THE SAGA CONTINUES: ADVANCEMENTS IN THE UNDERSTANDING OF COMPLEX SEED SCENARIOS

Case Studies from MR Sites and Synthetic Analysis

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SAGEEP: Session MR Saturated Response and Complex Seeds, Tuesday, April 15, 2025

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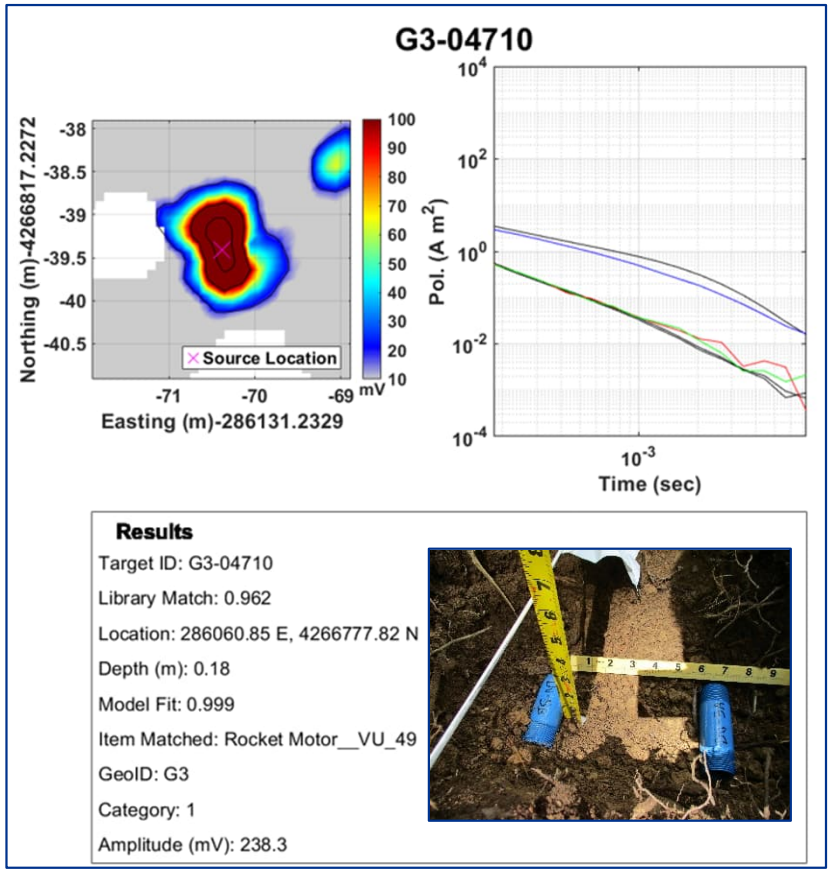
Agenda

1. Current Understanding
2. Challenges
3. Real-World Testing
4. Plot Twist (37mm projectiles)
5. Next Steps



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Episode V
THE GOVERNMENT STRIKES BACK

It is a dark time for GCOs. Although some *understanding of* complex seeds has been *gained, the* government has pursued *contractors across* the industry, requiring *complex* seeding in RFPs.

Evading the dreaded NCR, geophysicists *have attempted* to establish the data *usability implications* of complex seeding scenarios...

The Challenge of Complex Scenarios

- Determining sensor performance for each possible complex scenario is daunting:
  - Using only the 354 items currently in the DoD TOI library (not including countless clutter items)
  - Allowing only two combinations of items
  - Not including parameters such as depth, item orientation, or sensor type
  - **More than 62,400 possible complex scenarios!**

- Neither feasible nor practical to test every potential combination.
- However, testing can be designed to better understand and mitigate the limitations of AGC technology in complex item scenarios.

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Big Picture Question

- What is the overarching question? Risk!
  - Based on current technology and the an AGC dig radius of 0.25 m, is there a complex scenario where an item with an explosive hazard would be left in the ground?

- What is needed to answer the question? Data!
- How do you get the data?
  - Design and implement real-world tests
  - Supplement with synthetic testing
  - Use the results to design new tests…rinse, repeat

