Wait!!!
Need Geophysical Prove-Outs?

• Does not translate (or indicate) quality of field work
• Has significant statistical uncertainties
• GPO construction is not representative of site conditions
• Excess construction costs, needless document production requires two mob/de-mobs
Principal of GSV Process

- Provides documentation through the use of a physics-based approach that is transparent, objective, and provides quantifiable results allowing unbiased validation that the project data quality objectives (DQOs) and hence, the response action objectives have been met.
Paradigm Shift

- Classification - requires High Fidelity Data
- Quality from Start to finish
- Accreditation
- Not just for Classification - Quality from Start to finish
MR Response Process

Site Preparation
Vegetation and Surface Clearance, IVS, Seeding

Geophysical Data Collection
Dynamic Detection Survey, Cued Data as Needed

Analysis
Parameter Extraction, Classification, Initial Ranked Dig List

Digging
Training and Confirmation Digs until Final Ranked Anomaly List

Scoring
Evaluate Blind Seeds, Recovered TOI, Clutter Rejection
Uniform Federal Policy for Quality Assurance Project Plans

• Jointly developed by EPA, DoD, DOE
• Sets requirements for all environmental data collection, including MR data
• Provides details for
  – Specific data requirements or other information that must be collected to demonstrate conformance to requirements
  – Required data in 37 worksheets
  – Emphasis on systematic planning

California Department of Toxic Substances Control- November 1-2, 2016
## QAPP Worksheet for Classification

<table>
<thead>
<tr>
<th>Worksheet #</th>
<th>Title</th>
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<tbody>
<tr>
<td>1 &amp; 2</td>
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<tr>
<td>20</td>
<td>Quality Control and Corrective Action</td>
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<tr>
<td>3 &amp; 5</td>
<td>Project Organization and QAPP Distribution</td>
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<td>21</td>
<td>Field and Data Analysis SOPs</td>
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<td>4, 7, &amp; 8</td>
<td>Personnel Qualifications and Sign-off Sheets</td>
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<td>22</td>
<td>Field Equipment Calibration, Maintenance, Testing and Inspection</td>
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<td>6</td>
<td>Communication Pathways</td>
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<tr>
<td>29</td>
<td>Project Documents and Records</td>
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<tr>
<td>9</td>
<td>Project Planning Session Summary</td>
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<td>31</td>
<td>Planned Project Assessment</td>
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<tr>
<td>10</td>
<td>Conceptual Site Model</td>
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<tr>
<td>32</td>
<td>Change Control Document</td>
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<td>11</td>
<td>Data Quality Objectives</td>
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<td>33</td>
<td>QC Management Reports</td>
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<td>12</td>
<td>Measurement Performance Criteria</td>
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<td>37</td>
<td>Data Usability Assessment</td>
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<tr>
<td>13</td>
<td>Secondary Data Uses and Limitations</td>
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<tr>
<td>34</td>
<td>SAP Verification</td>
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<td>14 &amp;16</td>
<td>Project Tasks and Schedule</td>
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<td>35</td>
<td>SAP Validation</td>
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<td>17</td>
<td>Sampling Design and Project Work Flow</td>
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<td>36</td>
<td>Product QC Tier 3 Summary Report</td>
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Worksheet Not Used for Geophysical Classification

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<tr>
<td>15</td>
<td>Project Action Limits and Evaluation</td>
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<td>Analytical Methods/SOP Requirements</td>
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<td>20</td>
<td>Field Quality Control Sample Summary</td>
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<td>23</td>
<td>Analytical SOP References</td>
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<td>24</td>
<td>Analytical Instrument Calibration</td>
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<tr>
<td>25</td>
<td>Analytical Instrument &amp; Equipment Maintenance, Testing and Inspection</td>
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<tr>
<td>26</td>
<td>Sample Handling System</td>
</tr>
<tr>
<td>27</td>
<td>Sample Custody Requirements</td>
</tr>
<tr>
<td>28</td>
<td>Laboratory QC Samples Table</td>
</tr>
<tr>
<td>30</td>
<td>Analytical Services Table</td>
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</table>
Assemble the Geophysical Platform (MetalMapper, etc.,) and verify correct operation
Test Sensor and System at the IVS
Production Area Seeding
Collect Dynamic Data Using the advanced geophysical platform
Preprocess Dynamic Data and Identify Anomalies
Collect Static Background Measurements
Collect Cued Target Measurements
Verify Usability of Advanced Sensor Data
Background Correct Cued Anomaly Data
Invert anomaly data to extract source parameters
Compare extracted parameters to MEC signatures in the data library
Develop prioritized dig list using library matching and other factors
Verify recovered objects are compatible with predictions based on the advanced sensor data
Develop verification sampling dig list and perform verification sampling
Quality Throughout the Process

- Avoid Garbage in, Garbage out
Knowledge Test #1

Classification – a Paradigm Shift for Munitions Response
Questions?
Back Up Slides
Courtesy of Les Clarke, Battelle
MILITARY MUNITIONS RESPONSE PROGRAM (MMRP)

Advanced Geophysical Classification (AGC)
USACE NATIONWIDE CLEAN-UP PROGRAM

*Does not include USACE clean up work at Army, AF, NGB, and Reserve Installations

- **FUDS (Formerly Used Defense Sites)** – Mostly WWI, WWII, and later military sites
- **FUSRAP (Formerly Utilized Sites Remedial Action Program)** – Low-level radioactive, non-DOD sites, including DOE Atomic Energy Era projects
- **BRAC** – Current Projects
- **BRAC** – Closed Projects
- **SUPERFUND (National Priorities List)** – Former **Industrial** sites with hazardous waste; USACE work for EPA

US Army Corps of Engineers.
DERP Fiscal Year 13 Annual Report To Congress: MMRP CTC ~$13B
Fiscal Year 17 ER(IRP & MMRP) Budget Request: $1.3B
Fiscal Year 17 MMRP Budget Request: $221.1M
($13B/$221.1M/year=59 years)

Total Number Of DERP Projects
- Army
- BRAC
- FUDS
THE REALLY BIG PICTURE – AT THE TOP

DoD Instruction (DoDI) 4715.07, Defense Environmental Restoration Program (DERP), May 21, 2013
DoD Manual (DoDM) 4715.20, Defense Environmental Restoration Program (DERP) Management, March 9, 2012
THE REALLY BIG PICTURE – DERP INSTRUCTION

DoD Instruction (DoDI) 4715.07, *Defense Environmental Restoration Program (DERP)*, May 21, 2013

- Establishes policies, assigns responsibilities, and provides procedures for implementing the DERP
- Establishes DoD’s Interim Risk Management (IRM) policy
  - Implement IRM, when appropriate, to reduce potentially significant threats to human health at sites where DoD is not expected to conduct an investigation, removal action, or remedial action for an extended period of time
- Designates the Secretary of the Army as lead agent for the FUDS program
  - Army identifies FUDS program funding requirements, conducts cleanup activities at eligible properties, and reports on progress
- Establishes the DoD Cleanup Committee
  - DoD established the FUDS Forum Working Group under the DoD Cleanup Committee
THE REALLY BIG PICTURE – DERP MANAGEMENT


– Outlines procedures and provides further guidance on the policies in DoDI 4715.07, including:
  – Environmental Restoration Account Funding
  – DERP Eligibility
  – Environmental Liability and Cost-To-Complete (CTC) Management
  – Federal Facility Agreements
  – Response Complete (RC) Determinations
  – Green and Sustainable Remediation
  – Defense State Memorandum of Agreement (DSMOA) Eligibility
  – Vapor Intrusion
  – Administrative Record Keeping
  – 5-Year Reviews
  – Restoration Advisory Boards
  – Land Use Controls
THE REALLY BIG PICTURE – DERP MANAGEMENT

DERP

DERP-Air Force
  - AF IRP
  - AF MMRP

DERP-Navy
  - Navy IRP
  - Navy MMRP

DERP-Amy
  - AEC IRP
  - AEC MMRP

DERP-FUDDS
  - FUDS IRP
  - FUDS MMRP
  - FUDS BD/BR

DERP AF
  - Policies
  - Regs
  - Guidance
  - Contracting

DERP AF
  - Policies
  - Regs
  - Guidance
  - Contracting

DERP AEC
  - Policies
  - Regs
  - Guidance
  - Contracting

DERP FUDDS
  - Policies
  - Regs
  - Guidance
  - Contracting

This is why you get so many different format!
QUICK LOOK AT FUDS
A NEW FUDS VISION:
“RESPONSE COMPLETE IN OUR LIFETIME”

FUDS Guiding Principles:

1. **Goal Focused**: Focus our efforts on leveraging annual funding towards achieving DoD IRP goals of 90% Response Complete by the end of FY18 and 95% Response Complete by the end of FY21.

2. **Creativity**: Pursue progressive acquisition strategies to address multiple FUDS projects and phases under coordinated procurements that are based on well-defined and achievable objectives.

3. **Innovation**: Effectively assess and implement advanced geophysical classification at all phases of the CERCLA process at FUDS MMRP projects in order to reduce both time and costs for munitions cleanup.

4. **Fiscal Responsibility**: Plan, resource, and execute FUDS projects based on a commitment to complete the RI/FS phase of work to within four to five years of initiation.

5. **Commitment to Excellence**: Maximize the assignment of qualified, trained, and experienced FUDS project management, technical, and support staff to serve on high performing virtual PDTs that cross traditional boundaries.

6. **Continuous Improvement**: Integrate innovative technology and optimization processes to reduce time and costs to achieve Response Complete for ongoing FUDS projects with RA-C and RA-O phases with durations greater than five years.

7. **Collaboration**: Elevate regulatory and stakeholder disagreements and delays quickly up the chain of command in order to resolve through tiered partnering or to support timely decision making to implement response actions under our DERP authorities even when regulatory or stakeholder concurrence cannot be achieved.

8. **Transparency**: Share information and findings with our regulators, stakeholders, and public and support collaborative engagements that address issues and uncertainties as part of the decision-making process.
LINKS TO FUDS INFO

• DOD DENIX FUDS Page:
  https://denix.osd.mil/fuds/overview/

• USACE FUDS Home Page:
  http://www.fuds.mil

• USACE FUDS Public GIS Page:
  http://maps.crrel.usace.army.mil:7778/publicfuds/

• USACE FUDS Forum Community Portal:
  https://www.fudsforum.org/
WHAT IS A FUDS?

Definition: Real property that was under the jurisdiction of the Secretary and owned by, leased to, or otherwise possessed by the U.S. and those real properties where accountability rested with DoD but the activities at the properties were conducted by contractors that were transferred from DoD control prior to October 17, 1986.

There are three types of FUDS:

• Installation Restoration
• Building Demolition/Building Removal
• Military Munitions Response Program

Mission: The mission for the FUDS Program is to employ a risk management approach to perform appropriate, cost-effective cleanup of contamination caused by the Department of Defense and to protect human health, safety, and the environment.
CERCLA PROCESS

Interim Remedial Actions and Removal Actions may occur at any time during the CERCLA process.

Remedy in Place (RIP) is an important milestone in the CERCLA process. At this point, cleanup systems are constructed and operational.

If the investigation determines cleanup is not required, or when cleanup work is complete, a site achieves the Response Complete (RC) milestone (a site does not have to go through every phase to achieve RC).

Site Closeout indicates that all environmental restoration requirements are complete.
LOCATION OF FUDS SITES

Total Number of FUDS Project: 5,144
Note: Territories are not shown

As of 30 Sept 2015
FUDS PROJECT DISTRIBUTION
(AS OF 30 SEP 15)

Total FUDS
5,144

- MMRP, 1,955, 38%
- HTRW, 1,189, 23%
- CON/HTRW, 1,289, 25%
- PRP/HTRW, 211, 4%
- BD/DR, 375, 7%
- MMRP/CW M, 102, 2%

FUDS Projects Remaining
1,852

- MMRP, 1,181, 64%
- HTRW, 401, 21%
- MMRP/CW M, 17, 1%
- CON/HTRW, 131, 7%
- PRP/MMRP, 14, 1%
- PRP/HTRW, 69, 4%
- BD/DR, 39, 2%
Remaining FUDS Projects

Remaining FUDS Projects not at RC: 1,852  [IRP – 640/ MMRP – 1,212]

- Northern Mariana Islands 11
- Palau (PT) 0
- Puerto Rico (PR) 33
- U.S. Virgin Islands (VI) 1
- American Samoa (AS) 6
- Guam (GM) 9

As of 30 Sep 2015
FUDS Program CTC (FY* & Beyond)

(IRP = HTRW + CON/HTRW + BD/DR)

- $18.2
- $17.9
- $16.7
- $14.1
- $14.0
- $13.2
- $12.7
- $12.9

Fiscal Year

- CTC Down 29%

*Dollars shown reflect CTC reported amounts (not adjusted for inflation)
OSD GOALS FOR FUDS

• Installation Restoration Program (IRP):
  - Achieve Response Complete at 90% of IRP and BD/DR sites on FUDS by the end of FY2018
  - Achieve Response Complete at 95% of IRP and BD/DR sites on FUDS by the end of FY2021

• Military Munitions Response Program (MMRP):
  - Implement Interim Risk Management (IRM) or initiate a Munitions Response action, to include an investigation or a removal/remedial action at FUDS MRS that have not yet reached Response Complete for 90% of the FUDS MRS inventory by the end of FY2018
## FUDS Status

<table>
<thead>
<tr>
<th>IRP &amp; BD/DR Sites</th>
<th>FY10 Actual</th>
<th>FY15 Actual</th>
<th>FY16 Planned</th>
<th>FY18 Projected</th>
<th>FY21 Projected</th>
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<td>Sites Remaining</td>
<td>734</td>
<td>571</td>
<td>502</td>
<td>325</td>
<td>169</td>
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<tr>
<td>Sites at RC</td>
<td>73%</td>
<td>80%</td>
<td>82%</td>
<td>89%</td>
<td>94%</td>
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<tr>
<th>MMRP Sites</th>
<th>FY10 Actual</th>
<th>FY15 Actual</th>
<th>FY16 Planned</th>
<th>FY18 Projected</th>
<th>FY21 Projected</th>
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</thead>
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<tr>
<td>Sites Remaining</td>
<td>1054</td>
<td>1198</td>
<td>1185</td>
<td>1148</td>
<td>1135</td>
</tr>
<tr>
<td>Sites at RC</td>
<td>38%</td>
<td>42%</td>
<td>42%</td>
<td>44%</td>
<td>45%</td>
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Data as of 30 September 2015
FUDS PROPERTIES MMRP
COST TO COMPLETE (CTC)

- EOY2015 CTC $9.00B
- Net Change (+/-) in CTC from EOY2014 to EOY2015 +$70M

So Why Advanced Geophysical Classification?
COMPETITION TIME

Need Two Volunteers
• Right Side / Left Side
• Good in Counting Theory
• There will be a prize
IN 2000, BEFORE CLASSIFICATION (BC)

We dug all of this!

8

>50
AND THEN THERE WAS...

ADVANCED GEOPHYSICAL CLASSIFICATION
IN 2016, AFTER CLASSIFICATION (AC)

We dig this!

But not all this!
ADVANCED GEOPHYSICAL CLASSIFICATION (AGC) & USACE

- AGC Technologies were used at 14 Munition Response Sites (MRSs) at 9 properties in 2015. Properties have been mainly in the Remedial Investigation/Feasibility Study (RI/FS) phase or Removal Action – Construction (RmA-C) phase.

  - Buckley Field, Camp San Luis Obispo, Culebra (4 Projects), Marpi Point Field, Mount Owen Rifle Range, Raritan Arsenal, Scioto Ordnance Plant, Waikoloa Maneuver Area (4 Projects), Ft. Ord
ESTCP CLASSIFICATION
DEMONSTRATION SITES

Our Industry’s Treatability Study

20 demonstration sites
Over 30 datasets from 3 different sensors
BENEFITS SUMMARY:
THE MMRP AGC EPIPHANY

- Cheaper
  - Dig MEC, not MD

- Better
  - QC / QA for AGC
  - Confidence in Decisions

- Faster
  - Contracting Consistency
  - Performance Consistency

- Greener
  - Fewer needless digs
  - Smaller project carbon footprint
ADDITIONAL TRAINING AND RESOURCES

- SERDP/ESTCP website contains webcasts, tutorials, and demonstration reports on the classification technology
  - [www.serdp-estcp.org](http://www.serdp-estcp.org)
- ESTCP Technology Transfer Workshops
- M2S2 Webinar Series
  - [http://www.clu-in.org/conf/tio/m2s2fy16-2_042116/](http://www.clu-in.org/conf/tio/m2s2fy16-2_042116/)
  - [http://www.clu-in.org/conf/tio/m2s2fy15-2_022615/](http://www.clu-in.org/conf/tio/m2s2fy15-2_022615/)
  - [http://www.clu-in.org/conf/tio/m2s2fy14-3_022514/](http://www.clu-in.org/conf/tio/m2s2fy14-3_022514/)
  - [http://www.clu-in.org/conf/tio/m2s2-3_042213/](http://www.clu-in.org/conf/tio/m2s2-3_042213/)
- Interstate Technology Regulatory Council (ITRC) Geophysical Classification For Munitions Response: [http://www.itrcweb.org/gcmr-2/](http://www.itrcweb.org/gcmr-2/)
  - Archived web training: [https://clu-in.org/conf/itrc/GCMR_011416/](https://clu-in.org/conf/itrc/GCMR_011416/)
QUESTIONS?
Topic 3 – Summary of ESTCP Demonstrations 2007 to Now

Bryan Harre
NAVFAC EXWC
Enabling Objectives

- Identify investigation/removal site types where advanced geophysical classification was performed
- Discuss munitions types and combinations of munitions used at the demonstration sites
- Describe the anomaly density and geologic noise that can impact classification performance
- Explain the cost savings that advanced geophysical classification can provide
ESTCP Demonstration Sites

ESTCP-sponsored demonstrations at over 25 sites
## Summary of Demonstration Sites

<table>
<thead>
<tr>
<th>Degree of Difficulty</th>
<th>Characteristics</th>
<th>Example Demonstration</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Limited munitions types, low anomaly density, terrain and vegetation allow for high quality data collection, no geologic interference</td>
<td>Pole Mountain, WY Camp George West, CO SW Proving Ground, AR</td>
<td>Almost all analysts correctly classify all seeds, eliminate ~90% of the clutter from the final dig list</td>
</tr>
<tr>
<td>Typical</td>
<td>Mixed munitions, none smaller than 37-mm, low to moderate anomaly density, terrain and vegetation allow for high quality data collection, moderate geology</td>
<td>Spencer Range, TN Camp Beale, CA</td>
<td>Most analysts correctly classify all seeds, eliminate ~70% of the clutter from the final dig list</td>
</tr>
<tr>
<td>Difficult</td>
<td>Mixed munitions, smaller than 37-mm TOI, high anomaly anomaly density, conditions make data collection challenging, complex geology</td>
<td>Massachusetts Military Reservation, MA</td>
<td>Even the most skilled analysts may not detect all TOI, eliminate ~50-70% of the clutter from the final dig list</td>
</tr>
</tbody>
</table>

### Expectations for Easy, Typical, and Hard Sites

- **Easy Sites**: Limited munitions types, low anomaly density, terrain and vegetation allow for high quality data collection, no geologic interference. Almost all analysts correctly classify all seeds, eliminate ~90% of the clutter from the final dig list.
- **Typical Sites**: Mixed munitions, none smaller than 37-mm, low to moderate anomaly density, terrain and vegetation allow for high quality data collection, moderate geology. Most analysts correctly classify all seeds, eliminate ~70% of the clutter from the final dig list.
- **Difficult Sites**: Mixed munitions, smaller than 37-mm TOI, high anomaly anomaly density, conditions make data collection challenging, complex geology. Even the most skilled analysts may not detect all TOI, eliminate ~50-70% of the clutter from the final dig list.
Demonstrator Results

- Not all demonstrators are equal
  - Major reason DoD has implemented the DoD Advanced Geophysical Classification Accreditation Program (DAGCAP)

Photo courtesy of ESTCP.
Munitions Types and Combinations of Munitions

- Larger munitions are easier to classify than smaller munitions and classification is easier on sites with fewer different types of munitions.
- Smaller 37mm look more similar to the clutter to the sensor, particularly the fragments left by the detonation of larger items.
- 20mm look even more like clutter and will impact the economics of using classification.
- 37mm projectiles combined with other larger munitions are routine to classify.