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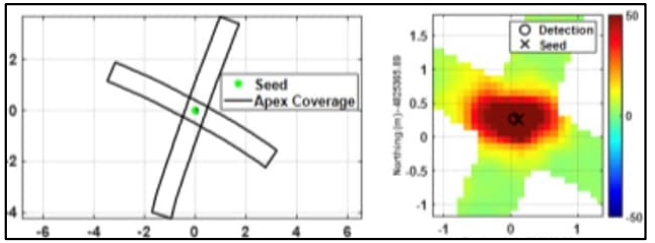
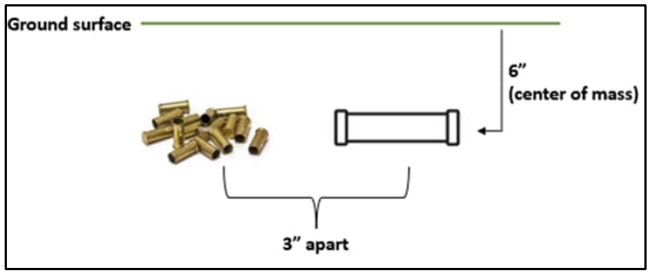
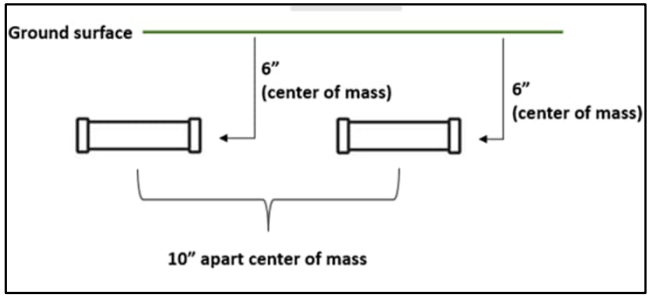
Overview of Real-World Testing

- Testing with White River Technologies' (WRT's) APEX sensor at two MR project sites
- Included placing 9 complex seeds and collecting data over them
  - Dynamic classification data (one-pass)
  - Dynamic-cued data
  - ISO + ISO combinations
  - ISO + clutter (spent small arms casings) combinations
  - Processed by WRT per their SOPs in EMClass using site-specific target selection criteria and WRT's usual TOI/non-TOI threshold of 0.8750







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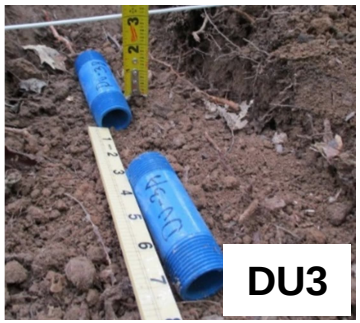
Complex Scenarios Tested – Site 1

- 5 complex seed pairs tested
- Full coverage survey ~ 3.1 acres, wooded/open areas
  - DU1/DU2*: In-line, 6” (15.2 cm) bgs, 3” (7.6 cm) separation
  - DU3: In-line, 3” bgs, 3” separation
  - DU4: Perpendicular, 6” bgs, 6” separation
  - DU5: Parallel, 6” bgs, 6” separation
- Two libraries: one with only small ISOs and the site-specific library (~50 items, ranging from 37- 155 mm projectiles)



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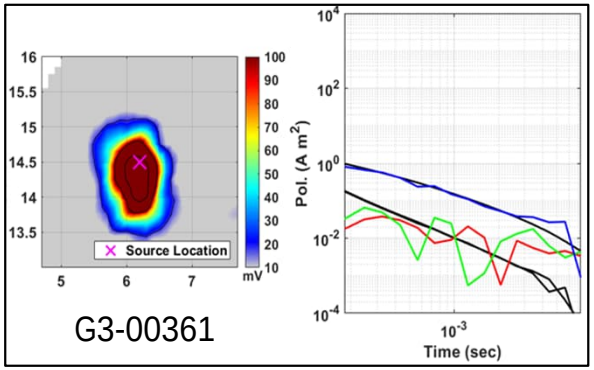
Results of Small ISO Library

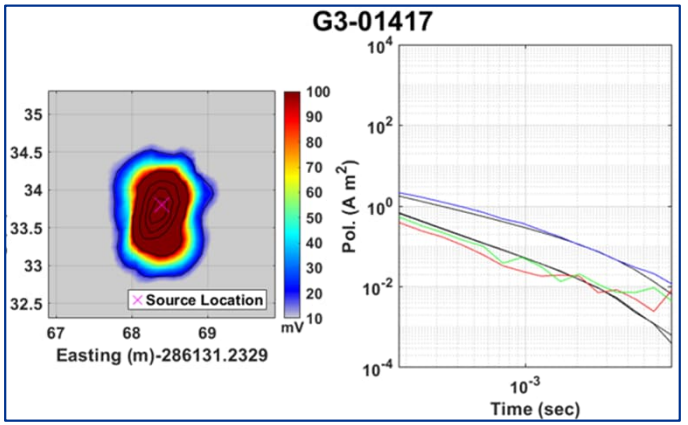
- All met X/Y and Z offset MQOs
- 5 of 6 produced a library match (confidence) to a small ISO that exceeded the TOI/non-TOI threshold of 0.8750
- DU1A produced a source with a library match of 0.8497 due to poor constraint of the secondary polarizabilities