ISO80 and 37mm Projectile. Photo courtesy of ESTCP.
Anomaly Density

- Detection survey typically used by project team to identify areas too dense for classification
- Portions of site may require a different approach, i.e. mag and flag or sifting
Geologic Background Variation (1)

Geologic Background Variation at the former Camp Beale

Graphic courtesy of ESTCP.
Geologic Background Variation at Waikaloa

Graphic courtesy of ESTCP.
Target of Interest (TOI) Signature Library

Collection of TOI signatures:
1. Metadata,
2. Sensor data
3. Polarizations

ESTCP generated
DOD maintained
Unexpected Munitions

- Beale – Digging uncovered a number of fuze parts that had not previously been identified. Explosives safety experts determined that these fuze parts were not hazardous, and not a TOI.

- Fort Sill – Presence of six “hollow steel ball assemblies,” which are hazardous components of the 40-mm grenades known to be present on the site.

- Involve Explosives Safety Specialists early in the planning process, and transmit knowledge of hazardous components to the analysts.

- Classification is robust to the presence of unexpected munitions on the site and procedures to process the data are now standardized.
Munitions Size

- Classification can identify the approximate size of munition
- Significant Benefit in reducing the Explosives Safety Quantity Distance Arc

Classification by size.
Advanced EMI Sensor developed by ESTCP

Multiple coils measure the complete response of buried items (spatially and temporally)
# Advanced Geophysical Classification Sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Description</th>
<th>Applicability</th>
</tr>
</thead>
</table>
| MetalMapper | • 1-meter cube  
• 3-axis transmit  
• Seven 3-axis 10-cm receive cubes  
• Continuously samples to 8 ms after transmitter turn-off | • Dynamic and cued modes  
• Requires vehicle to maneuver  
• Require GPS  
• Depth capability similar to EM61 – comparable transmit moment  
• Commercially available |
| MetalMapper 2X2 | • Four 35-cm transmitters  
• Four 8-cm, 3-axis receive coils centered in each transmitter  
• Overall dimension 80cm square  
• Backpack 15 pounds  
• Continuously samples to 25 ms after transmitter turn off | • Dynamic and cued modes  
• Cart and litter-carried deployment  
• Does not require GPS, but available  
• Will have less depth capability due to smaller transmit moment  
• Commercially available |
| MPV         | • 50-cm diameter transmitter – one dimension only  
• Five 3-axis 8cm receiver cubes  
• Can be manipulated in 3D to get multiple looks at the target  
• Carried on a wand, 12 pounds  
• Continuously samples to 8 ms after transmitter turn off | • Dynamic and cued modes  
• Small and maneuverable for wooded areas and challenging terrain  
• Does not require GPS to operate  
• Uses locating beacon  
• Will have less depth capability due to smaller transmit moment  
• Can be contracted through developer |
Dynamic Surveys with Advanced Sensors

- Advanced sensors for detection produce data that has higher spatial resolution and allow the use of advanced sensor data to make smarter anomaly selection decisions.

- Dynamic data
  - Informed Source Selection, a filtering step is used to identify only those anomalies that could have been caused by a metal object with the characteristics of a TOI, for example one that is well-modeled by a dipole.
  - Make classification decisions using intrinsic target parameters extracted from the dynamic data only.
Lessons Learned - Applicable at Most Sites But Not All

ESTCP-sponsored demonstrations at over 25 sites

Maybe Not Applicable

- Anomaly densities over ~4000 per acre
- Extensive geologic background
- Landfills and disposal pits
- OB/OD areas
- Almost all items are TOI
Potential Savings on a 100-acre Remediation

Current Practice

80% Reduction of Clutter

45% Savings

- Mob/Demob
- Surface Sweep
- IVS & Seeds
- Detection Survey
- Cued Data
- Dig UXO & Seeds
- Dig Clutter
Fun Facts About the Sites

- There are few native TOI on most sites. Their abundance ranged from 0.04% of the total 11 number of items dug at SWPG to 1.5% at Camp George West.
- Depth distribution of the native clutter is very similar for wide range of sites. On all six example sites, the depth distribution peaks in the top 10 cm and on four of the six, the vast majority of clutter was in the top 20 cm.
- Seed plans for the demonstrations, which were meant to put seeds at representative depths, were in fact conservative. Most of the TOI were found at depths shallower than the seeds were emplaced.
Additional Training and Resources

- SERDP/ESTCP website contains webcasts, tutorials, and demonstration reports on the classification technology
  - www.serdp-estcp.org
- ITRC has web document and online training
Summary

- Commercially available sensors - MetalMapper and MetalMapper 2x2 are available for sale or rental
- Analysis Software: The UX Analyze classification software has been incorporated into the GeoSoft Oasis Montaj platform
- Signature Library: ESTCP has assembled a comprehensive library of signatures of common munitions
- Quality Assurance Project Plan: The Environmental Data Quality Work Group, supported by ESTCP, has developed a QAPP template
- Experienced contractors: 10 companies have participated in the ESTCP demonstrations
- Accreditation Program: DoD has mandated an accreditation program for contractors
- Informed regulators: ESTCP has incorporated the input of regulators throughout the demonstration program
Questions
Navy Training
Advanced Geophysical Classification

John M. Jackson
Geophysicist
USACE- SPK/EMCX
Outline

- Why Classification
- How it Works
- Example Workflow and QC/QA – Former Camp San Luis Obispo Example
- Summary

Acknowledgements

- SERDP & ESTCP
- Camp San Luis Obispo PDT
  - CESPL, California EPA, ESTCP, CH2M Hill
Costs Are Dominated By Digging Scrap

- Often <1% are UXO
- Example: Camp Butner, NC
  - 146 UXO out of >500,000 digs
  - Only 0.03% are UXO!
What Is Classification?

- Attempts to assign an input value to one of a given set of *classes* based on some *attributes* of the input
  
  ❚ Is the incoming e-mail “spam” or “not-spam”?
  
  ❚ Is the buried object that caused this anomaly “UXO” or “not-UXO”?
  
à la Wikipedia

BUILDING STRONG®
How Do We Classify Munitions?
If It’s Going To Work...

- It’s got to be a principled, data-based approach to classify targets as either “non-hazardous” or “targets of interest”

1. Data Acquisition
2. Feature estimation
3. Classification

Feature vector
How It Works
Echolocation: a Familiar Analogy

- Acoustic waves...locating objects by reflected sound. Used by dolphins and bats...

Interesting fact: what causes the sound reflection?
Electromagnetic Induction Sensors - Review

Typical Electromagnetic Induction Sensor

Excitation Pulse
Electromagnetic Induction Sensors (cont.)

Typical Electromagnetic Induction Sensor

Induced Target Response
Electromagnetic Induction Sensors (cont.)

Typical Electromagnetic Induction Sensor

- Voltage vs. Time (ms)
- Induced Flux
- Transmit Coil
- Receive Coil
- Secondary (Induced) Field
- Induced Dipole Moment

Senses Induced Field

Horizontal

Nose Down
We’ve seen how the methods are similar, here is one major difference…

**Distance**: Using echolocation, Dolphins can detect a 2.54cm sphere at 73m!

**Your chance to shine…**
At what distance can EMI methods detect a 2.54cm metallic sphere?

**Answer**: 0.4m

![Detection Distance of a 1-inch Sphere](chart)

EMI response is inversely proportional to the Distance^6 (sensor to object).

The sensors have to be very close to the object in order to detect and characterize buried objects!
A Term You Need To Know: Polarizability

- A set of values that fully describe the decay of electromagnetic fields that have been induced in an object by an external EM source, after the external EM source is removed. Polarizability values exist for each of the object’s three principal axes.

- They are used here:
  - The EMI Dipole Model

\[
V(t) = \mu_0 n_R n_T I_0 C_R \cdot C_T B(t)
\]

- The EM Signal We Measure
- Sensor properties & Geometry of the sensor wrt target
- Target properties (polarizabilities)
Principal Axis Responses

- Normalized response (polarizability) for excitation in object’s principal axis directions are the fundamental EMI attributes.
- UXO items are symmetrical, so two of the principal axis responses are the same.
- Irregular clutter items have three different principal axis responses.

Key Point: Munitions are symmetrical, which is used to identify them.
A Simple Analogy

Name That Object…
A Simple Analogy

Name That Object…

Top View
(compare to “Top View Polarizability”)

Front View
(“Front View Polarizability”)

Side View
(“Side View Polarizability”)
Multiple Measurements are Required to Completely Characterize a Target with a Single-Axis Sensor (cont.)

At each position the field lines only intersect the target in one direction
Multiple Measurements are Required to Completely Characterize a Target with a Single-Axis Sensor (cont.)

At each position the field lines only intersect the target in one direction
Multiple Measurements are Required to Completely Characterize a Target with a Single-Axis Sensor (cont.)

At each position the field lines only intersect the target in one direction.
The Trick Is Illuminating Each Axis With a Tx Pulse
This is what Advanced EMI Sensors look like

- Multiple coils measure the complete response of buried items (spatially and temporally)
Advanced EMI Sensors: designed for UXO classification

Multiple transmitters and receivers are used to fully ‘light up’ or illuminate the object
Measured data are affected by burial depth and object orientation.
Measured data are affected by burial depth and object orientation
Measured data are affected by burial depth and object orientation.
Measured data are affected by burial depth and object orientation.
Measured data are affected by burial depth and object orientation.
Polarizabilities do not change with burial depth or orientation
Advanced Classification Is Inherently A Three-Step Process

1. Collect Field Data
   - Specialized, classification-specific instruments

2. Get fingerprint for each detected anomaly
   - Field Data
   - Specialized Software
   - Trained Analyst

3. Assess if the fingerprint is something we need to be concerned about
   - Polarizabilities
   - Library fingerprints of things I’m concerned about
   - Specialized Software
   - Trained Analyst
How Do We Get Those Fingerprints?

- Another Term you need to know: ‘Geophyiscal Inversion’
  - a.k.a. Backward model!
This Is A Forward Model

Given this:

For each value of $x$ we can calculate $y$

$y = 6x^2 + 4x - 8$

And we can graph it

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>138</td>
</tr>
<tr>
<td>-4.5</td>
<td>111.5</td>
</tr>
<tr>
<td>-4</td>
<td>88</td>
</tr>
<tr>
<td>-3.5</td>
<td>67.5</td>
</tr>
<tr>
<td>-3</td>
<td>50</td>
</tr>
<tr>
<td>-2.5</td>
<td>35.5</td>
</tr>
<tr>
<td>-2</td>
<td>24</td>
</tr>
<tr>
<td>-1.5</td>
<td>15.5</td>
</tr>
<tr>
<td>-1</td>
<td>10</td>
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<tr>
<td>-0.5</td>
<td>7.5</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
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<tr>
<td>0.5</td>
<td>11.5</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>1.5</td>
<td>27.5</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>2.5</td>
<td>55.5</td>
</tr>
<tr>
<td>3</td>
<td>74</td>
</tr>
<tr>
<td>3.5</td>
<td>95.5</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td>4.5</td>
<td>147.5</td>
</tr>
<tr>
<td>5</td>
<td>178</td>
</tr>
</tbody>
</table>
This Is A Backward Model (aka Inversion)

Given this:

We can make educated guesses on the formula...

Until we get it correct
From Field Data to Predictions

TEM TADS Field Data

Inversion Process

Sensor/Geometry Target properties (polarizabilities)

EM signal

Predicted Parameters of the Buried Object

4 Tx × 4 Rx × 3 coils/Rx × 50 channels/Rx coil = 2,400 measurements per anomaly

\[ V(t) = \mu_0 \mu_R n_T I_0 C_R \cdot C_T B(t) \]
From Field Data to Predictions

The software sequences through geometry & polarizabilities and calculates theoretical responses.

**EMI response model**

\[ V(t) = \mu_0 n_R n_T I_0 C_{R} C_{P}(t) \]

1. **Sensor Design & sensor**
2. **Polarizabilities**
3. **Mystery Object Location \((x,y,z)\) & orientation \((\theta,\phi,\phi)\)**
4. **Field Data**

Software stops when theoretical response matches TEMTADS data.

(1) Field Data
(2) Sensor Design & sensor
(3) Polarizabilities
(4) Mystery Object Location \((x,y,z)\) & orientation \((\theta,\phi,\phi)\)

From Field Data to Predictions
Once We Have The Fingerprint…We Classify!

- Classification via template matching

0.58
...too large for 37mm

0.75
...too small for 105mm

0.99
...just right. MATCH

...37mm

...105mm
Polarizability Examples “EMI Fingerprints”

Graphics courtesy of ESTCP.
Polarizabilities completely specify the target’s EMI response characteristics

<table>
<thead>
<tr>
<th>Object Property</th>
<th>Polarizability Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical Shape</td>
<td>Axial Symmetry</td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>Decay Rate</td>
</tr>
<tr>
<td>Physical Size</td>
<td>Magnitude</td>
</tr>
</tbody>
</table>
What If...

- Someone thinks there’s a UXO out there that’s not in my library?
  - First: make sure it makes sense
  - Then
    - Add it if you can
    - Look for obvious traits

  ...Big, Ugly & Scary
  (i.e. large, axial symmetry and thick walled)
What If…

There are groups of things with the same fingerprint that I don’t know about?

We call this: Analyze for clusters

How it works:

1- Select one of the inversion solutions to be the basis of the analysis
2- Rack & Stack every other inversion solution
3- Compare each of (2) to (1), one by one
   If (2) similar to (1) then add to the (1) group

This is just like library matching, except the fingerprint in (1) is “the library” for each run
Cluster Analysis Basics

- Some Cluster Analysis Basics
  - Need to select a match metric
    - 0.95 is common
  - Decide on a minimum number of items that defines “group”
    - Have seen numbers such as 3, 4, 5, 10
  - Only use inversion solutions that pass all QC
  - Have an expert on your team!

Let’s see how this works using 0.95 match metric
Analyze For Clusters Example

Set this as our “Library”

x: 438739.55
y: 3743932.28
z: -0.09
Phi: 180.0
Theta: 1.5
Psi: 16.0
Analyze For Clusters Example

Rack & Stack’em…
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature
aka “The Library”

0.82

0.34

The Stack

0.34
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature
aka “The Library”
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”

get A.

\[ x: 438739.55 \quad \text{Phi: 180.0} \]
\[ y: 3743932.28 \quad \text{Theta: 1.5} \]
\[ z: -0.09 \quad \text{Psi: 16.0} \]

get B.

\[ x: 438741.07 \quad \text{Phi: 350.0} \]
\[ y: 3743933.38 \quad \text{Theta: 60.4} \]
\[ z: -0.08 \quad \text{Psi: -15.7} \]

get C.

\[ x: 438741.31 \quad \text{Phi: 163.4} \]
\[ y: 3743933.02 \quad \text{Theta: 8.9} \]
\[ z: -0.03 \quad \text{Psi: -7.6} \]
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature
aka "The Library"
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”

- **A**
  - x: 438739.55
  - y: 3743932.28
  - z: -0.09
  - Phi: 180.0
  - Theta: 15
  - Psi: 16.0

- **B**
  - x: 438740.50
  - y: 3743937.73
  - z: -0.18
  - Phi: 177.5
  - Theta: 45.8
  - Psi: -7.7
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”

get A.

\[ \begin{align*}
x & : 438739.55 \\
y & : 3743932.28 \\
z & : -0.09 \\
\Phi & : 180.0 \\
\Theta & : 15.5 \\
\Psi & : 16.0
\end{align*} \]

get B.

\[ \begin{align*}
x & : 438740.50 \\
y & : 3743937.73 \\
z & : -0.18 \\
\Phi & : 177.5 \\
\Theta & : 45.8 \\
\Psi & : -7.7
\end{align*} \]

0.11
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature aka “The Library”
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature
aka “The Library”
Analyze For Clusters Example Match Better Than 0.95?

The basis of comparison signature aka "The Library"
Analyze For Clusters Example

Match Better Than 0.95?

The basis of comparison signature
aka “The Library”

And on...and on...and on...
Compare each signature to all other signatures on site

- look for clusters (groups of items with similar response)
- most clusters correspond to things we know about, like these two examples

![Graphs showing 155mm Match and ISO Match with Library, Unknown, and Similar Unknowns plotted against time (ms) and polarizability.](image-url)
Compare each signature to all other signatures on site

- If there are clusters of items that do not match the library signatures, we excavate some of them and proceed accordingly…

![Graph showing polarizability over time](image)

No Library Match

- T-Bar Fuze
  - Non-hazardous clutter, did not add to library
Classification Techniques
Summary

- **Library Matching**
  - Asks what an unknown target “looks like” in EMI sense
  - Compares polarizability against bank of signatures for expected munitions and other training objects

- **Be a Cluster of things of interest**
  - Same-shaped objects have the same polarizabilities
  - Groups of identical things that turn out to be UXO

- **Be Large, long, axisymmetric and thick-walled**
Something New…sort of…

- **Informed Source Selection** (formerly called Informed Source Identification and Selection until Abu Bakr al-Baghdadi was named as Caliph!)