Seed ID	Target ID	Confidence	AutomatedUXOType	Model Fit	Horizontal Offset (m)	Vertical Offset (m)
DU1A	G3-00361	0.8497	Small ISO80_V_268	1	0.13	0.01
DU1B	G3-00413	0.9206	Small ISO80_V_267	1	0.07	0.03
DU2A	G3-00209	0.9390	Small ISO80_V_268	1	0.06	0.01
DU2B	G3-00468	0.9675	Small ISO80_V_268	1	0.07	0.00
DU3A	G3-00175	0.9540	Small ISO80_V_268	1	0.05	0.01
DU3B	G3-00214	0.9634	Small ISO80_V_267	1	0.09	0.02
DU4A	G3-00542	0.9580	Small ISO80_V_268	1	0.05	0.01
DU4B	G3-00557	0.9481	Small ISO80_V_268	1	0.05	0.01
DU5A	G3-00291	0.9390	Small ISO80_V_268	1	0.12	0.04
DU5B	G3-00406	0.9563	Small ISO80_V_268	1	0.03	0.03

Results of Site-Specific Library

- All met X/Y and Z offset MQOs
- All resolved into a single item larger than a small ISO
- All classified as a TOI (minimum confidence of 0.9510)
- All successfully recovered during intrusive investigation



Seed ID	Target ID	Confidence	AutomatedUXOType	Model Fit	Horizontal Offset (m)	Vertical Offset (m)
DU1A	G3-01438	0.9750	60mm Mortar_M49A2_VND_173	1	0.12	-0.06
DU1B				1	0.10	-0.06
DU2A	G3-01417	0.9510	60mm Mortar_M49A2_VND_173	1	0.17	0.00
DU2B				1	0.04	0.00
DU3A	G3-02174	0.9612	60mm Mortar_M49A2_VND_173	1	0.06	-0.02
DU3B				1	0.14	-0.02
DU4A	G3-02785	0.9540	Rocket Motor_HPt1_51	1	0.06	0.00
DU4B				1	0.15	0.00
DU5A	G3-04710	0.9617	Rocket Motor_VU_49	1	0.17	-0.03
DU5B				1	0.03	-0.03

Site 1: Additional Observations

- In-line: 
  - No apparent correlation between depth and results.
  - Single source match to 60-mm mortar (dimensions 60/248 mm).
- Perpendicular: 
  - ISO-library, best confidence value of all pairs.
  - Site-library, lowest confidence value of all pairs.
  - Single source match to rocket motor (dimensions 30/337 mm).
- Parallel: 
  - ISO library, lowest confidence value of all pairs
  - Site-specific library, similar confidence to in-line pairs.
  - Single source match to rocket motor (dimensions 30/337 mm).

	Small ISO Library			Site-Specific Library		
Orientation	**Confidence Average**	**X/Y Offset Average**	**Z Offset Average**	**Confidence Average**	**X/Y Offset Average**	**Z Offset Average**
In-Line	0.9324 / 0.9489*	0.08	0.01	0.9624	0.10	-0.03
Perpendicular	0.9531	0.05	0.01	0.9540	0.11	0.00
Parallel	0.9477	0.08	0.04	0.9617	0.10	-0.03
All Tests	0.9326 / 0.9495*	0.07	0.02	0.9606	0.10	-0.02

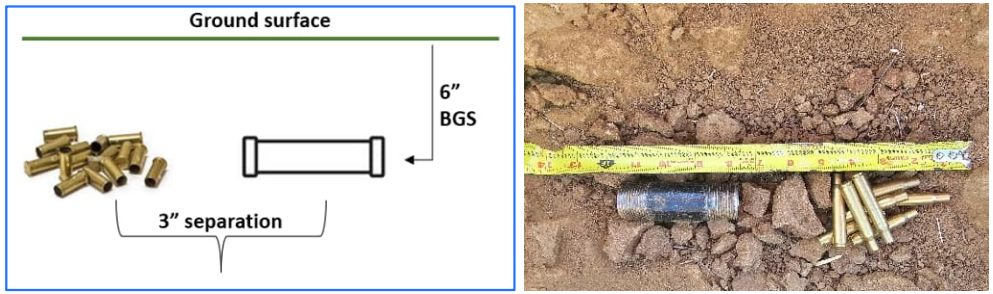
**Removed source with poor constraint of secondary polarizabilities.*

Note: Small ISO dimensions 32/101 mm.

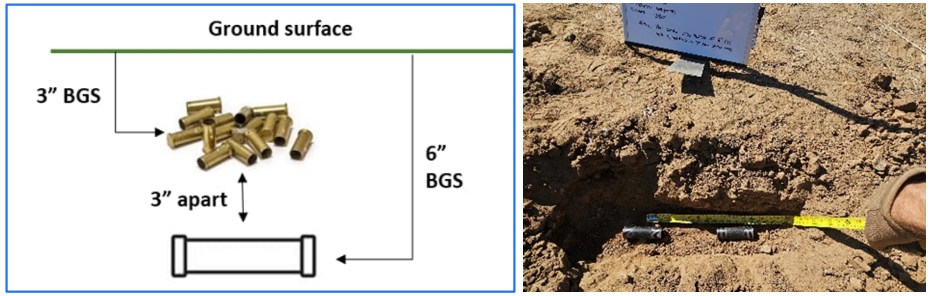
Complex Scenarios Tested – Site 2

- 4 complex tests: ISO + Clutter and ISO + ISO
- IVS style: 11-12 data collection events, dynamic classification and dynamic-cued

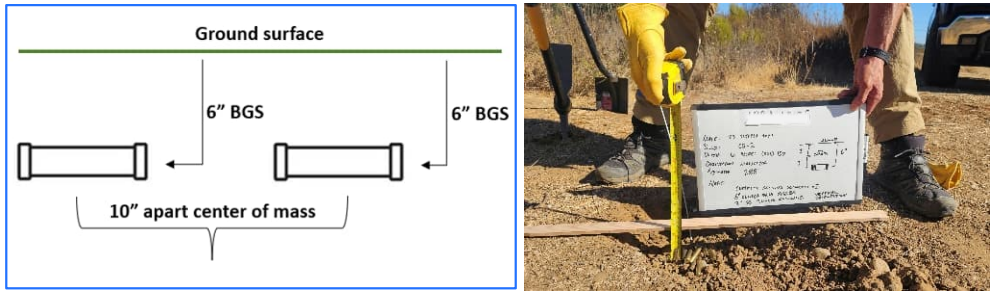
DU1: SISO + Clutter – Horizontal Offset



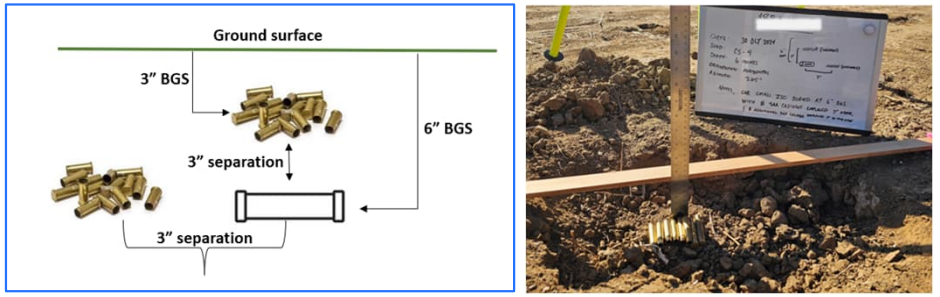
DU2: SISO + Clutter – Vertical Offset



DU3: SISO + SISO – Horizontal Offset



DU4: SISO + Clutter – Horizontal & Vertical Offset



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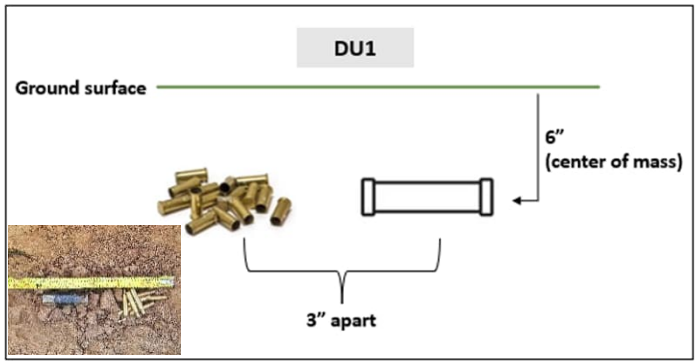
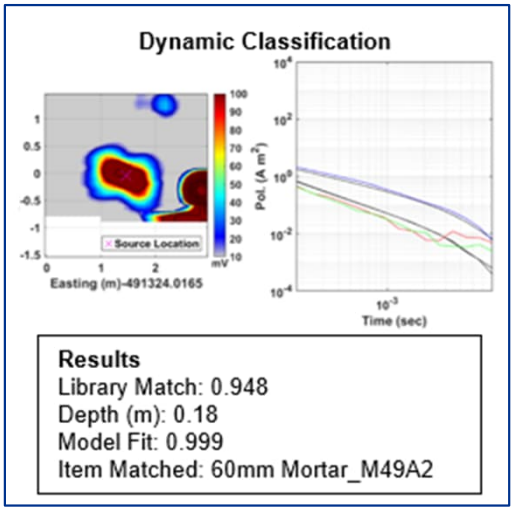
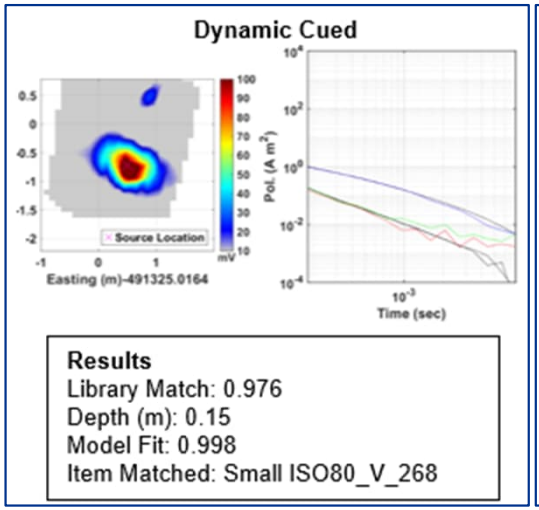
Site 2: Complex Seed DU1