How it works

- Uses new sensors in dynamic (detection) mode
- Collects lower volume of data, at a much higher rate (~10Hz vs. 0.01-0.03Hz)
- Uses same inversion process to get size and wall thickness
- Culls really small anomalies off the cue list
Two Stage Process

- **Stage 1:** Find anomaly locations
- **Stage 2:** Calculate parameters and screen
Stage 1: Detect Anomalies

Two ways of doing this:

**Look For Peaks**
- TEMTADS TzRz Signal

**Look For Metal**
- Dipole Inversion Output
Detect Anomalies: Look For Peaks

**WAIT! What Threshold Do We Use?**

- **Three-steps process:**
  - **Step 1:** Calculate threshold for vertical (z) component data
    - All calculations for smallest or most difficult TOI to detect
    - All calculations for worst case scenario
    - Artificially add noise & superimpose on real site data
Detect Anomalies: Look For Peaks

**WAIT!** What Threshold Do We Use?

Step 2: Synthetic Seeding & Monte Carlo Simulations

Can Do This For Any Number Of TOI (shown here: 20mm TP added at white triangle locations)
Step 3: Invert & Analyze All Monte Carlo Simulations

- Run regular inversion at each detected anomaly (figure below)
- Adopt a conservative approach: only anomalies that can be declared non-TOI with high confidence can be removed

Example for 3 small artificially seeded TOI:
20mm TP (orange circles)
20mm AP (yellow circles)
37mm AP (grey stars)

→ all other detected anomalies: Purple dots
Detect Anomalies: Look For Metal

- Invert a square meter of data every 10cm assuming a smallest TOI or larger piece of metal is present
- Resulting Map = How well inversion matches data
Where We Are Now
Diversity of Deployment Platforms

► MetalMapper

Ellis

Hawthorne

Sibert

MMR
Diversity of Deployment Platforms

► TEMTADS 2x2

Ft. Bliss

New Boston

MMR

Spencer
Diversity of Deployment Platforms

♦ MPV

New Boston Dynamic (GPS or Line/Fiducial)

New Boston Cued (local Beacon positioning)

Spencer Dynamic (GPS or Line/Fiducial)

Spencer Cued (local Beacon positioning)
## Potential Savings on a 100-acre Site

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Cost</th>
<th>Classification</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mob/Demob</td>
<td>1</td>
<td>$25,000 range: $15,000 to $30,000</td>
<td>same as traditional</td>
<td>$25,000</td>
</tr>
<tr>
<td>Surface Sweep</td>
<td>acre</td>
<td>$1,500 range: $500 to $5,000</td>
<td>same as traditional</td>
<td>$150,000</td>
</tr>
<tr>
<td>IVS</td>
<td>each</td>
<td>$6,000 One day of three-person crew</td>
<td>same as traditional</td>
<td>$6,000</td>
</tr>
<tr>
<td>Seed Emplacement</td>
<td>per day</td>
<td>$5,250 assumes 25 seeds emplaced per day, crew size of 3</td>
<td>= 200 QC + 200 validation</td>
<td>$84,000</td>
</tr>
<tr>
<td>EM61 Data Collection and Analysis</td>
<td>acre</td>
<td>$1,000 range: $1,000 with array to $5,000 with single sensor</td>
<td>= 100 acres * TMTADS costs</td>
<td>$600,000</td>
</tr>
<tr>
<td>Dynamic TEMTADS Collection and Analysis</td>
<td>acre</td>
<td>$6,000 range: $3,300 to $5,500</td>
<td>= 50% reduction from advanced analysis</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Cued TEMTADS Collection and Analysis</td>
<td>per anomaly</td>
<td>$40</td>
<td>= seeds * cost per dig</td>
<td>$48,000</td>
</tr>
<tr>
<td>Intrusive Investigation</td>
<td>per dig</td>
<td>$120 range: $75 to $200</td>
<td>same as traditional</td>
<td>$120</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$6,697,500</strong></td>
<td></td>
<td><strong>$3,561,000</strong></td>
</tr>
</tbody>
</table>
Not Only Direct Cost Savings

- Fewer holes $\rightarrow$ less environmental damage
  - Wetlands
  - Sensitive environments
  - Golf courses
- Fewer digs $\rightarrow$ less disruption and fewer evacuations
Is Classification Applicable at This Site?

- **If EM61 or Magnetometer Today, Then YES!**
- **What are the targets of interest at this site?**
  - Historical research
  - Recovered munitions and fragments/scrap
  - Depth and density

Photo courtesy of Estrella Warbirds Museum
Classification Planning

- What classification sensor is appropriate for the site?
  - Benign terrain
    - MetalMapper
  - Rougher terrain with steeper slopes and trees
    - TEMTADS 2x2, MPV, Handheld BUD

Photos courtesy ESTCP
Classification Planning (cont.)

- What parts of the site have an anomaly density that will allow classification to be successful and at what cost?
  - Small sites and densities greater than 3K to 4K per acre may not be appropriate
  - For sites with few anomalies, the costs of remediation must justify the extra expense required for data collection
    - Wetlands, chemical sites, sensitive habitat, disruptive evacuations, land owner needs, public interest etc.

Landfill Surprise

Not Appropriate

40-mm Anti-Aircraft Projectile

Appropriate

Photos courtesy U.S. Navy
Classification – Where We Stand And What It Means

It works a lot better than we imagined
► Even with seven different UXO in the site
► Even with 37mm projectiles
► Even in up to 4,000 anomalies per acre

Former Camp San Luis Obispo
37 mm projectiles to 155mm projectiles
Example
Full-Scale Application
Example Site

- University owned
  - No access restrictions
  - Cattle grazing
  - Geotechnical classes
  - Camping
- Multiple, overlapping range fans
- MRS ~ 2,500 acres
- 100 acres in Year 1
Site History

- Initially established in 1928
- Expanded during WWII
- Transferred to private owners after Korean War
- Previous investigations
  - Preliminary Assessment (1986 and 1993)
  - Site Inspection (2007)
  - Remedial Investigation (2011)
CSM – Spatial Distribution of MEC
CSM – Vertical Distribution of MEC
Remedial Objective

- Detect and dispose of MEC that can be detected using a detection threshold required to detect a 37mm projectile at 12 inches below the ground surface, and to do so as efficiently as possible

  - Remove any MEC detected irrespective of depth
  - As efficiently as possible = most economical method to accomplish remedial objectives
# Projected Costs for Year 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Cost</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mob/Demob</td>
<td>1</td>
<td>$25,000</td>
<td>range: $15,000 to $30,000</td>
</tr>
<tr>
<td>Surface Sweep</td>
<td>acre</td>
<td>$1,500</td>
<td>range: $500 to $5,000</td>
</tr>
<tr>
<td>IVS</td>
<td>each</td>
<td>$6,000</td>
<td>One day of three-person crew</td>
</tr>
<tr>
<td>Seed Emplacement</td>
<td>per day</td>
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<td>assumes 25 seeds emplaced per day, crew size of 3</td>
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<td>range: $1,000 with array to $5,000 with single sensor</td>
</tr>
<tr>
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<td>acre</td>
<td>$6,000</td>
<td>range: $3,300 to $5,500</td>
</tr>
<tr>
<td>Cued TEMTADS Collection and Analysis</td>
<td>per anomaly</td>
<td>$40</td>
<td></td>
</tr>
<tr>
<td>Intrusive Investigation</td>
<td>per dig</td>
<td>$120</td>
<td>range: $75 to $200</td>
</tr>
</tbody>
</table>

## Traditional Approach – No Classification

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Cost</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mob/Demob</td>
<td>= unit costs</td>
<td>$25,000</td>
<td>same as traditional $25,000</td>
</tr>
<tr>
<td>Surface Sweep</td>
<td>= 100 acres * per acre</td>
<td>$150,000</td>
<td>same as traditional $150,000</td>
</tr>
<tr>
<td>IVS</td>
<td>= unit cost</td>
<td>$6,000</td>
<td>same as traditional $6,000</td>
</tr>
<tr>
<td>Seed Emplacement</td>
<td>= 25 QC + 25 QA</td>
<td>$10,500</td>
<td>= 200 QC + 200 validation $84,000</td>
</tr>
<tr>
<td>EM61 survey and analysis</td>
<td>= 100 acres * DGM costs</td>
<td>$100,000</td>
<td>n/a</td>
</tr>
<tr>
<td>Dynamic TEMTADS</td>
<td>n/a</td>
<td></td>
<td>= 100 acres * TEMTADS costs $600,000</td>
</tr>
<tr>
<td>Cued TEMTADS</td>
<td>n/a</td>
<td></td>
<td>= 50% reduction from advanced analysis $1,000,000</td>
</tr>
<tr>
<td>Seeds Dug</td>
<td>= seeds * cost per dig</td>
<td>$6,000</td>
<td>= seeds * cost per dig $48,000</td>
</tr>
<tr>
<td>Native UXO Dug</td>
<td>= # UXO * cost per dig</td>
<td>$60,000</td>
<td>same as traditional $60,000</td>
</tr>
<tr>
<td>Clutter Dug</td>
<td>= # clutter * cost per dig</td>
<td>$5,940,000</td>
<td>= 80% clutter rejection $1,188,000</td>
</tr>
<tr>
<td>Fixed Costs</td>
<td></td>
<td>$400,000</td>
<td></td>
</tr>
</tbody>
</table>

## Total Costs

<table>
<thead>
<tr>
<th>No Classification</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>$6,697,500</td>
<td>$3,561,000</td>
</tr>
</tbody>
</table>

*Note: DGM = Detection, Geolocation, Mapping; UXO = Unexploded Ordnance*
Initial TPP Meeting

- Agree on:
  - Remedial Objective
  - Survey lane spacing
  - Anomaly selection methodology
    - Advanced detection methods
  - Sensor Selection
  - Schedule
  - …..
MR Project Work Elements that Classification Significantly Changes

- GIS setup
- Document management and control
- Subcontracting
- Technical and operational approach
- Work Plan preparation and approval
- Site prep and mobilization
- Site survey/grid layout
- Vegetation removal
- Surface removal

- Geophysical System Verification (GSV)
- Geophysical survey, data collection, and processing
- Anomaly reacquisition and investigation
- MEC/MPPEH management
  - Demobilization
  - Final report
  - Archiving
  - Project closeout
What follows is based on beta draft template
# Project Workflow

<table>
<thead>
<tr>
<th>TPP → QAPP</th>
<th>DFWs</th>
<th>Example Tasks</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Prep</strong></td>
<td>1,2</td>
<td>Surface Clearance</td>
<td>Surface Clearance Tech Memo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QC &amp; QA Seed Emplacement</td>
<td>QC Seed Emplacement Memo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IVS Construction</td>
<td>Validation Seed Memo (Govt Only)</td>
</tr>
<tr>
<td><strong>Detection Survey</strong></td>
<td>3,4,5</td>
<td>Dynamic Survey</td>
<td>IVS Tech Memo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anomaly Selection</td>
<td>Weekly QC Submittal</td>
</tr>
<tr>
<td><strong>Cued Survey</strong></td>
<td>6,7</td>
<td>Background Data Collection</td>
<td>IVS Tech Memo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anomaly Data Collection</td>
<td>Weekly QC Submittal</td>
</tr>
<tr>
<td><strong>Classify Anomalies</strong></td>
<td>9,10</td>
<td>“Training” Digs</td>
<td>Classification Tech Memo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construct Ranked Anomaly List</td>
<td>Ranked Anomaly List</td>
</tr>
<tr>
<td><strong>Intrusive Investigation</strong></td>
<td>11</td>
<td>Dig Items</td>
<td>Intrusive Investigation Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compare Recoveries to Predictions</td>
<td>Photos</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Final Draft Validation Plan</td>
</tr>
<tr>
<td><strong>Verification and Validation</strong></td>
<td>12</td>
<td>Verify Thresholds</td>
<td>Final Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Validate Process</td>
<td></td>
</tr>
</tbody>
</table>
Surface Clearance Memo

- Was everything found consistent with the CSM?
- Is there anything the analysts need to know?
- Opportunity for cost savings

<table>
<thead>
<tr>
<th>CSM</th>
<th>Evidence from Surface Sweep?</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-mm projectile</td>
<td>Y</td>
</tr>
<tr>
<td>2.36-in rocket</td>
<td>Y</td>
</tr>
<tr>
<td>60-mm mortar</td>
<td>Y</td>
</tr>
<tr>
<td>75-mm projectile</td>
<td>Y</td>
</tr>
<tr>
<td>81-mm mortar</td>
<td>N</td>
</tr>
<tr>
<td>3-in stokes mortar</td>
<td>Y</td>
</tr>
<tr>
<td>unexpected munition</td>
<td>N</td>
</tr>
</tbody>
</table>
Contractor’s QC Seeds

- Inert 37-mm projectiles and small ISO80s
- 200 QC seeds, approximately 50% of each
- Seeds placed at six depths up to the maximum PWS detection depth (5, 10, 15, 20, 25, & 30 cm)
Government Validation Seeds

- ~200 seeds
- Small ISO80, 37-mm projectiles, mortars
- Full depth range of interest
  - 30 cm for small ISO and 37mm
  - 45 cm for 60-mm mortar
  - 65 cm for 81-mm mortar
IVS Construction

TPP → QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

I.V.S. Construction
IVS Tech Memo

Is the Sensor Functioning Properly and Ready to Collect Data?

TPP ➔ QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

IVS 1
IVS 2
IVS 3
IVS 5
Are the Remedial Objectives Achievable?

TPP → QAPP

- Site Prep
- Detection Survey
- Cued Survey
- Classify Anomalies
- Intrusive Investigation
- Verification and Validation
Detection Survey

TPP ➔ QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

Monostatic Z Component Response Amplitude
Anomaly Selection Methodology

- **Amplitude Threshold**
  - Small, near-surface frag results in amplitude equal to deeper targets of interest – lots of unnecessary “detections”

- **Informed Source Selection**
  - Use all channels of data collected from all receivers in analysis. Only flag anomalies that result from items big enough to be the smallest TOI (37-mm projectile in this case).
Anomaly Selection

- TPP → QAPP
- Site Prep
- Detection Survey
- Cued Survey
- Classify Anomalies
- Intrusive Investigation
- Verification and Validation

Advanced Anomaly Selection

Reduced detections by 50% on average
Detection of QC Seeds

TPP → QAPP

1. Site Prep
2. Detection Survey
3. Cued Survey
4. Classify Anomalies
5. Intrusive Investigation
6. Verification and Validation
Cued Data

TPP → QAPP

- Site Prep
- Detection Survey
- Cued Survey
- Classify Anomalies
- Intrusive Investigation
- Verification and Validation
Government Evaluation of Validation Seed Locations after Inversions

TPP → QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation
Identify Clusters

TPP → QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

Cluster #2
(18 matches)

Cluster Match Threshold = 0.95

Cluster #3
(41 matches)
Intrusive Investigation

TPP → QAPP

- Site Prep
- Detection Survey
- Cued Survey
- Classify Anomalies
- Intrusive Investigation
- Verification and Validation
Intrusive Investigation Report

Were all recovered items consistent with analyst's predictions?

Site Prep
Detection Survey
Cued Survey
Classify Anomalies
Intrusive Investigation
Verification and Validation

Anomaly 22_00327
Anomaly 46_00056
Anomaly 76_01015

Decision Statistic vs. Dig Number

Clutter
TOI
UXO
Intrusive Investigation Report

TPP → QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

Anomaly 46_00056
Decision Metric = 0.9896

Anomaly 46_00056
Decision Metric = 0.9896
Intrusive Investigation Report

TPP ➔ QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

Anomaly 76_01015
Decision Metric = 0.9856

Anomaly 22_00327
Decision Metric = 0.9855
Verification and Validation

- Verify the stop-dig threshold
  - dig past the last TOI
Contractor Stop Dig Point

TPP → QAPP

1. Site Prep
2. Detection Survey
3. Cued Survey
4. Classify Anomalies
5. Intrusive Investigation
6. Verification and Validation

Graph:
- Green dots: Clutter
- Red dots: TOI
- Red star: UXO

120 digs past the last TOI
Verify The Threshold

TPP ➔ QAPP

Site Prep
Detection Survey
Cued Survey
Classify Anomalies
Intrusive Investigation
Verification and Validation

200 digs past the last TOI
Verification and Validation

- Verify the stop-dig threshold
  - dig past the last TOI
- Validate the whole process
  - targeted investigation of items classified as likely clutter
Validate the Process

TPP → QAPP

Site Prep

Detection Survey

Cued Survey

Classify Anomalies

Intrusive Investigation

Verification and Validation

200 randomly selected TPP → QAPP

200 digs past the last TOI
After Action Vertical CSM

Depth Below Ground Surface (cm)

- small ISO80
- 37mm
- 60mm mortar
- 2.36” rocket
- 81mm mortar
- 4.2” mortar

- seed interval
- UXO
- inert
- deepest recovery
- detection depth
Everybody Is Happy Now!

State PM

DoD PM

Tax Payer

Land Owner
Summary
Classification Basics – Summary

- Modern sensors → Reliable classification
- Analysis procedures → Extract intrinsic EMI signature
  - Depends only on size, shape and material properties of target
- Library-based classifiers → Reliably distinguish between munitions and clutter items
  - Match unknown targets with other objects with similar EMI signatures (i.e., things they “look like”)
  - Presumptive UXO (dig) if EMI “vision” is fuzzy or obscured
Where Do We Stand Today?

✓ Commercially-available sensor
✓ Available analysis tools
✓ Trained contractor base
✓ Trained Government geophysicists
✓ Regulator and Stakeholder acceptance

~ Government business practices
~ Government PM acceptance
On-Going…

- Transfer of the technology to mainstream use
- Some of the challenges
  - DoD explosive safety policies
  - Equipment availability
  - Contracting language and request for proposal requirements
  - Quality control and assurance processes
  - Workforce/practitioner qualifications
Additional Training and Resources

- SERDP/ESTCP website contains webcasts, tutorials, and demonstration reports on the classification technology
  - www.serdp-estcp.org

- ESTCP Technology Transfer Workshops (June 6-7 2012 & June 10-11 2015 Golden, Colorado)
  - Results of site demonstrations, outdoor technology demonstrations, tutorials, and software

- M2S2 Webinar Series
  - http://www.clu-in.org/conf/tio/m2s2fy15-2_022615/
  - http://www.clu-in.org/conf/tio/m2s2fy14-3_022514/
  - http://www.clu-in.org/conf/tio/m2s2-3_042213/

- Interstate Technology Regulator Council
  - Geophysical Classification For Munitions Response: http://www.itrcweb.org/gcmr-2/
  - Archived web training: https://clu-in.org/conf/itrc/GCMR_011416/
Army UXO Safety Program

Learn and Follow the 3Rs

**RECOGNIZE:** The danger that a souvenir munition poses to yourself, your family and your neighbors

**RETREAT:** Do not disturb, touch or move it
Do not give or throw it away

**REPORT:** Call 911
THE VERTICAL CONCEPTUAL SITE MODEL, AND VISUAL SAMPLE PLAN

Advanced Geophysical Classification (AGC)
CONCEPTUAL SITE MODELS

IN THE BEGINNING…
PRELIMINARY ASSESSMENT: FURTHER RESPONSE NEEDED → THE INITIAL CSM

Areas suspected to contain MEC...
Now What?
SI: PRESENCE OR ABSENCE?