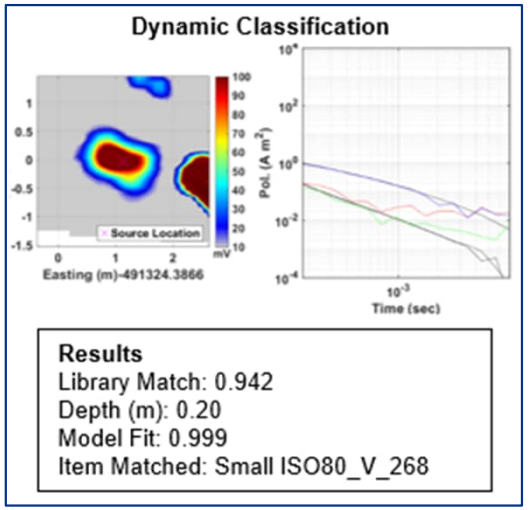
- 11 tests: 5 dynamic cued, 6 dynamic classification, all resulted in a TOI designation
  - Lowest confidence = 0.9424 (dynamic classification)
  - Highest confidence = 0.9763 (dynamic cued)
  - Average confidence dynamic classification = 0.9539
  - Average confidence dynamic cued = 0.9691



- Library match
  - 10 matches to small ISO
  - 1 match to 60-mm mortar (dynamic classification)