Found one!
REMOVAL ACTIONS – MIGHT BE NEEDED SOMETIMES

Maybe a TCRA?
PURPOSE FOR THE RI

To investigate the project area to define nature and extent of release, and determination of “acceptable versus unacceptable” risk to support a recommendation for one of the following:

– No action is appropriate (Acceptable/Protective)
– Conduct Feasibility Study (Unacceptable/not Protective)
– Collect additional data via an “expanded” RI (Inconclusive Protectiveness / Characterization)
“The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site.”


Note that the Remedial Investigation and Feasibility Study (RI/FS) share the same objective.
The post-RI CSM forms the basis for the Remedial Design, to include Advanced Geophysical Classification.

- What is the *unacceptable* risk?
- What will we look for?
- Where will we look?
- To what depth?
- What is the Remedial Action Objective?
BASELINE RISK ASSESSMENT

The baseline risk assessment should demonstrate whether there is unacceptable risk associated with DoD releases.

– Toxicity and concentration of contaminants
– Fate and transport of contaminants
– Current and potential future land use
– Current and potential receptors (human and ecological)
CONCEPTUAL SITE MODELS
CONCEPTUAL SITE MODEL (CSM)

Basic understanding of what is going on.
  – Where MEC is expected
  – Identifies receptors
  – Describes exposure scenarios (land use)

Forms basis for communication with stakeholders.
Assists in developing investigation strategy and DQOs.

A CSM is a **model** that illustrates what we know and suspect is going on at an MRS.
Let’s look at some different types of models...
Weather Models
Mississippi River Model
Boom.
Of the seven preceding models, which TWO have been used in FUDS MMRP reports?
INITIAL CSM
Tell the Story

There once was a camp....
Some Army guys used it

CSM
They REALLY used it….blew some stuff up.
... and they practiced and practiced...
... and they left some stuff behind
LAND USE: WHY WE NEED TO KNOW
MMRP & HTRW DIFFERENCE IN CSM CONCEPTS

HTRW: source → receptor
MMRP: source ← receptor
POTENTIAL RI RESULTS
This example shows 209 grids (50’ x 50’) in MRS 3.
VERTICAL CSM

Critical for planning the remedial action.

– What’s out there?
– How deep is it?
– Can we reliably detect it, and with what degree of certainty?
FIRST CUTS AT [X] VS. DEPTH

Where are the munitions?

#md  #mec
CHARACTERIZATION: VERTICAL DISTRIBUTION?

Land Use-Depth = Action Limit (AL)

Detection Limit (DL) → DL → DL → DL

Surface

Number items [x]
HOW DOES ALL THIS TIE-IN TO AGC?
AGC & Visual Sample Plan in the Remedial Investigation
THE FUNDAMENTALS DO NOT CHANGE

Visual Sample Plan
- Find Target Areas (areas of Concentrated Munitions Use)
- Estimate upper bound of potentially remaining UXO (buffer areas or unused lands)
- Estimate numbers of anomalies
EXAMPLES OF CMUA AND ANOMALY ANALYSES

CSLO
IGE Anomaly Estimate: 15,000
Actual: 19,000

FLBGR
IGE Anomaly Estimate: ~7,000
Actual: 6,282
AGC BENEFITS IN THE RI

Conventional Approach
Transects: $200K
Grids: $200K
Cueing: $0
Digging: $400K
-------------------------------
Project Total: $1M

Total # Anomalies with answers: 2,000 to 3,000

AGC
Transects: $200K
Grids: $200K
Cueing: $300K
Digging: $100K
-----------------------------------------------
Project Total: $1M

Total # Anomalies with answers: ~8,500!
Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP)

AGC Training QAPP Introduction
Movie: Manager’s Role in Assuring Data Quality: Overview of the Uniform Federal Policy for Quality Assurance Project Plans

View/download: https://www.epa.gov/sites/production/files/fedfac/manager_role_quality_data.mpg
Historical Overview

- Inspectors General
- Cited data quality issues
- Task force formed
Uniform Federal Policy

- Intergovernmental Data Quality Task Force (IDQTF)
  - Consensus workgroup
  - Representatives from EPA Headquarters and Regions, DoD services, and DOE
    - Navy chair DoD Environmental Data Quality Workgroup
      - NAVSEA Laboratory Quality and Accreditation Office
Information Quality Guidelines

- Required by the Data Quality Act- PL106-554 (2001)
- …for Ensuring and Maximizing the Quality, Objectivity, Utility and Integrity of Information…
- In essence, requires that data have a pedigree that permits users and potential users to assess usability of data for specific purposes
- A good, implemented QAPP is the foundation of data pedigree
UFP for Implementing Quality Systems

- First Product of IDQTF
  - Signed by EPA and DOE (2002)
  - Signed by DoD (2003)

- Based on *Quality Systems for Environmental Data Collection and Environmental Technology Programs*, ANSI/ASQ E4 Section 5 (Part A)
  - Section 5, Management Elements of a Quality System
UFP for Quality Assurance Project Plans (UFP QAPP)

- Based on ANSI/ASQ E4 Section 6 (Part B)
  - Project-Specific
- Consistent with EPA QA/R-5 and QA/G-5

- Organized around four major QAPP elements
  - Project Management and Objectives
  - Measurements and Data Acquisition
  - Assessment and Oversight
  - Data Review
UFP-QAPP Implementation

- UFP-QAPP is voluntary consensus policy
  - Once adopted by Federal department, agency, or program, use is mandatory within that organization
- OSWER Directive 9272.0-17. June 7, 2005
- OSWER Guidance 9272.0-20. Dec 21, 2005
- Office of the Under Secretary of Defense Memorandum of April 11, 2006
- DoD Instruction 4715.15 Dec 11, 2006
UFP-QAPP Documents

To download documents:
https://www.epa.gov/fedfac/assuring-quality-federal-cleanups

Manual
Workbook
Compendium
Example QAPP
UFP QAPP

- **PART 1** is the UFP work book manual
  - Provide instructions and guidance on QAPP preparation

- **PART 2A** is the blank forms
  - The forms are not mandatory, but facilitate ease of use

- **PART 2B** is the Compendium
  - Lists required QC activities for the CERCLA process
  - A minimum set of requirements
  - Other Programs (e.g. RCRA) can use the Compendium if agreed by all parties
Overview of UFP-QAPP Manual

- **Principles**
  - Applicable to *any* environmental program
  - Minimum QA/QC activities - QA/QC Compendium
  - Documentation, detail and effort varies by project
  - Recommends use of worksheets
  - Cross referencing to other documents
  - Does not require rewrite of any current QAPP

- **Applicable to:**
  - Investigation
  - Remediation activities or remedy solutions
  - Final Clean-up and long term monitoring/stewardship activities
Format

- Follows *Systematic Planning Process (SPP)*
  - Formal DQO Process (EPA QA/G-4) or other
- Fill-in-the-blank worksheets for each QAPP element from project team *decisions*
- Allows for *graded approach*
  - Amount of documentation and detail will depend on complexity and scope of project
Quality Assurance Project Plan (QAPP)

- Integrates technical and quality control aspects of a project including ...
  - planning, implementation, assessment, and corrective actions
- Documents steps taken to ensure environmental data are ...
  - of the correct type and quality required for a specific decision or use
QAPP (Continued)

- Organized and systematic description of …
  - quality assurance (QA)
  - quality control (QC)
  - application to the collection and use of environmental data
Other Documents

- Work Plans, Health & Safety, Sampling and Analysis Plans
  - Can be ‘stand-alone’ documents or incorporated into the UFP-QAPP using the graded approach
  - NAVFAC Sampling and Analysis Plan is the UFP QAPP
    - Work Plan refers to QAPP
    - Munitions and Chemical Templates available

- At a minimum, other documents must be REFERENCED in the UFP-QAPP
UFP-QAPP Process Elements

- Scoping Sessions
- Project Management and Objectives
- QAPP Approval
- QAPP Implementation
- Assessment/Oversight
- Data Review
- Measurement/Data Acquisition
IDQTF Current Activities

- Worksheet streamlining
- MMRP implementation
  - Advanced Geophysical Classification (AGC) Template finalized
  - MMRP UFP QAPP Template under development to combine/standardize USACE/NAVFAC templates
- Looking into UFP QAPP templates for emerging contaminants
Review

What is Systematic Planning?

- Group effort to balance cost vs. amount of data needed to make decision
- Understand how the data will be used
- Ensure you get what you pay for by defining project needs in detail
- Knowing what was & was not delivered and why

Better planning may add cost at the beginning of my project
Questions ??

Doug Maddox
USEPA Federal Facilities Restoration and Reuse Office
maddox.doug@epa.gov
202-564-0553
Navy Training: UFP-QAPP

John M. Jackson
Geophysicist
USACE- SPK/EMCX
Uniform Federal Policy
Quality Assurance Project Plan
(UFP QAPP)

- UFP-QAPP is mandatory for all DERP (MMRP and IRP) funded environmental projects

- Requires:
  - The Right Technical Team
  - Systematic Planning
  - Development of Clear Data Quality Objectives
  - Defines Quality Checks before we start Field Work
UFP QAPP

is a:

SAMPLING & ANALYSIS PLAN (SAP)
SAP = FSP + QAPP

→ IT’S A WORK PLAN!!
To download documents:


- Manual
- Workbook
- Compendium
- AGCMR QAPP Template
- Example QAPP
Worksheet Templates

- Prompt Planning Process
- Organized by Process Elements
  - **WS’s 1-8: Management**
    Background, PDT Lead Agency, Training Requirements, Proof of Review, and Approval Pages
  - **WS 9: Documents**
    ALL Project Meetings and Agreements
  - **WS’s 10-16: Project Objectives**
    CSM & DQO Development, and Performance Objectives.
  - **WS’s 17-30: Design and Data Collection, and Quality Control Requirements**
  - **WS’s 31-33: Assessment and Oversight**
  - **WS 34-37: Data Review**
Before You SPP (whole team)

- Take to First Scoping Meeting:
  - Management and Organization Worksheets
    - Worksheets 1-8
  - Planning Worksheets
    - 10: CSM
    - 11: Data Quality Objectives
    - 12: Measurement Performance Criteria
    - 13: Secondary Data; Use and Limitations
      - For MMRP -- *Land Use Depth*.
    - 17: Study Design and Rational
    - 22: QC, Equipment Testing, Inspection
    - 14 & 16: Tasks and Schedule
  - *Document Agreements / Discussions in Worksheet 9!*
Figure 3-1: Advanced Geophysical Classification Organizational Structure

Lines of Authority

- Regulators/Stakeholders
- Corporate Safety Manager (Prime Contractor)
- UXO Expertise
- Data Processor
- GIS Manager
- DoD Remedial Project Manager
- Project Manager (Prime Contractor)
- Project Geophysicist
- Field Team Leader
- DoD QA, Safety, Geophysicist
- Corporate QA Manager (Prime Contractor)
- Quality Control (QC) Geophysicist

Lines of Communication

^UXO expertise is required to make sure the TOI, which can range from intact munitions to sub-components or fragments with residual explosive and/or chemical constituents, are defined.
Worksheets 1-8: Lessons Learned

- Section 1.3.5 of the UFP QAPP Manual, “all lead organization's project personnel are to be listed and roles must be assigned and sign off on those rolls…”
- Section 2.3.1, “key personnel includes those working for the lead organization”
- Section 2.4.1 supports inclusion of the lead agency personnel, including data review personnel.

- DoD (not contractor) is the lead.
- Include QA technical team members, specifically the geophysicist, chemist, and OESS in org structure.
- Include Contractor field team leads and QC, not just Contractor PM, Geophysicist and OESS, unless they are the field team leads.
**Worksheet #6- Communication Pathways**

<table>
<thead>
<tr>
<th>Communication Driver</th>
<th>Initiator (name, title/role, and contact info)</th>
<th>Recipient (name, title/role, and contact info)</th>
<th>Approval (timing, frequency, documentation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory agency interface</td>
<td>Name, DoD RPM Phone/email</td>
<td>Name, Organization Phone/email</td>
<td>USACE PM provides weekly project update memorandum to Regulator via email</td>
</tr>
<tr>
<td>Stop work due to safety issues</td>
<td>Name, Contractor SUXOS Phone/email</td>
<td>Name, Contractor SUXOS PM Phone/email</td>
<td>As soon as possible following discovery, SUXOS informs Contractor PM by phone of critical safety issues and generates follow-up Stop Work Memorandum</td>
</tr>
<tr>
<td>Minor QAPP changes during project execution</td>
<td>Name, Contractor SUXOS PM Phone/email</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major QAPP changes during project execution</td>
<td>Name, Contractor SUXOS PM Phone/email</td>
<td>Name, USACE PM Phone/email</td>
<td>Within 24 hours, Contractor PM submits field change request form to USACE PM for approval. Following approval, USACE PM informs regulator via email.</td>
</tr>
<tr>
<td>Mobilization and surface clearance activities are complete</td>
<td>Name, Contractor SUXOS Phone/email</td>
<td>Name, USACE QA &amp; Safety Phone/email</td>
<td>Upon completion of surface clearance activities, the SUXOS informs the USACE QA &amp; Safety via Surface Clearance Memorandum</td>
</tr>
<tr>
<td>Field progress update</td>
<td>Name, Contractor SUXOS PM Phone/email</td>
<td>Name, USACE PM Phone/email</td>
<td>At end of each day of field work, Contractor PM provides daily QC reports to USACE PM via email</td>
</tr>
</tbody>
</table>

*Communication, Communication Communication!!!*
WS 10: Conceptual Site Model (CSM):

(UFP-QAPP Manual Section 2.5.2)
(EPA 2106-G-05 Section 2.2.5)

- Narrative history supported by
  - Figures / Graphic Model
  - Tables

- Updated as new data are collected.

- Multiple sites, unique problems,
  → separate CSM for each

- Data gaps and uncertainties in the CSM clearly identified.

- **Background** – description, history, including key physical aspects (e.g., site geology, hydrology, topography, climate);

- **Sources** – Range type, known or suspected munitions (MEC/MC);

- **Release Mechanism** - including fate and transport considerations;

- **Land use & Receptors / Pathways** - potential for exposure;

- **Model** - nature and extent
  (Consider Air-to-ground, vs artillery fan, vs multi-use ranges, etc.)

---

How to Use WS # 10?

- **Identify Data Gaps**
  - NOTE: data gap does not = data need

- **Present What We Know**
  - Known or Suspected Munitions (Specifically)
  - Confirmed as Practice? Training? Live?

- **Define What We Need to Know**
  - Can we define an unacceptable risk?
  - What other data will we need to make these decisions?
WS # 10: CSM
Narrative Supported by Graphic Model

- Background Information,
  - i.e. Site History
- Define the MRS
  - Acreage & Map
- Primary Release Mechanisms for MEC/MC
  - Ground to ground
  - Air to ground
  - Burial…etc.
- Findings from Previous Studies
- Fate & Transport

- Sources of Known or Suspected MEC/MC
  - Types of Known/Suspected MEC/MC
  - Anomaly Distribution
    - Are there Concentrated Munitions Use Areas (CMUAs)?
    - Can we define Depth of Distribution?
Worksheet # 10 Cont’d

- **Key physical aspects**
  - Geology - background?
  - Topography / Terrain
  - Vegetation
  - Runoff/Groundwater

- **Land use considerations**
  - Accessibility
  - Ownerships/ ROEs, Parcel Map
  - Potential receptors and exposure pathways
    - Man hours
    - Depth of use, specific site activities and users
  - Surrounding Use
  - Existing Deed Restrictions or Controls
Traditional Report on Characterization: Horizontal Distribution

This example shows 209 grids (50’ x 50’) in MRS 3.
Worksheet # 9 Project Scoping Session Participants & Agreements

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Site Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projected Date(s) of Sampling:</td>
<td>Site Location:</td>
</tr>
<tr>
<td>Project Manager:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of Session:</th>
<th>Scoping Session Purpose:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Affiliation</th>
<th>Phone</th>
<th>E-mail Address</th>
<th>Project Role</th>
</tr>
</thead>
</table>

Document, Document, Document !!
So the PDT Agrees to the CSM

- Document Decisions in Worksheet #9

So Now Let’s DQO!!!
Systematic Planning: Developing DQOs

- Uses what we know about the Site
  - Develop Plan for Additional Data Needs

- What kind of data do we need?
  - During Characterization?
  - During Remedial Action?
Understanding DQOs

- Who will use the data?
- What will the data be used for?
- Phase of Data Acquisition?
  - Remedial Investigation?
    - Characterization
  - Remedial Action?
    - Support Confidence & Achievement of RAO
SO, We Have the CSM

Worksheet 10: CSM
- Develop the Story
- Lead into the Problem
- Supports Need for Further Remedial Response

Worksheet 11: DQOs
- Step 1: Problem Statement
- Step 2: Goals of the Study
- Step 3: Information Inputs
- Step 4: Boundaries
- Step 5: Analytic Approach
- Step 6: Performance Objectives
- Step 7: Detailed Plan to Obtain Data
How to Use WS #11?

- 7 Step DQO Process
  - Template Prompts each of 7 steps.

- First, see the template.
WS # 11 DQOs: Steps 1-4

(UFP-QAPP Manual Section 2.6.1) (EPA 2106-G-05 Section 2.2.6)

Document project quality objectives (PQOs) or data quality objectives (DQOs) using a systematic planning process (SPP)

EPA’s 7 Step DQOs:

1. **State the Problem.** - consistent with the CSM (data gaps).

2. **Identify the Goals of the Study.** specific study questions with alternative outcomes.

   (Explain goals in terms of how the data will be used to choose among the stated outcomes.)

3. **Identify Information Inputs.**
   a. Specify the types of data required to fill data gaps.
   b. Explain in specific terms how all data will be used.