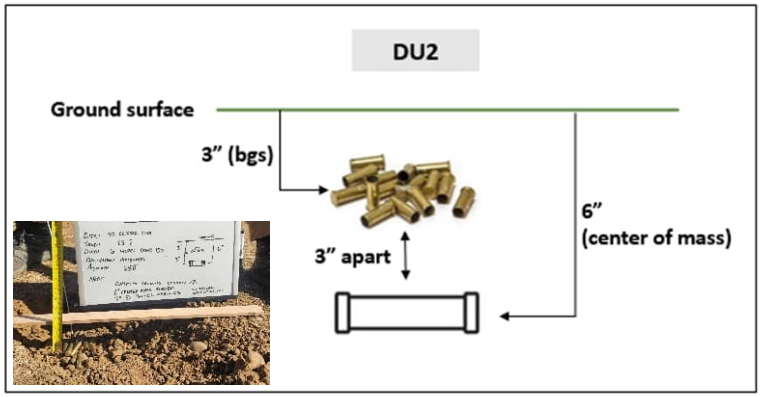




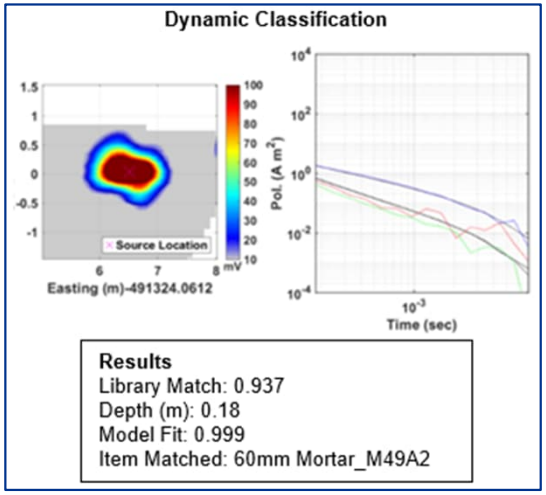


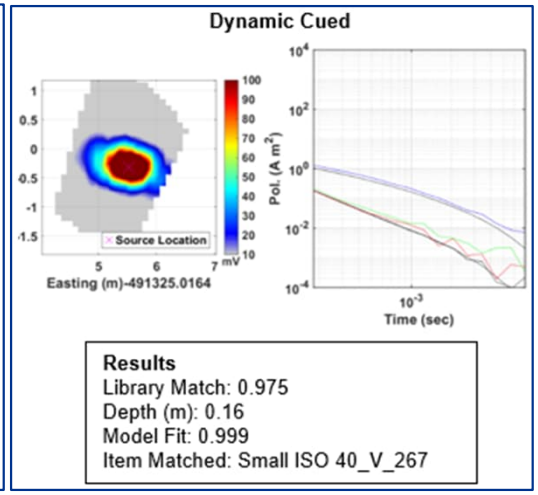
Site 2: Complex Seed DU2

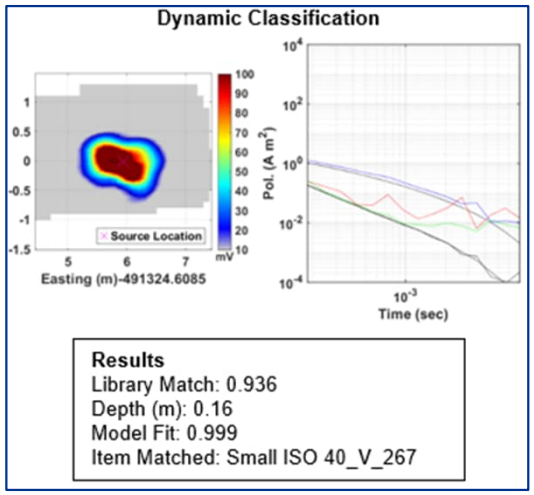
- 11 tests: 5 dynamic cued, 6 dynamic classification, all resulted in a TOI designation
  - Lowest confidence = 0.9362 (dynamic classification)
  - Highest confidence = 0.9749 (dynamic cued)
  - Average confidence dynamic classification = 0.9488
  - Average confidence dynamic cued = 0.9707



- Library match
  - 10 matches to small ISO
  - 1 match to 60-mm mortar (dynamic classification)