4. **Define the Boundaries of the Study.**
   a. Specify the target population and characteristics of interest, define spatial/temporal limits and the scale of inference (i.e., which populations will be represented by which data.)

---

DQOs Step 1: The Problem

End of the RI:
- Extent
- Nature
- Unacceptable risk?

During Feasibility Study:
- Develop the RAO
- Assess Paths to RC

End of the RA:
- Verify CSM assumptions
- Confidence in Remedial Action
- Support Achievement of RAO
## Difference in Planning for RI & RAs

### Remedial Investigation

- **Determine Extent**
  - Vertical & Horizontal
- **Land Use**
  - Accessibility
  - Site Activities
- **Munitions**
  - Sensitivity
  - Severity
- **Determine Risk**
  - Acceptable vs Unacceptable

### Remedial Action

- **Remediate!!**
  - Meet the RAO
- **Confirm CSM**
The UFP QAPP Template for AGC: Remedial Investigation vs. Remedial Action

RI Template

RA Template

Uniform Federal Policy
For
Quality Assurance Project Plans
Advanced Geophysical Classification for Munitions Response
(AGC-QAPP)
Version 1.0, March 2016

AGCMR QAPP Template
So We Have an Unacceptable Risk
And We Have the Decision Document
DQO Steps 1 & 2: Remedial Action

- Support Achievement of RAO
- Support Confidence in Remedial Action
  - Depth of Detection/Retrieved vs Land Use Depth
  - Verify Horizontal and Vertical Distribution
- Achieve an Acceptable End State
  - Determine if remedy (UU/UE or other) can be supported (MQO/DQOs met and CSM confirmed)
  - Determine if additional response required (CSM or DQOs were not achieved; maybe ESD?)
Step 1: State the Problem. Define the problem that necessitates the study. Examine budget and schedule issues.

Site-specific problem statement: (Example) Previous investigations (list) have indicated that MEC in the form of DMM and UXO including (x, y, and z) are present at site ________________, resulting from its use between (years) _______ and _______ as a (describe the type of facility and its uses). As shown in the CSM these materials present an unacceptable risk from explosive hazards to (describe current receptors and potential future receptors based on anticipated land use.)

Advanced geophysical classification uses advanced sensors and geophysical classifiers to estimate physical properties of the item (e.g., depth, size, aspect ratio, wall thickness, symmetry) and determine whether the item is a TOI (i.e., highly likely to be MEC) or non-TOI (i.e., highly unlikely to be MEC). Using this information in a structured decision-making process, project teams will be able to make informed decisions about whether an item should be excavated or can be left in place.
Worksheet 11: Step 2, Goals of the Study

**Step 2: Identify the goals of the data collection.** State how data will be used in meeting objectives and solving the problem. Identify study questions, including RA objectives. Define alternative outcomes.

**Identify the principal study question:** (Example) Based on current and anticipated future land use scenarios, which detected buried metal objects must be removed, and which ones may be left in place?

**Identify alternative outcomes:** (Example) To classify an object as a TOI and remove it, or to classify it as non-TOI and leave it in place.

**State how the data will be used in solving the problem:** (Example) Advanced geophysical classification will be used to 1) detect anomalies resulting from DMM, UXO, and other metallic debris and 2) classify anomalies so that informed decisions can be made as to whether the anomaly results from a TOI that should be removed, or a non-TOI that may be left in place. Geophysical data collected using advanced EMI sensors in a dynamic mode will be used to initially detect and document the locations of subsurface anomalies. Geophysical data collected using advanced EMI sensors in a cued (static) mode will then be used to classify each anomaly as follows: 1) TOI, i.e., highly likely to be DMM or UXO; 2) Non-TOI, i.e., highly unlikely to be DMM or UXO; or 3) Inconclusive. Detected items classified as “TOI” and “inconclusive” will be targeted for removal. Items classified as non-TOI will be left in place. The results of geophysical detection and classification and the subsequent intrusive investigation must meet established DQOs to allow the anticipated land reuse to take place after the removal of TOI.
DQOs Step 3: Information Inputs

- What type of data are needed?
  - Magnetometer, EMI, digital geophysical mapping
  - Detection capabilities meet land use depth??

- Data Gaps
  - True Vertical and Lateral Extent
  - Detection Depth Achieved
  - Background S/N ratio
Data Needs for the Remedial Action

- Boundaries (resulting from RI, Defined in DD)
- Remedial Action Objective
  - Contaminant & Media (from RI)
  - Depth, to Protect Specific Users (from RI)
  - The Objective
- Specific Type of Munitions
  - Size, ~Detection Limits
  - Sensitivities, Severities
DQOs Step 3: Information Inputs

- The AGC QAPP is comprehensive
  - Detection Components
  - Cueing Components
  - Intrusive Components

Step 3: Identify information inputs. Identify data and information needed to answer the study questions.

(Example)

- Up-to-date CSM summarizing site conditions based on previous studies (e.g., Preliminary Assessment (PA), Site Inspection (SI) and Remedial Investigation/Feasibility Study (RI/FS)). [See Worksheet #10]:
  - Detection survey results, including:
    - Areas covered
    - System QC test results
    - Instrument Verification Strip (IVS) results
    - Surveyed validation seed and QC seed locations
    - Anomaly detections and responses
    - Data analysis results, including
      - Anomaly locations
      - Unique anomaly identification numbers
      - Z-component amplitude and dipole response for each anomaly
      - Detection survey data validation report
      - Detection survey data usability evaluation
      - Updated CSM
  - Cued survey results, including:
    - System QC results
    - IVS results
    - Background data
    - Surveyed validation seed and QC seed locations and types
    - Unique anomaly identification numbers and locations
    - Site-specific munitions library
    - Definition of items representing unacceptable explosive hazard
    - Classification of anomalies with confidence metric
    - Cued survey data validation report
    - Cued survey data usability evaluation

Etc…
Worksheet #11: Step 4 - Boundaries

All Other Areas (MRS 3)

Suspected Target Area #1 (MRS 1)

Suspected Target Area #2 (MRS 2)

LU-Depth = Action Limit (AL)

Surface

Confidence →

Detection Limit (DL) ←

DL ←

DL ←

This example shows 209 grids (50' x 50') in MRS 3.
Step 4: Define the boundaries of the project. Specify the target population and characteristics of interest. Define spatial and temporal boundaries. [Discuss NAOC Comment 129]

Target population: (Example) The target population for this study includes the following MEC confirmed or suspected to exist in the study area:

Table 11-1: Target Population

<table>
<thead>
<tr>
<th>Confirmed Munitions (including nomenclature, if known)</th>
<th>MEC Type (UXO, DMM, or both)</th>
<th>Munition Length</th>
<th>Observed Depth of Penetration (to center of mass)</th>
<th>Expected Detection Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>37mm (unknown mark/mod)</td>
<td>UXO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75mm (unknown mark/mod)</td>
<td>UXO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suspected Munitions (including nomenclature, if known)</strong></td>
<td><strong>MEC Type (UXO, DMM, or both)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 mm mortar, M49A3</td>
<td>UXO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>155mm, M107</td>
<td>UXO</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Characteristics of interest: (Example) The characteristics of interest are those characteristics (e.g., size, symmetry, aspect ratio, object density, and wall thickness) that will allow classifiers to determine whether an anomaly is a TOI or non-TOI.
DQO Steps 1-4

Lots to Digest here…
…and not even finished with WS #11!
(We still have DQO steps 5-7…)
Data Quality Objectives: Steps 5-7

5. Develop the Project Data Collection and Analysis Approach.
   Define the parameter(s) of interest, and develop the logic or statistics for drawing conclusions from findings.

   (What kind and how much data?)

   For decision problems -“if---then” statements, or decision rules, to link potential results with outcomes.

   Develop performance criteria (for new data being collected) or acceptance criteria (for existing data being considered for use).

   Focus on WS # 12 & 22

7. Develop Detailed Plan for Obtaining Data
   WS #11 overview of sampling design
   WS #17 -design details.
   WS #19, 20, 24-28, and 30 – analysis design requirements.
Cued Phase

**Parameters of interest:** (Example) Spatial extent of detected anomaly, cued measurement SNR, inversion fit coherence, and inversion outputs of $\beta_1$, $\beta_2$, $\beta_3$, $x$, $y$, and $z$.

**Type of inference:** (Example) If any of the following three criteria are met, the anomaly will be selected as a TOI: 1) the polarizability matches (within specifications established on Worksheet #22) that of an item in the project-specific TOI library, 2) estimates of the size, shape, symmetry, and wall thickness calculated from the polarizability, indicates the item is long, cylindrical, and thick-walled, or 3) there is a group (cluster) of $x$ or more anomalies having similar polarizabilities that, after investigation, are discovered to be TOI. Anomalies with poor inversion fit coherence that, after considering all available information, cannot be ruled as non-TOI (i.e., the data are inconclusive) will be added to the TOI list.

**Decision rules:** (Examples)

- If all or a portion of the study area is determined to have an anomaly density too high for cued analysis, then an alternative approach will be developed (factors for evaluating anomaly density are discussed in Worksheet #17).
- If the object is classified as TOI (highly likely to be a munition), then the object will be excavated.
- If the object is classified as non-TOI (highly unlikely to be a munition), then the object will be left in place.
- If the object is classified as inconclusive, then the object will be excavated.
Data Quality Objectives: Steps 5-7

5. Develop the Analytic Approach.
Define the parameter(s) of interest, and develop the logic or statistics for drawing conclusions from findings.

(What kind and how much data?)

For decision problems - “if---then” statements, or decision rules, to link potential results with outcomes.

Develop performance criteria (for new data being collected) or acceptance criteria (for existing data being considered for use).

Focus on WS # 12 & 22

7. Develop Detailed Plan for Obtaining Data
WS #11 overview of sampling design
WS #17 - design details.
WS #19, 20, 24-28, and 30 – analysis design requirements.

WS 11: Steps 6

Step 5: Develop Approach

- Advanced Classification
  - Discuss Applicability
  - Benefits
  - Limitations

Step 6: Measurement

Performance Criteria
Worksheet #12

Measurement Performance Criteria

- Quantitative measurement of data quality.
- Tabulated for the following activities.
  - General measurement performance criteria
  - Geophysical Instrument functionality
  - Positioning instrument functionality
  - Data collection
  - Data processing
  - Auditing procedures
  - Other project requirements

Data Quality Indicators
Data Quality Indicators

- Precision
- Accuracy
- Representativeness
- Completeness

- Comparability
- Sensitivity
Example, Develop Performance Criteria for Advanced Geophysical Classification

- **DQI’s addressed for each measurement phase/activity**
- **Three phases in AGC:**
  - Detection (Dynamic) Survey
  - Classification (Cued) Survey
  - Intrusive Survey
Phases for Advanced Geophysical Classification

3 Phases of AGC Data
a. Dynamic
b. Cued
c. Intrusive

DQI for each Phase
- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability
- Sensitivity

Worksheet Development:
Dynamic Survey QC

- Performance Objectives:
  - verify geophysical sensor is operating properly, and
  - provide ongoing monitoring of the data quality.

- Two key elements:
  - Instrument Verification Strip (IVS)
  - Production Area Blind Seeding
    - Contractor QC seeds and
    - Blind QA/validation seeds
Step 6: Performance Criteria

**IVS**
- Confirms that the geophysical detection system is operating properly
  - Usually single pass over an IVS line before start and after completion of production work each day.

**QC & Validation Seeding**
- Ongoing monitoring of the quality of data collection and analysis as it is performed
  - Expect 1-3 per day, one at limit of detection depth

- QC seed failure results in CA in the Field
- QA seed failure results in loss of confidence in data and the whole system
IVS Requirement

**IVS**
- Define Project’s minimum frequency for IVS and necessary criteria to demonstrate instrument is fully functional.

**Criteria**
- Different for Dynamic vs Cued Surveys
  - See Decision Tree: WS 17
What's the Detection Limit?
What Does It Mean?

QA Seeds: System Test
QC Seeds: Verify DL Throughout Fieldwork

Increased Possibility of False Negatives
Reduction in Confidence

High Confidence

? Detection Limit (DL)
### Key Worksheets for “The Plan”

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Criteria that collected data must meet to satisfy the DQOs.</td>
<td>• Criteria that collected data must meet to satisfy the DQOs.</td>
<td>• Defines Specific Acceptance Criteria for each test.</td>
</tr>
<tr>
<td>• Failure impacts end uses of the data.</td>
<td>• Failure impacts end uses of the data.</td>
<td>• Failure response and root cause analysis for each MPC, each phase.</td>
</tr>
</tbody>
</table>

*DFW= definable features of work*
### WS #12: Measurement Performance Criteria - Detection

<table>
<thead>
<tr>
<th>Measurement Performance Activity (or DFW)</th>
<th>Data Quality Indicator</th>
<th>Specification</th>
<th>Activity Used to Assess Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC Seeding</td>
<td>Representativeness</td>
<td>Blind QC seeds will be placed at the site by the contractor. Blind QC seeds must be detectable as defined by the DQOs and located throughout the horizontal and vertical survey boundaries defined in the DQOs. [The blind seed plan should describe the number and types of blind QC seeds.] Blind QC seeds will be distributed such that the field team can be expected to encounter between one and three seeds per day per team.</td>
<td>Review of Production Area QC Seeding Report</td>
</tr>
<tr>
<td>Detection Survey</td>
<td>Completeness</td>
<td>100% of the site is sampled.</td>
<td>Verification of conformance to measurement quality objectives (MQOs) for in-line spacing and cross-line spacing (see Worksheet #22)</td>
</tr>
<tr>
<td>Detection survey</td>
<td>Sensitivity</td>
<td>This worksheet must describe the project-specific detection threshold. (Example) A detection threshold of .1.7 mV/A and SNR .5 is required to detect a [37 mm projectile] lying horizontally at a depth of [0.3 m].</td>
<td>Initial and ongoing Instrument Verification strip (IVS) surveys Blind QC and validation seed detection Analysis of background variability across the site</td>
</tr>
<tr>
<td>Detection survey</td>
<td>Accuracy/Completeness</td>
<td>100% of validation seeds must be detected.</td>
<td>Review of validation seed detection results per survey unit</td>
</tr>
<tr>
<td>Detection survey</td>
<td>Completeness/Comparability</td>
<td>Complete project-specific databases and target lists delivered.</td>
<td>Data verification/data validation</td>
</tr>
</tbody>
</table>

**Notes:**
- DQOs: Data Quality Objectives
- MQOs: Measurement Quality Objectives
- SNR: Signal-to-Noise Ratio
Figure 17-1: Advanced Geophysical Classification Decision Tree

Preliminary Tasks and Anomaly Detection Survey

WS #17: Design
Work Flow Decision Tree

Preliminary Tasks & Detection Survey
<table>
<thead>
<tr>
<th>Measurement Quality Objective</th>
<th>DFW/SOP Reference</th>
<th>Frequency</th>
<th>Responsible Person/ Report Method/Verified by</th>
<th>Acceptance Criteria</th>
<th>Failure Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify correct assembly</td>
<td></td>
<td>Once following assembly</td>
<td>Field Team Leader/instrument assembly checklist/Project</td>
<td>As specified in Assembly checklist</td>
<td>RCA/CA: Make necessary</td>
</tr>
<tr>
<td>Initial Instrument Function Test (TEMTADS) (Instrument response amplitudes)</td>
<td></td>
<td>Once following assembly</td>
<td>Field Geophysicist/ Initial IVS Memorandum/ Project Geophysicist</td>
<td>Response (mean static spike minus mean static background) within 20% of predicted response for all transmit/receive (Tx/Rx) combinations</td>
<td>RCA/CA: Make necessary adjustments, and re-verify</td>
</tr>
<tr>
<td>Initial Instrument Function Test (MetalMapper) (five measurements over a small ISO80 target, one in each quadrant of the sensor and one directly under the center of the array). Derived polarizabilities for each measurement are compared to the library.</td>
<td></td>
<td>Once following assembly</td>
<td>Field Team Leader/ Instrument Assembly Checklist/ Project Geophysicist</td>
<td>Library match metric ≥ 0.95 for each of the five sets of inverted polarizabilities</td>
<td>RCA/CA: Make necessary adjustments, and re-verify</td>
</tr>
<tr>
<td>Initial Instrument Function Test (EM61)</td>
<td></td>
<td>Once following assembly</td>
<td>Field Geophysicist/ Initial IVS Memorandum/ Project Geophysicist</td>
<td>Response (mean static spike minus mean static background) within 20% of predicted response for all channels</td>
<td>RCA/CA: Make necessary adjustments, and re-verify</td>
</tr>
<tr>
<td>Initial detection survey positioning accuracy (IVS) [NAOC 101]</td>
<td></td>
<td>Once prior to start of detection survey data acquisition</td>
<td>Project Geophysicist/ IVS Memorandum/QC Geophysicist</td>
<td>Derived positions of IVS target(s) are within 25cm of the ground truth locations</td>
<td>RCA/CA: Make necessary adjustments, and re-verify</td>
</tr>
<tr>
<td>Measurement Quality Objective</td>
<td>DFW/SOP Reference</td>
<td>Frequency</td>
<td>Responsible Person/Report Method/Verified by</td>
<td>Acceptance Criteria</td>
<td>Failure Response</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------</td>
<td>-----------</td>
<td>---------------------------------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Ongoing Instrument Function Test (EM61)</td>
<td></td>
<td>Beginning and end of each day and each time instrument is turned on</td>
<td>Field Team Leader/running QC summary/Project or QC Geophysicist</td>
<td>Response (mean static spike minus mean static background) within 20% of predicted response for all channels</td>
<td>CA: Make necessary repairs and re-verify</td>
</tr>
<tr>
<td>Ongoing dynamic positioning precision (IVS)</td>
<td></td>
<td>Beginning and end of each day</td>
<td>Project Geophysicist/running QC summary/QC Geophysicist</td>
<td>Derived positions of IVS target(s) within 25 cm of the average locations</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>In-line measurement spacing (TEMTADS)</td>
<td></td>
<td>Verified for each survey unit using [describe tool to be used] based upon monostatic Z coil data positions</td>
<td>Project Geophysicist/running QC summary/QC Geophysicist</td>
<td>100% ≤ 0.20m between successive measurements</td>
<td>RCA/CA CA assumption: data set fails, (recollect portions that fail)</td>
</tr>
<tr>
<td>In-line measurement spacing (MetalMapper)</td>
<td></td>
<td>Verified for each survey unit using [describe tool to be used] based upon monostatic Z coil data positions</td>
<td>Project Geophysicist/running QC summary/QC Geophysicist</td>
<td>100% ≤ 0.25m between successive measurements</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>In-line measurement spacing (EM61)</td>
<td></td>
<td>Verified for each survey unit using [describe tool to be used] based upon monostatic Z coil data positions</td>
<td>Project Geophysicist/running QC summary/QC Geophysicist</td>
<td>100% ≤ 0.25m between successive measurements</td>
<td>RCA/CA</td>
</tr>
</tbody>
</table>
What SOPs?