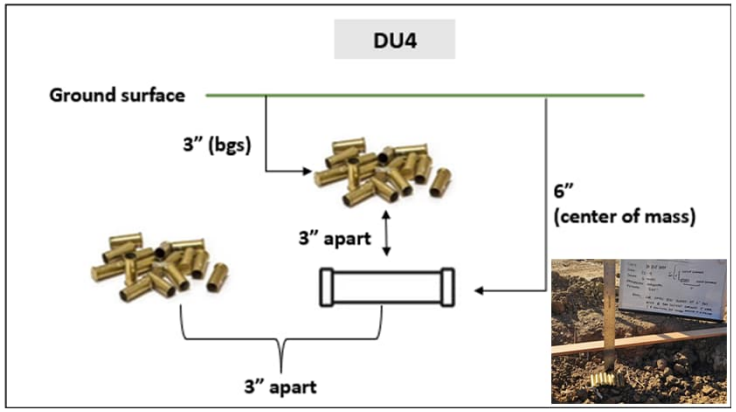


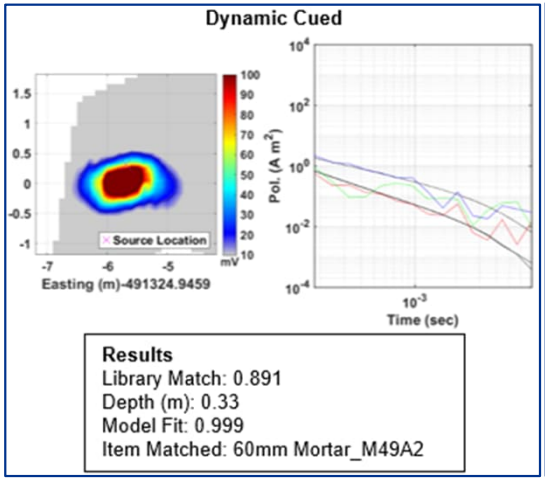


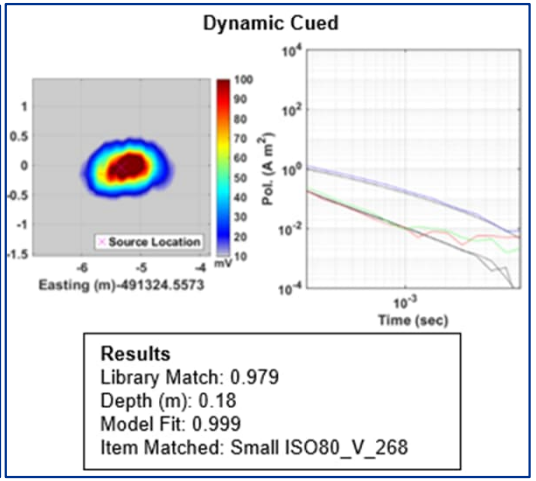


Site 2: Complex Seed DU4

- 12 tests: 6 dynamic cued, 6 dynamic classification, all resulted in a TOI designation
  - Lowest confidence = 0.8914 (dynamic cued)
  - Highest confidence = 0.9795 (dynamic cued)
  - Average confidence dynamic classification = 0.9651
  - Average confidence dynamic cued = 0.9589
- Library match
  - 11 matches to small ISO
  - 1 match to 60-mm mortar (dynamic cued)

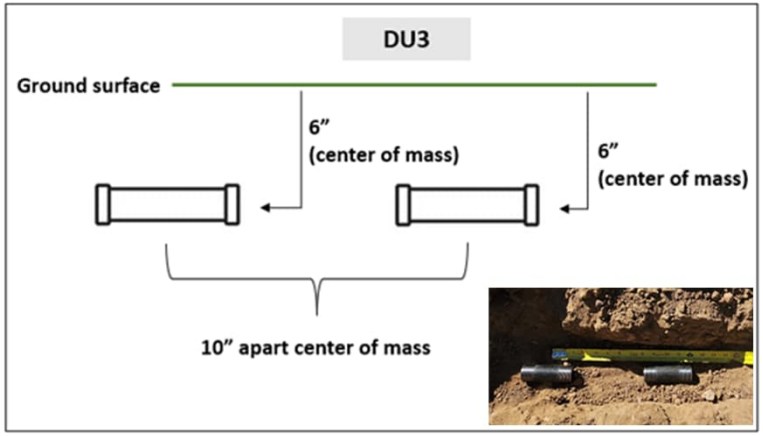






Site 2: Complex Seed DU3

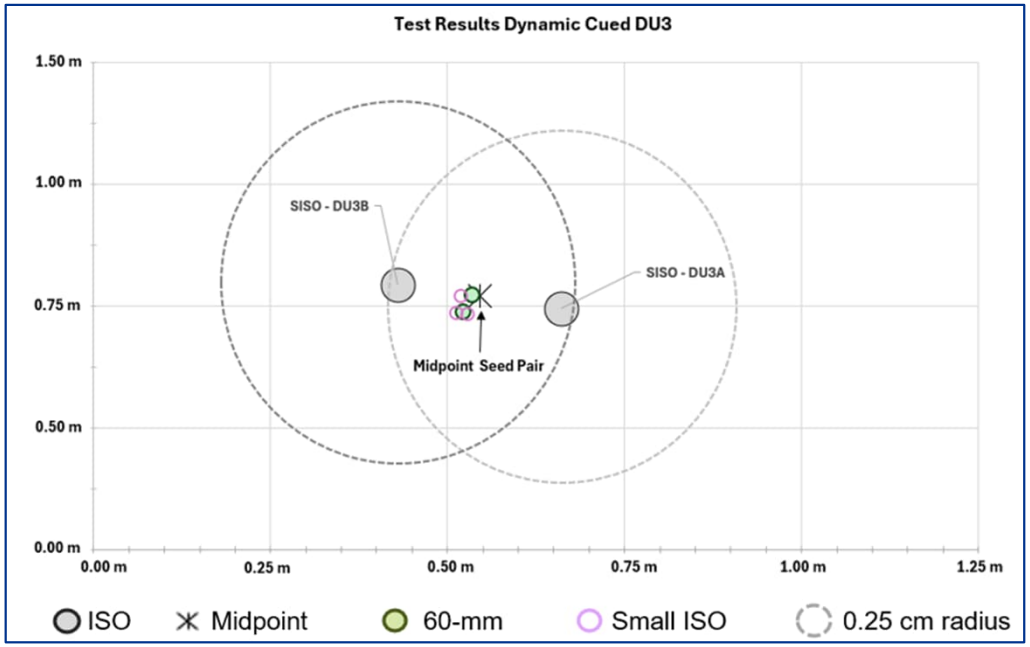
- 11 tests: 5 dynamic cued, 6 dynamic classification, all resulted in a TOI designation
  - Lowest confidence = 0.8827 (dynamic classification)
  - Highest confidence = 0.9696 (dynamic cued)
  - Average confidence dynamic classification = 0.9350
  - Average confidence dynamic cued = 0.9545