- Instrument Assembly
- Setup/Continued Testing
  - Processing procedures
  - How is it tested/calibrated?
    - Background Tests
    - Instrument Verification Strip (IVS)
      - Initial Calibration
    - Continued Testing (QC)
      - QC Seeds
    - Quality Systems Test (QA)
      - QA Seeds

- Data Use
### WS #12: Measurement Performance Criteria – Cued Survey

<table>
<thead>
<tr>
<th>Measurement Performance Activity (or DFW)</th>
<th>Data Quality Indicator</th>
<th>Specification</th>
<th>Activity Used to Assess Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification survey</td>
<td>Completeness/Comparability</td>
<td>Library must include signatures for all munitions known or suspected to be present at the site, as listed in the CSM.</td>
<td>Verification of site-specific library</td>
</tr>
<tr>
<td>Classification survey</td>
<td>Representativeness/Accuracy</td>
<td>Background data will be collected at least once every two hours of cued survey data collection. Background locations will be selected such that background data will be representative of the various subsurface conditions expected to be encountered within each survey unit at the site.</td>
<td>Data verification/data validation</td>
</tr>
<tr>
<td>Classification survey</td>
<td>Completeness</td>
<td>All detected anomalies classified as: 1. TOI 2. Non TOI 3. Inconclusive</td>
<td>Data verification</td>
</tr>
<tr>
<td>Classification survey</td>
<td>Accuracy/Completeness</td>
<td>Cued survey must correctly classify 100% of all validation seeds.</td>
<td>Review of validation seed classification results</td>
</tr>
<tr>
<td>Classification survey</td>
<td>Accuracy</td>
<td>100% of predicted non-TOI that are intrusively investigated are confirmed to be non-TOI.</td>
<td>Visual inspection of recovered items from classification validation</td>
</tr>
</tbody>
</table>
WS #17: Design
Work Flow Decision Tree

Cued Survey
<table>
<thead>
<tr>
<th>Measurement Quality Objective</th>
<th>DFW/SOP Reference</th>
<th>Frequency</th>
<th>Responsible Person/Report Method/Verified by</th>
<th>Acceptance Criteria</th>
<th>Failure Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify correct assembly</td>
<td></td>
<td>Once following assembly</td>
<td>Field Team Leader/instrument assembly checklist/Project Geophysicist</td>
<td>As specified in instrument assembly checklist</td>
<td>RCA/CA: Make necessary adjustments, and re-verify</td>
</tr>
<tr>
<td>Initial sensor function test (TEMTADS)</td>
<td></td>
<td>Once following assembly</td>
<td>Field Team Leader/instrument assembly checklist/Project Geophysicist</td>
<td>Response (mean static spike minus mean static background) within 20% of predicted response for all Tx/Rx combinations</td>
<td>RCA/CA: make necessary repairs/ adjustments and re-verify</td>
</tr>
<tr>
<td>Initial instrument function test (MetalMapper) (five measurements over a small ISO80 target, one in each quadrant of the sensor and one directly under the center of the array). Derived polarizabilities for each measurement are compared to the library</td>
<td></td>
<td>Once following assembly</td>
<td>Field Team Leader/instrument assembly checklist/Project Geophysicist</td>
<td>Library match metric ≥ 0.95 for each of the five sets of inverted polarizabilities</td>
<td>RCA/CA: make necessary repairs/ adjustments and re-verify</td>
</tr>
</tbody>
</table>
## WS #22: Testing, Inspection and QC - Cued

<table>
<thead>
<tr>
<th>Measurement Quality Objective</th>
<th>DFW/SOP Reference</th>
<th>Frequency</th>
<th>Responsible Person/Report Method/Verified by:</th>
<th>Acceptance Criteria</th>
<th>Failure Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial IVS background measurement and background verification (five background measurements, one centered at the flag and one offset at least ½ sensor spacing in each cardinal direction)</td>
<td></td>
<td>Once during initial system IVS test</td>
<td>Field Team Leader/Initial IVS memorandum/Project Geophysicist</td>
<td>All five measurements (decay amplitude) within the noise level of each other and library match from all four offset measurements &gt; 0.9</td>
<td>RCA/CA: reject/replace BG location</td>
</tr>
<tr>
<td>Initial derived polarizabilities accuracy (IVS)</td>
<td></td>
<td>Once during initial system IVS test</td>
<td>Project Geophysicist/Initial IVS memorandum/QC Geophysicist</td>
<td>Library Match metric ≥ 0.9 for each set of inverted polarizabilities</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Derived target position accuracy (IVS)</td>
<td></td>
<td>Once during initial system IVS test</td>
<td>Project Geophysicist/Initial IVS Memorandum/QC Geophysicist</td>
<td>All IVS item fit locations within 0.25m of ground truth locations</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Ongoing derived polarizabilities precision (IVS)</td>
<td></td>
<td>Beginning and end of each day as part of IVS testing</td>
<td>Project Geophysicist/tracking summary/QC Geophysicist</td>
<td>Library Match to initial polarizabilities metric ≥ 0.9 for each set of three inverted polarizabilities</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Ongoing derived target position precision (IVS)</td>
<td></td>
<td>Beginning and end of each day as part of IVS testing</td>
<td>Project Geophysicist/tracking summary/QC Geophysicist</td>
<td>All IVS items fit locations within 0.25m of average of derived fit locations</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Measurement Quality Objective</td>
<td>DFW/SOP Reference</td>
<td>Frequency</td>
<td>Responsible Person/Report Method/Verified by</td>
<td>Acceptance Criteria</td>
<td>Failure Response</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Ongoing instrument function test (MetaMap)</td>
<td></td>
<td>Each time instrument is turned on</td>
<td>Field Team Leader/tracking summary/Project Geophysicist</td>
<td>Response within 20% of predicted response</td>
<td>CA: Make necessary repairs and re-verify</td>
</tr>
<tr>
<td>Transmit current levels (TEM/TADS)</td>
<td></td>
<td>Evaluated for each sensor measurement</td>
<td>Field Team Leader/tracking summary/Project Geophysicist</td>
<td>Current must be ≥5.5A</td>
<td>CA: stop data acquisition activities until condition corrected</td>
</tr>
<tr>
<td>Transmit current levels (MetaMapper)</td>
<td></td>
<td>Evaluated for each sensor measurement</td>
<td>Field Team Leader/tracking summary/Project Geophysicist</td>
<td>Current must be ≥3.5A</td>
<td>CA: stop data acquisition activities until condition corrected</td>
</tr>
<tr>
<td>Confirm all background measurements are valid</td>
<td></td>
<td>Evaluated for each background measurement</td>
<td>Project Geophysicist/Background summary/QC Geophysicist</td>
<td>Ensure background variation does not impact ability to classify correctly</td>
<td>CA: BG measurement rejected and removed from active BG measurements</td>
</tr>
<tr>
<td>Confirm adequate spacing between units (TEM/TADS)</td>
<td></td>
<td>Evaluated at start of each day (or grid)</td>
<td>Field Team Leader/Field Logbook/Project Geophysicist</td>
<td>Minimum separation of 50m</td>
<td>CA: Recollect all coincident measurements</td>
</tr>
<tr>
<td>Confirm adequate spacing between units (MetaMapper)</td>
<td></td>
<td>Evaluated at start of each day (or grid)</td>
<td>Field Team Leader/Field Logbook/Project Geophysicist</td>
<td>Minimum separation of 25m</td>
<td>CA: Recollect all coincident measurements</td>
</tr>
<tr>
<td>Confirm inversion model supports classification (1 of 3)</td>
<td></td>
<td>Evaluated for all models derived from a measurement (i.e. single item and multi-item models)</td>
<td>Project Geophysicist/Measurement QC summary/QC Geophysicist</td>
<td>Derived model response must fit the observed data with a fit coherence ≥ 0.8⁶</td>
<td>Follow procedure in SOP or RCA/CA</td>
</tr>
<tr>
<td>Confirm inversion model supports classification (2 of 3)</td>
<td></td>
<td>Evaluated for derived target</td>
<td>Project Geophysicist/Measurement QC summary/QC Geophysicist</td>
<td>Fit location estimate of item ≤ 0.4 m from center of sensor</td>
<td>Follow procedure in SOP or RCA/CA</td>
</tr>
</tbody>
</table>
## WS #12: Performance Criteria - Intrusive

<table>
<thead>
<tr>
<th>Measurement Performance Activity (or DFW)</th>
<th>Data Quality Indicator</th>
<th>Specification</th>
<th>Activity Used to Assess Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrusive Investigation (classification validation)</td>
<td>Accuracy</td>
<td>Inversion results correctly predict one or more physical properties (e.g. size, symmetry, or wall thickness) of the recovered items (specific tests and test objectives established during project planning).</td>
<td>Visual inspection and qualitative evaluation of items recovered during classification validation</td>
</tr>
<tr>
<td>Intrusive Investigation</td>
<td>Completeness/Comparability</td>
<td>Complete project-specific database including records reconciling inversion results to the physical properties of the recovered items.</td>
<td>Data Verification Data Validation</td>
</tr>
</tbody>
</table>
WS #17: Design Work Flow Decision Tree

Intrusive Investigation

Adjust Threshold

Identify stop-dig threshold, Verification targets and Validation targets

Reacquire locations Excavate items

Evaluate items

Was stop-dig threshold correct?

Outputs

Database (Excavation results) Photos Weekly QC Reports Disposal Records Comparison Results

RCA

Are verification and validation digs consistent with predictions?

Identify Data Limitations

Outputs

Final DUA Final Report Updated CSM

Conduct and Document Final DUA

Y

N

Y

N

Y
## WS #22: Testing, Inspection and QC - Intrusive

<table>
<thead>
<tr>
<th>Measurement Quality Objective</th>
<th>DFW/SOP Reference</th>
<th>Frequency</th>
<th>Responsible Person/ Report Method/Verified by</th>
<th>Acceptance Criteria</th>
<th>Failure Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirm derived features match ground truth (1 of 2)</td>
<td></td>
<td>Evaluated for all recovered items</td>
<td>Project Geophysicist/Measurement QC Summary or intrusive</td>
<td>100% of recovered (excluding inconclusive category) item positions ≤ 0.25m from predicted position (x, y)</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Confirm derived features match ground truth (2 of 2)</td>
<td></td>
<td>Evaluated for all recovered items</td>
<td>UXO Dig Team/ Dig List and intrusive database/Project or QC Geophysicist</td>
<td>100% of recovered object size estimates (excluding inconclusive category) qualitatively match</td>
<td>RCA/CA</td>
</tr>
<tr>
<td>Verification of TOI/non-TOI threshold</td>
<td></td>
<td>Dig 200 anomalies beyond last TOI on Dig List</td>
<td>Project Geophysicist/ Verification and Validation Report/QC Geophysicist</td>
<td>100% of predicted non-TOI intrusively investigated are non-TOI</td>
<td>RCA/CA. Adjust threshold</td>
</tr>
<tr>
<td>Classification validation</td>
<td></td>
<td>Random selection of 200 non-TOI</td>
<td>and Validation Report/ QC Geophysicist</td>
<td>qualitatively matches predicted size/shape</td>
<td>RCA/CA. Document in DUA</td>
</tr>
</tbody>
</table>
Worksheets 14 & 16

- Tabulate Project Tasks from Flow Diagram
  - Activity
  - Responsible Party
  - Planned Start Date
  - Planned Completion Date
  - Deliverable
  - Deliverable Due Date
Oversight and Assessment: WS #29

- Data Management Tasks
  - Documents to be Generated
  - Frequencies
  - All Record Location & Durations
  - Distributions

Field Team Generated & Reported
Oversight and Assessment: WS #31, (32 & 33)

- Assessment & Corrective Actions: WS #31
  - Assessment Type for
    - Preparation
    - Initial Setup
    - Ongoing
  - Responsible Party
    - For Review
  - Frequency
  - Assessment Deliverable
    - Checklist / Summary of Findings
  - Due Date

QC Reviewed & Reported
Oversight and Assessment: WS #31, (32 & 33)

- Assessment & Corrective Actions: WS #31
  - Assessment Type for
    - All Phases
  - Responsible Party for Response
  - Timeframe for Response
  - Responsible Party for Implementation of Corrective Action
  - Responsible Party for Oversight of Corrective Action
  - Due Date

QC Review Responses
Verification, Validation and Usability Input
WS #34

- Verification
  - Completeness of tasks and data
- Validation
  - Conformance to Specifications
- Usability
  - Achievement of MPCs
  - Overall Achievement of DQOs
    • Decision can be made with confidence

Identifies QA Review Inputs
Verification and Validation Procedures: WS #35

- Verification and Validation Reviews
  - Who is Responsible?
  - What is Reviewed?
  - When (Frequency)?
  - How Reported?

Lists QA Oversight Review and Reports
Detailed Validation Procedures: WS #36

- General Plan for QA
- How Thresholds are Tested
  - “Blind Validation” Seed Plan (Firewalled)
  - Verification of the “Threshold” for “Dig List”
Data Usability Assessment: WS #37

Requirements:
- Performed by “key members” of the PDT
- Completed at conclusion of each phase of investigation
  - Delivery Units

Review:
- SPP in Retrospect
- Support Assumptions
  - CSM
  - Managed Uncertainty
- Representative Data
- Confidence in Data
WS #37: Key Personnel and Delivery Unit

Key Personnel
- Project Manager
- QA Manager
- QA Geophysicist
- QC Geophysicist
- Field Geophysicist (Lead)

Delivery Unit (DU)
- Each (or grouped) Survey Units prepared as a data set for reporting.
  - Daily?
  - Weekly?
  - Bulk anomalies?
WS #37: Inputs to Usability

Usability Documents
- QAPP
  - Verification & Validation Plan
- QASP
- Contract
- QC Reports
- Corrective Actions
- IVS Memoranda
- Detection Survey Validation Report
- Site Specific Library
- Cued Survey Validation Report
- Prioritized Target “Dig” List
- Target Classification Report
- Classification Validation Report
WS #37: Process

Step 1.
- Review Objectives and Sampling Design
- Is Design Consistent with objectives?
- Identify Deviations

Step 2.
- Review Verification / Validation Inputs
- Evaluate Conformance to MPCs (WS #12)

Step 3.
- Document Data Usability
  - Implications of missed QC and corrective actions
- Update CSM
- Draw Conclusions
  - Next Phase?

Step 4.
- Lessons Learned
- Recommendations for changes to DQOs in future DUs if needed.
Planning Complete!!!!

Develop the Design

Develop Data Quality Objectives

Data Quality Control / Quality Assurance

Management: Define PDT Roles & Responsibilities

Data Assessment and Usability

Supports a Decision!
Questions?

John M. Jackson

[Email Link]

(916) 557-6614
Group Exercise!!!
Remember Camp SLO?

- University owned
  - No access restrictions
  - Cattle grazing
  - Geotechnical classes
  - Camping
- Multiple, overlapping range fans
- MRS ~ 2,500 acres
Former Camp SLO RI Results
Step 1 - Delineate the site
Step 2- Develop RAOs for each (sub)MRS
Step 3- Pick one MRS, create your DQO

7-step Process

- Step 1: Problem Statement
- Step 2: Goals of the Study
- Step 3: Information Inputs
- Step 4: Boundaries
- Step 5: Analytic Approach
- Step 6: Performance Objectives
- Step 7: Detailed Plan to Obtain Data

Instructions

- Write a detailed problem statement
- Provide general statements or ideas for the other 6 steps
Post Remedy- Scenario 1

1 foot
Scenario 1- High density not completed - data gap

Target Count Estimates:
- Inside High Density area: 3,913
- Outside High Density Area: 14,925
- Total: 18,838

Density From Dynamic TEMTADS

High Density Area (>4,000 targets/acre)
Scenario 1- High density not completed- data gap

Questions

- Did we meet the RAO and intent of the ROD?
- ROD requires explanation of significant differences?
  - What would the ESD look like?
- LUCs?
  - How do we implement on state lands?
  - How do we implement on private lands?
Scenario 2- High density completed- NO data gap

Questions

- Did we meet the RAO and intent of the ROD?
- ROD requires explanation of significant differences?
  - What would the ESD look like?
- LUCs?
  - How do we implement on state lands?
  - How do we implement on private lands?
### Scenario 3- Dig results comparison

#### 3a

<table>
<thead>
<tr>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude Response</td>
<td></td>
</tr>
<tr>
<td>Anomalies Detected</td>
<td></td>
</tr>
<tr>
<td>Advanced Detection Analysis</td>
<td>7,035</td>
</tr>
<tr>
<td>Targets (Potential TOI Identified for Cued Analysis)</td>
<td></td>
</tr>
<tr>
<td>Targets Identified for Dig List</td>
<td>753</td>
</tr>
<tr>
<td>Can’t Analyze</td>
<td>(104)</td>
</tr>
<tr>
<td>Potential TOI Calibration, Threshold Verification and Validation</td>
<td>(418)</td>
</tr>
<tr>
<td>Digs</td>
<td>(231)</td>
</tr>
<tr>
<td>Dig Records in Database (more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)</td>
<td>1,456</td>
</tr>
<tr>
<td>Munitions Debris (note that some of the individual records indicate multiple pieces of frag)</td>
<td>(1,223)</td>
</tr>
<tr>
<td>QC or QA Seed</td>
<td>(94)</td>
</tr>
<tr>
<td>Other Debris (Primarily Scrap Metal)</td>
<td>(62)</td>
</tr>
<tr>
<td>Small Arms</td>
<td>(36)</td>
</tr>
<tr>
<td>No Contact</td>
<td>(36)</td>
</tr>
<tr>
<td>Other (shared with adjacent anomaly)</td>
<td>(4)</td>
</tr>
<tr>
<td>UXO</td>
<td>(1)</td>
</tr>
</tbody>
</table>

#### 3b

<table>
<thead>
<tr>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude Response</td>
<td></td>
</tr>
<tr>
<td>Anomalies Detected</td>
<td></td>
</tr>
<tr>
<td>Advanced Detection Analysis</td>
<td>7,035</td>
</tr>
<tr>
<td>Targets (Potential TOI Identified for Cued Analysis)</td>
<td></td>
</tr>
<tr>
<td>Targets Identified for Dig List</td>
<td>753</td>
</tr>
<tr>
<td>Can’t Analyze</td>
<td>(104)</td>
</tr>
<tr>
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<td>(418)</td>
</tr>
<tr>
<td>Digs</td>
<td>(231)</td>
</tr>
<tr>
<td>Dig Records in Database (more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)</td>
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<td>Small Arms</td>
<td>(36)</td>
</tr>
<tr>
<td>No Contact</td>
<td>(36)</td>
</tr>
<tr>
<td>Other (shared with adjacent anomaly)</td>
<td>(4)</td>
</tr>
<tr>
<td>UXO</td>
<td>(1)</td>
</tr>
</tbody>
</table>
## Scenario 4- verification/validation

### 4a

<table>
<thead>
<tr>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
<th>4b</th>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude Response</td>
<td></td>
<td></td>
<td>Amplitude Response</td>
<td></td>
</tr>
<tr>
<td>Anomalies Detected</td>
<td></td>
<td></td>
<td>Anomalies Detected</td>
<td></td>
</tr>
<tr>
<td>Advanced Detection Analysis</td>
<td>7,035</td>
<td></td>
<td>Advanced Detection Analysis</td>
<td>7,035</td>
</tr>
<tr>
<td>Targets (Potential TOI Identified for Cued Analysis)</td>
<td></td>
<td></td>
<td>Targets (Potential TOI Identified for Cued Analysis)</td>
<td></td>
</tr>
<tr>
<td>Targets Identified for Dig List</td>
<td>553 (104) (418) (31)</td>
<td></td>
<td>Targets Identified for Dig List</td>
<td>2753 (2104) (418) (231)</td>
</tr>
<tr>
<td>Can’t Analyze</td>
<td></td>
<td></td>
<td>Can’t Analyze</td>
<td></td>
</tr>
<tr>
<td>Potential TOI</td>
<td></td>
<td></td>
<td>Potential TOI</td>
<td></td>
</tr>
<tr>
<td>Calibration, Threshold Verification and Validation</td>
<td></td>
<td></td>
<td>Calibration, Threshold Verification and Validation</td>
<td></td>
</tr>
<tr>
<td>Digs</td>
<td></td>
<td></td>
<td>Digs</td>
<td></td>
</tr>
<tr>
<td>Dig Records in Database (more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)</td>
<td>1,456 (1,223)</td>
<td></td>
<td>Dig Records in Database (more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)</td>
<td>1,456 (1,223)</td>
</tr>
<tr>
<td>Munitions Debris (note that some of the individual records indicate multiple pieces of frag)</td>
<td></td>
<td></td>
<td>Munitions Debris (note that some of the individual records indicate multiple pieces of frag)</td>
<td></td>
</tr>
<tr>
<td>QC or QA Seed</td>
<td>14 (4)</td>
<td></td>
<td>QC or QA Seed</td>
<td>94 (4)</td>
</tr>
<tr>
<td>Other Debris (Primarily Scrap Metal)</td>
<td>62</td>
<td></td>
<td>Other Debris (Primarily Scrap Metal)</td>
<td>62</td>
</tr>
<tr>
<td>Small Arms</td>
<td>36 (36)</td>
<td></td>
<td>Small Arms</td>
<td>36 (36)</td>
</tr>
<tr>
<td>No Contact</td>
<td>36 (36)</td>
<td></td>
<td>No Contact</td>
<td>36 (36)</td>
</tr>
<tr>
<td>Other (shared with adjacent anomaly)</td>
<td>4</td>
<td></td>
<td>Other (shared with adjacent anomaly)</td>
<td>4</td>
</tr>
<tr>
<td>UXO</td>
<td>1 (1)</td>
<td></td>
<td>UXO</td>
<td>38 (4)</td>
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</tbody>
</table>
ACCREDITATION

Advanced Geophysical Classification (AGC)
The AGC process consists of three steps:

1. Measure the response of a subsurface metal object to an electromagnetic field using an advanced geophysical sensor.
2. Analyze the measured response to determine target parameters such as depth, size, aspect ratio, and wall thickness.
3. Use these parameters as inputs to a classifier to help decide whether the detected item is most likely a munition that must be investigated.
Intergovernmental Data Quality Task Force
An interagency partnership with a shared mission and goals

- EPA Waste Programs - Headquarters And Regions
- Department of Defense Components
- Department of Energy
- Other Federal Agencies (Observers)

Intergovernmental Data Quality Task Force (IDQTF) (est. 1997)

IDQTF Subgroups
Mission
- To document an intergovernmental quality system, beginning with the hazardous waste programs (CERCLA and RCRA)

Goals
- To document an intergovernmental quality system based on ANSI/ASQC E-4
- To identify the roles and responsibilities of EPA and other Federal agencies regarding QA/QC oversight
- To develop guidance for implementing Federal Government-wide requirements and procedures regarding data quality
# IDQTF PRODUCTS

<table>
<thead>
<tr>
<th>IDQTF PRODUCT</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform Federal Policy for Implementing Environmental Quality Systems</td>
<td>Final, signed by all three agencies, January 2003</td>
</tr>
<tr>
<td>Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP), Manual and Workbook</td>
<td>Review draft, Fall 2003</td>
</tr>
<tr>
<td>QA/QC Compendium: Minimum QA/QC Activities</td>
<td>Review draft, Fall 2003</td>
</tr>
<tr>
<td>Roles and Responsibilities Guidance, Appendix to UFP-QS</td>
<td>Review draft, Spring 2004</td>
</tr>
<tr>
<td>AGC QAPP</td>
<td>Final, March 2016</td>
</tr>
<tr>
<td>MEC QAPP</td>
<td>Draft, 2016/2017</td>
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</tbody>
</table>
Uniform Federal Policy
For
Quality Assurance Project
Plans
Advanced Geophysical Classification for
Munitions Response
(AGC-QAPP)
Version 1.0, March 2016

COMMITMENT TO IDQTF PRODUCT

- Each agency will decide how best to implement products.
- Each agency will be responsible for its own oversight.
- IDQTF will have a continuing role to address issues and ensure improvement.
AGC IMPLEMENTATION IN THE DOD

DAGCAP IS THE NEW NORMAL
MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, DEFENSE LOGISTICS AGENCY (DSS-E)

APR 11 2016

SUBJECT: Department of Defense Advanced Geophysical Classification Accreditation Program

The Department of Defense (DoD) developed the munitions response advanced geophysical classification process (hereinafter referred to as advanced classification) to improve the efficiency of cleaning up munitions and to focus resources on potential explosives safety risks at munitions response sites (MRSs). To ensure quality data, my office has established the DoD Advanced Geophysical Classification Accreditation Program (DAGCAP) to accredit organizations that use advanced classification at MRSs. The DAGCAP is modeled after the laboratory accreditation program.

The DAGCAP provides a unified program for organizations performing advanced classification to demonstrate competency and document conformance to minimum quality systems requirements based on the International Organization for Standardization and the International Electrotechnical Commission standards. DoD ensures quality control measures are in place to satisfy both DoD project managers and regulators for the accreditation process. Accreditation is achieved by: (1) assessment of the organization’s quality system; and (2) a successful demonstration of capability performed at the Aberdeen Proving Ground DAGCAP test site. The attachment outlines the accreditation process and also includes frequently asked questions. The DAGCAP webpage on the Military Munitions Response Program page, http://www.denix.osd.mil/ammr, will maintain the latest documentation and stakeholder information.

Organizations may begin the DAGCAP accreditation process in the second quarter of calendar year 2016. The DoD Components shall begin using accredited organizations on their MRSs beginning in calendar year 2017.

My points of contact for the DAGCAP are Dr. Jordan Adelson, DoD Environmental Data Quality Workgroup Chair, at Jordan.adelson@navy.mil; and Ms. Deborah Morefield, ODSS(EESI), at deborah.a.morefield.civ@mail.mil.

[Signature]
Deputy Assistant Secretary of Defense (Basing)
Performing the duties of the Assistant Secretary of Defense (Energy, Installations, and Environment)

Attachment: As stated
DAGCAP OVERVIEW

- Modeled after DoD Environmental Laboratory Accreditation Program (ELAP)
- Third-party Accreditation Bodies (ABs) conduct assessments to Quality Systems Requirements (QSR)
- Applies to all testing organizations regardless of size or volume of business
- Applies to use of AGC at all MRSs
A STATE’S PERSPECTIVE ON ADVANCED GEOPHYSICAL CLASSIFICATION AND THE EVOLUTION OF MMRP

COPIED FROM:
2016 NATIONAL FUDS FORUM
AUGUST 2016
PRESENTED BY: TRACIE WHITE & JEFF SWANSON
COLORADO DEPARTMENT OF PUBLIC HEALTH & ENVIRONMENT
BIG PICTURE – KEY IDEAS
ADVANCED SENSORS & GEOPHYSICAL CLASSIFICATION

Technology Acceptance & Adoption
- It works, really good!
- Not a “silver bullet”, not appropriate everywhere

Quality Systems is the key to success
- Accreditation is a game changer
- QAPP provides the quality framework
- Sustain with policy, training, and implementation

Implementation & Oversight
- Focus on decision points
- Classification is hands-on technology
- Requires active stakeholder participation
CLASSIFICATION TECHNOLOGY

Classification is a disruptive technology
- Changing how munitions cleanup is conducted…
- Driving several important secondary changes…

Major changes
- Contracting
- Planning & Design
- Field Implementation
- Quality Systems
- Corps Oversight Role
- State Oversight Role

T Touches all Stakeholders
EVOLUTION OF MUNITIONS CLEANUP

Technology Gen 3
- Advanced sensors
- Classification decisions

Work Force
- Smaller work force
- Multiple field mobs
- Reduced digging cost

Cost & Complexity
- Significant cost savings
- Increased complexity of decision making
- New oversight & quality requirements
COLORADO’S EXPERIENCE

Former Lowry Bombing & Gunnery Range
Geophysical Classification Demonstration

Project Site
- 57mm Recoilless Rifle Range (GM MRS)
- 57mm, 37mm projectiles (20mm?)

Scope of Demo
- Leave it in the ground – No 100% ground truth
- Start-to-finish demonstration of complete MEC removal project
  • Contracting, QAPP implementation
  • USACE & State QA Oversight

Technology
- EM61-MKII & MetalMapper detection surveys
- MetalMapper dynamic classification survey
- MetalMapper cued classification survey

Objective
- Safe for future recreation use and development next to new major reservoir
LESSONS LEARNED
LOWRY CLASSIFICATION DEMONSTRATION

Communication, communication, communication

Remedial Design & Planning
– QAPP effective tool as project work plan
– Data quality objectives must be munitions specific
– All QAPP Worksheets are important
– SOPs must be detailed and implementable

Field Implementation
– Don’t “Go rogue” – Field teams must follow QAPP & SOPs
– Rigorous QC program – seeding and inspections
– Full root-cause analysis (5 Why’s)
KEYS TO REGULATORY ACCEPTANCE
REMEDIAL DESIGN

Begin at the beginning, **before** contracting
  – Agreement on fundamental design and use of classification

Establish clear RAOs for each munitions item
  – Identify all munitions of concern **and** depths
  – Must be able to **detect** before you can classify

Establish verification and validation requirements
  – IVS, QA seeds, Library Items, Verification Digs
KEYS TO REGULATORY ACCEPTANCE
CLASSIFIER DECISION POINTS

No “Black Box” analysis or decisions

Transparent decisions - Detection & Classification
  – Understand all decision points
  – Well documented decision trees
  – Establish decision thresholds, criteria, and standards

Verification and Validation Strategy
  – Specifications for data quality and monitoring
  – Classifier models and decision thresholds
  – Final project results

“Make the right decisions, for the right reasons.” Aristotle.
KEYS TO IMPLEMENTATION
QUALITY ASSURANCE OVERSIGHT

Demand rigorous remedial design
  – Clearly documented in QAPP
  – Detailed and implementable SOPs
Disciplined field implementation
  – Strict adherence to QAPP and SOPs
  – Not acceptable to “get to the field, then figure it out”
QA as QA
  – Expect QC program to find and fix issues
  – No excuses at QA level – failing QA is a big deal
  – Root cause analysis and corrective actions (5 Why’s)
KEYS TO IMPLEMENTATION
STATE OVERSIGHT FOCUS

Remedial design
- Verify approach for detection and classification
- Confirm munitions-of-interest and depths-of-interest
- Ensure QAPP fully documents project

Decision point verification
- Verify data quality objectives are met
- Validate detection & classification decisions

Quality systems implementation
- Verify full implementation of QAPP and QC/QA
- Independent QA and validation
- Rigorous root-cause analysis and corrective actions
IMPLEMENTATION CHALLENGES
STATE OVERSIGHT

Project Manager training
- Technical fundamentals, design, quality systems and tools
- Sharing of Lessons Learned and practical experience

Independent Technical Support
- Access to independent technical experts
- Experts to validate design and classifier models
- Independent data and analysis verification

Technical Guidance on State Oversight Plans
- Document available tools and expectations
- Worksheet companion to QAPP template
QUESTIONS?

Jordan Adelson
QAPP NINJA
COMMUNICATING RISK MANAGEMENT

Advanced Geophysical Classification (AGC)
AGENDA

Basic QAPP
Assessing End States
WHY BASIC QAPP?

WHEN ACCEPTING DATA & CLOSING OUT PROJECT

Critical Worksheets according to Andy
  – WS10: Conceptual Site Model
  – WS11: Data Quality Objectives
  – WS12: Measurement Performance Criteria
  – WS22: Measurement Quality Objectives

Because the QAPP is our best guarantee we’re using the right data for all our decisions
BASIC QAPP

WHEN ACCEPTING DATA & CLOSING OUT PROJECT

WS10: Conceptual Site Model
- Foundation of entire project
- Explains why we planned what we planned
BASIC QAPP
WHEN ACCEPTING DATA & CLOSING OUT PROJECT

WS11: Data Quality Objectives

- GCMR QAPP template is comprehensive
  - Only needs minor editing for project specific thresholds
  - Explains solutions to relatively simple problem:
    Which anomalies are TOI, which are not
Step 1: State the Problem. Define the problem that necessitates the study. Examine budget and schedule issues.

Site-specific problem statement: (Example) Previous investigations (list) have indicated that MEC in the form of DMM and UXO including (x, y, and z) are present at site ________________, resulting from its use between (years) _______ and _______ as a (describe the type of facility and its uses). As shown in the CSM these materials present an unacceptable risk from explosive hazards to (describe current receptors and potential future receptors based on anticipated land use.)

Advanced geophysical classification uses advanced sensors and geophysical classifiers to estimate physical properties of the item (e.g., depth, size, aspect ratio, wall thickness, symmetry) and determine whether the item is a TOI (i.e., highly likely to be MEC) or non-TOI (i.e., highly unlikely to be MEC). Using this information in a structured decision-making process, project teams will be able to make informed decisions about whether an item should be excavated or can be left in place.
BASIC QAPP
WHEN ACCEPTING DATA & CLOSING OUT PROJECT

WS12: Measurement Performance Criteria
  – The single most important Worksheet
    • Because if we meet all these requirements, we’re DONE!
    • GCMR QAPP template is comprehensive
      – Edits usually not needed
BASIC QAPP
WHEN ACCEPTING DATA & CLOSING OUT PROJECT

WS22: Measurement Quality Objectives
- Second most important worksheet
- Tells us the data we’re using is good
- GCMR QAPP template is comprehensive
  • Minor edits only for project specific needs
ASSESSING END STATES
AGENDA

First Up: Need to make you smart on what you’re starting out with
Then: Dive in to implementing and defending our exit plan
How We Got Here...
RI→FS→PP/DD→RD→RA QAPP followed by field work

RI→Baseline Risk→Have An Unacceptable Risk Scenario
This means, Per 40 CFR Part 300.430(e)(i), the Lead Agency established remedial action objectives (RAOs) that specify:

– *contaminants and media of concern*
– *potential exposure pathways*, and
– *remediation goals*
GENERAL RESPONSE ACTIONS

The Three General Response Actions in our GRA Toolbox

No Action     Modify Behavior
             (Not an action)

Restrict / Preclude   Remove the Source
Access
The four General Response Actions in our GRA Toolbox

- No Action
  (Not an action)
- Modify Behavior
- Restrict / Preclude Access
- Remove the Source
- Physical Removal
- LUCs
- LUCs
RAO IN PLAIN ENGLISH

HTRW: “Meet this standard” (i.e. 30ppm Pb in soil)

MMRP: When we can show either:
   1. People aren’t likely to encounter UXO, or
   2. People know what NOT to do if they encounter a UXO,
   3. The consequences are not severe, or
   4. A combination of the above
Risk is essentially a combination of probabilities

Example: Your Car Insurance Rate

- probability of having an accident
  - Hours on the road, your experience, your driving history
- probability you will make a claim

<table>
<thead>
<tr>
<th>Event</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound System theft 2010</td>
<td>$1,500</td>
</tr>
<tr>
<td>Sound System theft 2012</td>
<td>$1,000</td>
</tr>
<tr>
<td>Crazed Soccer Mom driving a minivan talking on the phone</td>
<td>$6,700</td>
</tr>
<tr>
<td>Total Claims Payouts</td>
<td>$9,200</td>
</tr>
<tr>
<td>My approximate lifetime premiums paid to date</td>
<td>~$350/6mo for 12 years = $8,400</td>
</tr>
</tbody>
</table>
WE ARE TALKING PROBABILITIES

What’s the probability of rolling a 6?
One in six, or about 16%

What’s the probability of rolling two sixes?
one in six? (~16%)
two in twelve? (~16%)
one in six + one in six? (~32%)
one in six X one in six? (~3%)
RISK CALCULATIONS

Risk is essentially the multiplication of several probabilities

Example: Lead In Soil

– probability of exposure
  (being present where the contamination is)
– probability of intake
  (something happens that results in ingestion)
– probability of bioloadung
  (probability your body retains the contaminant)
– probability of adverse health effect
  (probability that the retention ultimately leads to a health effect)
SOMETHING BAD HAPPENS WHEN:

✓ UXO or DMM is at a location
✓ Someone imparts energy to the item
✓ The item functions
✓ Energy from the detonation injures that someone

Consider Reality:

UXO are generally rare
Just because it’s there does not mean someone finds it
If it is found, it’s not always picked-up
If it is picked up, it doesn’t automatically detonate
If it does detonate, injury is proportional to energy release
Lot Of Overlap $\approx$ Multiplying Large Probabilities

$\text{Lot Of Overlap} \approx \text{Multiplying Large Probabilities} = \text{Unacceptable Risk}$
Like the presence of UXO, Likelihood of Human Interaction, Likelihood of Item Causing Item To Function, Injury Severity, Likely Presence of UXO, Little To No Overlap ≈ Multiplying small probabilities = Acceptable End State
Likely Presence of UXO

Let's look at:

Education

Injury Severity

Likelihood of Causing Item To Function

Likelihood of Human Interaction

These stay the same!

Little to No Overlap ≈ Multiplying small probabilities = Acceptable End State
Potential Acceptable End-States

CSM:

Documented Use As Target Areas

Confirmed Use as HE Training

Interaction expected during land use

Current and planned land use:
1- Residential
2- Agricultural
EXAMPLE

- Potential Acceptable End-States
  - 100% coverage & High Confidence UXO recovery → Unlikely Encounter
    - Potential for UU/UE
    - 5-year reviews if no UU/UE
    - Are LUCs or ICs needed?
  - Potential Acceptable End-States
    - No. LUCs or ICs don’t provide any added benefit
      → Already at Unlikely Encounter
Baseline Risk Assessment

Is an Unacceptable Hazard Identified?

- No: Response Complete
- Yes: Define Acceptable End States

1) Feasibility Study
2) Proposed Plan & DD
3) RD/RA & Collect Remedy Data
4) Post Remedy Assessment

Physical remedy support acceptable end state?

- Yes
- No: LUCs = acceptable end state?

- No additional Response Action

Acceptable End States

You Are Here
EXAMPLE

Potential Acceptable End-States

- 100% coverage & High Confidence UXO recovery → Unlikely Encounter
  - Potential for UU/UE
  - 5-year reviews if no UU/UE
  - Are LUCs or ICs needed?

No. LUCs or ICs don’t provide any added benefit → Already at Unlikely Encounter

- 100% coverage, Moderate Confidence UXO recovery → Seldom
  - Are LUCs or ICs needed?
Baseline Risk Assessment

Is an Unacceptable Hazard Identified?

No:
Response Complete

Yes:
Define Acceptable End States

1) Feasibility Study
2) Proposed Plan & DD
3) RD/RA & Collect Remedy Data
4) Post Remedy Assessment

You Are Here

Is UU/UE Supported?

Yes:
6YRs Response Complete

No:
5YRs Response Complete

Physical remedy support acceptable end state?

Yes

No

LUCs = acceptable end state?

Yes: UU/UE, 5YRs are required Response Complete

No: additional Response Action

Acceptable End States

Unacceptable End State
EXAMPLE

- Potential Acceptable End-States
  - 100% coverage & High Confidence UXO recovery → Unlikely Encounter
    - Potential for UU/UE
    - 5-year reviews if no UU/UE
    - Are LUCs or ICs needed? **No**. LUCs or ICs don’t provide any added benefit → Already at Unlikely Encounter

  - 100% coverage, Moderate Confidence UXO recovery → Seldom
    - Are LUCs or ICs needed? **Yes** → Unlikely
      - LUCs/ICs achieve Unlikely to impart energy when encountered
      - Program LUCs/ICs costs indefinitely
      - 5-year reviews
EXAMPLE

- Potential Acceptable End-States (con.t)
  - Large contiguous area with 100% (or reduced coverage under infrastructure) coverage and *No UXO or DMM or other native TOI recovered*
    - Indicates buffer/safety zones between/around targets
    - Potential for UU/UE? ➔ Yes
    - 5-year reviews if no UU/UE
    - LUCs or ICs? Don’t provide any added benefit ➔ already at Unlikely Encounter
  - 100% (or reduced coverage under infrastructure) coverage, High confidence intact UXO recovered, moderate confidence small, modest injury potential fuze components recovered
    - High confidence intact UXO recovered ➔ achieves Unlikely Encounter for those items
    - Moderate confidence fuzes recovered ➔ achieves Seldom Encounter for those items
    - LUCs or ICs? Not likely ➔ Both cases *Acceptable*
SUMMARY

We Achieve one or more GRAs through
- Physical Removal
- LUCs
- Combination

Risk is the product of probabilities (in our current formulation)

\[ p\text{(presence)} \times p\text{(encounter)} \times p\text{(detonation)} \times p\text{(injury)} \]

LUCs need to increase effectiveness of the remedy, AND the remedy effectiveness needs the bump!

More than one End State definition is likely throughout an MRS
VISUAL SAMPLE PLAN

Advanced Geophysical Classification (AGC)
Things you need to know about Visual Sample Plan

The VSP Sparse Transect Sampling Tools have been completed and demonstrated.

**Statistical Transect Design**
- Quantify the probability of traversing and detecting a target area with a specified transect spacing.

**Sparse Transect Analysis**
- Sparse transect density analysis tools developed specifically for DoD surveys.
- Geostatistical Modeling and mapping.

[Graphs and images related to statistical transect design and sparse transect analysis]
Purpose *is*: to find area(s) with elevated anomaly densities. Purpose *is not*: to delineate extent of UXO, or even to find UXO

**Design**

CSM accuracy is not critical
- VSP will tell you how to find the “area” you define
- Can bias towards conservative assumptions
- Okay if you get it wrong

Can be step-wise process
- Look for larger areas first
- Look for smaller areas if needed

**Analysis**

Does not incorporate design CSM
Will tell you what you found
Can run multiple scenarios to test various assumptions
UNDERLYING PRINCIPLE

The “thing” we’re looking for has more anomalies per acre than the area surrounding it.

We need at least one transect through that “thing” (sometimes more, VSP’s planning module will tell us).

Pin-flags everywhere

No pin-flags
SIMPLIFIED EXAMPLE
SIMPLIFIED EXAMPLE
SIMPLIFIED EXAMPLE

Anomalies on transects

MRS

Scale: 500m
SIMPLIFIED EXAMPLE

What Can We Deduce?

Scale: 500m

MRS
VSP BASICS

Model:
60mm M49A3 fragmentation distribution (1500 rounds)

Detection Confidence
Purple >25 anomalies/acre
Blue >15 anomalies/acre
Yellow >5 anomalies/acre

Initial R&D Problem was to find this
Design Phase uses Monte Carlo simulations to estimate probabilities of traversing area & detecting anomalies
Analysis Phase just looks at the data
– Geostatistics
GENERAL CONCEPTS

If: Many munitions types & Heavy use

- Then: Start looking for Largest Area First

Known:
- 220mm
- 155mm
- 105mm
- 75mm
- 37mm
GENERAL CONCEPTS

If: Many munitions types & Heavy use

Then: Start looking for Largest First

Known:
220mm
155mm
105mm
75mm
37mm
GENERAL CONCEPTS

If: Don’t find what you expected

▪ Then: Do more
GENERAL CONCEPTS

If: Don’t find what you expected

- Then: Do more
GENERAL CONCEPTS

If: Don’t find what you expected

- Then: Do more
GENERAL CONCEPTS

If: Don’t find what you expected

Then: Do more
YOU GET TO DEFINE “TARGET AREA”

Any scenario where there is a contrast between “background” anomaly densities and densities in the “area” you are trying to find

– Typical practice target (normal distribution)
– Open Detonation area (normal distribution)
– Maneuver area (uniform distribution model)
– Could even be a disposal pit (but the geophysical detection definition will be different)
250 ACRE MRS SUSPECTED 5AC MANEUVER AREA

BACKGROUND ANOMALY DENSITY: 10 BKG/ACRE (UNIFORM DISTRIBUTION)

MANEUVER AREA DENSITY: 10 /ACRE (UNIFORM DISTRIBUTION)
Example: Contrast
Uniform Distribution

250 ACRE MRS
SUSPECTED
5 AC
MANEUVER
AREA

BACKGROUND
ANOMALY
DENSITY:
10 BKG/ACRE
(UNIFORM DISTRIBUTION)

MANEUVER
AREA
DENSITY:
20 /ACRE
(UNIFORM DISTRIBUTION)

Where is the area?

Model showing all anomalies

MRS Boundary
Model showing all anomalies

250 ACRE MRS
SUSPECTED
5AC
MANEUVER
AREA

BACKGROUND
ANOMALY
DENSITY:
10 BKG/ACRE
(UNIFORM
DISTRIBUTION)

MANEUVER
AREA
DENSITY:
50 /ACRE
(UNIFORM
DISTRIBUTION)
CASE STUDY
CASTNER RANGE, FT BLISS

Size (7,000 acres)
Three Factors to define target shape
- Where rounds land
- Where the frag goes
- Firing directions
VSP EXERCISE

Assumed Munition: 2.36” Rocket
  – Semi-major Axis: 6m + 38m = 44
  – Semi-minor Axis: 2m + 38m = 40
Random Target Orientation
VSP Calculated Transect Spacing = 57m
Set anomaly threshold low (4mV) to include frag from HE rounds. Trying to delineate target areas.
WHERE ARE THE POTENTIAL PROBLEM AREAS?
QUIZ TIME!
QUIZ #1. WHAT DO I NEED AT THE END OF THE PROJECT?

- QAPP w/ my signature on WS 1&2
- Draft-Final Report
- Source Selection
- Classification results
- Intrusive Investigations results
- Quality Control
- QC & QA Seed results
- Coverage
- Function tests
- Data Usability Assessment
- Verification dig results
- Validation dig results
- Summary of any plan deviations
- Map showing UXO & TOI locations
- Map showing anomaly densities
- Vertical CSM
- Technical Memoranda
QUIZ #2. FORMER CAMP SAN LUIS OBISPO - 7ACRES LOCATION MAP

LAND USE: Education & Cattle Grazing
QUIZ #2. FORMER CAMP SAN LUIS OBISPO - 7ACRES
SCOPING INFORMATION

LAND USE: Education & Cattle Grazing

- Anticipate 14,000 Anomalies
- Estimate $1.4M w/ AGC
- Estimate $3M w/out AGC
QUIZ #2. FORMER CAMP SAN LUIS OBISPO - 7ACRES

...MORE SCOPING INFORMATION

Remedial Investigation
Site-wide Vertical CSM

![Graph showing depth and detected objects]

Legend:
- Deepest Recovered UXO at SLO (historically)
- Deepest Recovered UXO from the Treatability Study
- Treatability Study QC/QA depth range
- Amplitude
  - Response Detection Performance (any orientation)
  - Advanced Detection Performance (any orientation)
QUIZ #2. FORMER CAMP SAN LUIS OBISPO - 7ACRES REMEDIAL RESPONSE RESULTS

LAND USE: Education & Cattle Grazing

Actual: ~19,000 Anomalies
QUIZ #2. FORMER CAMP SAN LUIS OBISPO - 7ACRES REMEDIAL RESPONSE RESULTS

- Delineation
- UU/UE
- Deed Restriction
- Construction Support
- Signage or Education
- Other LUC

LAND USE: Education & Cattle Grazing

Legend:
- Deepest Recovered UXO at SLO (historically)
- If Deepest Recovered In Cleanup

Our Site

Depth (meters below ground surface)

Amplitude
- Response Detection Performance (any orientation)
- Advanced Detection Performance (any orientation)

US Army Corps of Engineers.
QUIZ #3. FORMER CAMP WHEELER

TCRA Results

☐ Delineation
☐ UXO/UE
☐ Deed Restriction
☐ Construction
☐ Signage or Education
☐ Other LUC
QUIZ #4. FORT ORD

“California Characterization”
QUIZ #4. FORT ORD

If This Is The Plan
QUIZ #5. FORT ORD

If This Is The Plan & What We Find

- Delineation
- UU/UE
- Deed
- Restriction
- Construction
- Support
- Signage or Education
- Other LUC
Suggested Path Forward: Surface clearance & vegetation removal tasks become Site Preparation task: Clear the surface of all MEC, reduce vegetation to meet AGC needs, and reduce anomaly densities to less than 3,500/acre.
RECOMMENDATIONS FOR MMRP FS, PP, & DD

Consideration of LUCs
If RAO can be achieved via physical removal, no LUCs necessary.
If physical removal CSM = RI CSM, remedy is achieved.
If physical removal CSM ≠ RI CSM, and RAO not achieved, ESD may be required if LUCs achieve RAO.

Consideration of UU/UE
Separate from assessment of RAO Achievement.
5 YrR required if remedy implemented that does not achieve UU/UE
Document in DD
Based on comparing pre-clean-up CSM to post-clean-up CSM
BOOM… WE’RE DONE
Group Exercise!!!
Remember Camp SLO?

- University owned
  - No access restrictions
  - Cattle grazing
  - Geotechnical classes
  - Camping
- Multiple, overlapping range fans
- MRS ~ 2,500 acres
Former Camp SLO RI Results
Step 1- Delineate the site
Step 2- Develop RAOs for each (sub)MRS
Step 3- Pick one MRS, create your DQO

7-step Process
- Step 1: Problem Statement
- Step 2: Goals of the Study
- Step 3: Information Inputs
- Step 4: Boundaries
- Step 5: Analytic Approach
- Step 6: Performance Objectives
- Step 7: Detailed Plan to Obtain Data

Instructions
- Write a detailed problem statement
- Provide general statements or ideas for the other 6 steps
Post Remedy - Scenario 1

1 foot
Scenario 1- High density not completed - data gap

Target Count Estimates:
- Inside High Density area: 3,913
- Outside High Density Area: 14,925
- Total: 18,838

Density From Dynamic TEMTADS

High Density Area (>4,000 targets/acre)
Scenario 1- High density not completed- data gap

Questions

- Did we meet the RAO and intent of the ROD?
- ROD requires explanation of significant differences?
  - What would the ESD look like?
- LUCs?
  - How do we implement on state lands?
  - How do we implement on private lands?
Scenario 2- High density completed- NO data gap

Questions

- Did we meet the RAO and intent of the ROD?
- ROD requires explanation of significant differenced?
  - What would the ESD look like?
- LUCs?
  - How do we implement on state lands?
  - How do we implement on private lands?
## Scenario 3- Dig results comparison

### 3a

<table>
<thead>
<tr>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude Response</td>
<td></td>
</tr>
<tr>
<td>Anomalies Detected</td>
<td></td>
</tr>
<tr>
<td>Advanced Detection Analysis</td>
<td></td>
</tr>
<tr>
<td>Targets (Potential TOI Identified for Cued Analysis)</td>
<td>7,035</td>
</tr>
<tr>
<td>Targets Identified for Dig List</td>
<td></td>
</tr>
<tr>
<td>Can’t Analyze</td>
<td></td>
</tr>
<tr>
<td>Potential TOI</td>
<td></td>
</tr>
<tr>
<td>Calibration, Threshold Verification and Validation Digs</td>
<td></td>
</tr>
<tr>
<td>Dig Records in Database</td>
<td>1,456</td>
</tr>
<tr>
<td>(more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)</td>
<td></td>
</tr>
<tr>
<td>Munitions Debris (note that some of the individual records indicate multiple pieces of frag)</td>
<td>(1,223)</td>
</tr>
<tr>
<td>QC or QA Seed</td>
<td>(94)</td>
</tr>
<tr>
<td>Other Debris (Primarily Scrap Metal)</td>
<td>(62)</td>
</tr>
<tr>
<td>Small Arms</td>
<td>(36)</td>
</tr>
<tr>
<td>No Contact</td>
<td>(36)</td>
</tr>
<tr>
<td>Other (shared with adjacent anomaly)</td>
<td>(4)</td>
</tr>
<tr>
<td>UXO</td>
<td>(1)</td>
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</tbody>
</table>

### 3b

<table>
<thead>
<tr>
<th>Anomaly/Target Quantities</th>
<th>16,202</th>
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<tbody>
<tr>
<td>Amplitude Response</td>
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<tr>
<td>No Contact</td>
<td>(36)</td>
</tr>
<tr>
<td>Other (shared with adjacent anomaly)</td>
<td>(4)</td>
</tr>
<tr>
<td>UXO</td>
<td>(38)</td>
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</table>
### Scenario 4 - verification/validation

#### 4a

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<th>Anomaly/Target Quantities</th>
<th>Amplitude Response</th>
<th>Anomalies Detected</th>
<th>Advanced Detection Analysis</th>
<th>Targets (Potential TOI Identified for Cued Analysis)</th>
<th>Targets Identified for Dig List</th>
<th>Can't Analyze</th>
<th>Potential TOI Calibration, Threshold Verification and Validation Digs</th>
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<tr>
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#### 4b

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<th>Anomaly/Target Quantities</th>
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<th>Anomalies Detected</th>
<th>Advanced Detection Analysis</th>
<th>Targets (Potential TOI Identified for Cued Analysis)</th>
<th>Targets Identified for Dig List</th>
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<th>Potential TOI Calibration, Threshold Verification and Validation Digs</th>
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<td>7,035</td>
<td>2753</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dig Records in Database (more than one item found within a 0.4 meter radius resulted in multiple records for an investigated location)
- Munitions Debris (note that some of the individual records indicate multiple pieces of frag)
- QC or QA Seed
- Other Debris (Primarily Scrap Metal)
- Small Arms
- No Contact
- Other (shared with adjacent anomaly)
- UXO

- Munitions Debris (note that some of the individual records indicate multiple pieces of frag)
- QC or QA Seed
- Other Debris (Primarily Scrap Metal)
- Small Arms
- No Contact
- Other (shared with adjacent anomaly)
- UXO
Sorry about the scales!
Size

A is ____________ B

- Larger Than
- Smaller Than
- The Same Size as
Size

A is ______________ B

- Larger Than
- Smaller Than
- The Same Size as
Size

A is ______________

- Larger Than
- Smaller Than
- The Same Size as

B
Size

A is ____________ B

- Larger Than
- Smaller Than
- The Same Size as
Wall Thickness

A  has  ____________ wall thickness than/as  B

- A Thinner
- A Thicker
- The Same
Wall Thickness

A has ______________ wall thickness than/as B

- A Thinner
- ✜ A Thicker
- ○ The Same
Wall Thickness

A has ____________ wall thickness than/as B

- A Thinner
- A Thicker
- The Same
Wall Thickness

A has ____________ wall thickness as B

- A Thinner
- A Thicker
- The Same
Symmetry

This source is
- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is

- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is

- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is

- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is
- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is

- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
Symmetry

This source is

- Axially symmetric
- Cubic or Spherical
- Rectangular
- None of the above
True or False

This source is...

- Large: True
- Axially symmetric: True
- Thick walled: False
- Is probably a UXO: False
True or False

This source is...

- Large: True
- Axially symmetric: True
- Thick walled: True
- Is probably a UXO: True
True or False

This source is...

- Large: True
- Axially symmetric: False
- Thick walled: True
- Is probably a UXO: False
True or False

This source is...

- Large: False
- Axially symmetric: False
- Thick walled: False
- Is probably a UXO: False
True or False

This source is...

- Large: True
- Axially symmetric: True
- Thick walled: Maybe?
- Is probably a UXO: Maybe?
True or False

This source is...

- Large: True
- Axially symmetric: True
- Thick walled: True
- Is probably a UXO: True
True or False

This source is...

- Large: True
- Axially symmetric: False
- Thick walled: True
- Is probably a UXO: False