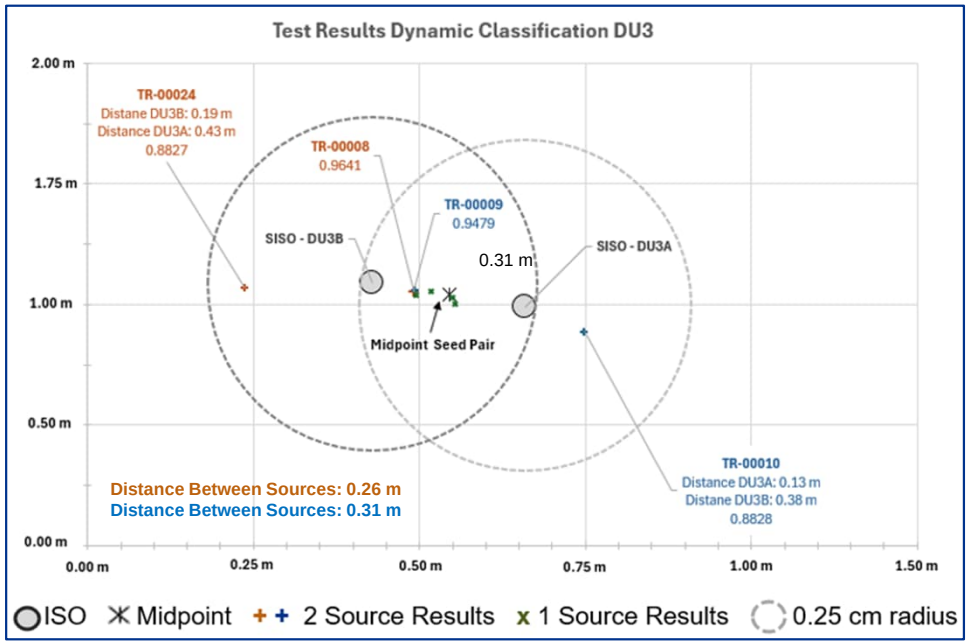
- Library match
  - Dynamic classification:
    - All matched to 60-mm mortar (60/248 mm, total length of two ISOs = 202 mm, with 254 mm [10”] separation total length 456 mm)
    - 4 were resolved as a single source and 2 as two sources
  - Dynamic cued:
    - 2 matches to 60-mm mortar (60/248 mm) and 3 to a small ISO (32/101 mm)
    - All 5 resolved as a single source

Site 2: Complex Seed DU3 Offsets

- Dynamic cued
  - All within 25 cm radius of both ISOs
  - Average offset of 60-mm solutions 0.13 m and small ISO solutions 0.16 m



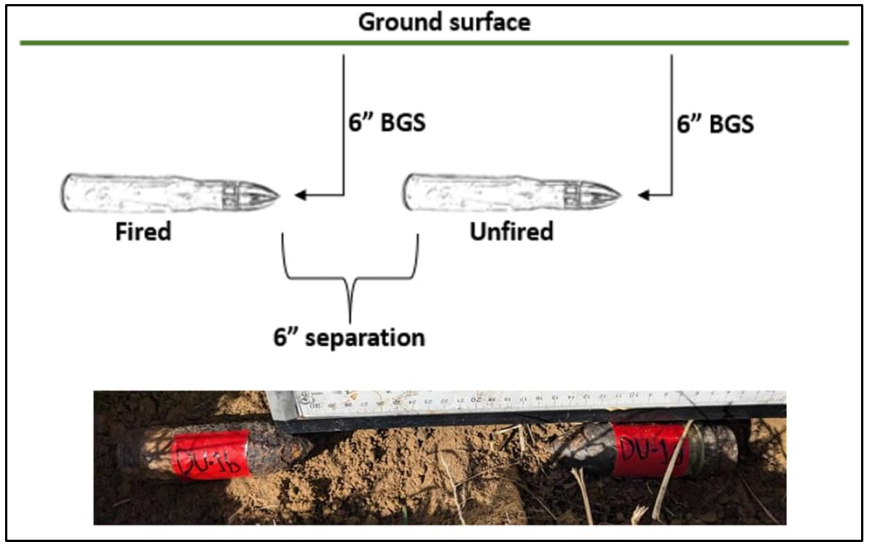
- Dynamic classification
  - Single source solution: all within 25 cm radius of both ISOs, average offset 0.13 m
  - Two source solutions: one source within 25 cm of both ISOs and one within 25 cm of only one ISO, average offset 0.20 m



NOW FOR THE PLOT TWIST…

37-mm Projectile Testing

- Placed inert 37-mm projectiles as a complex seed at third project site
  - Both M74 AP-T, 1942 era
  - DU1b was fired, DU1a unfired
- Placed in-line at 6” (15 cm) bgs and 6” separation (end to end)
- Processed in UXA and EMClass using the site-specific library and 37-mm only library



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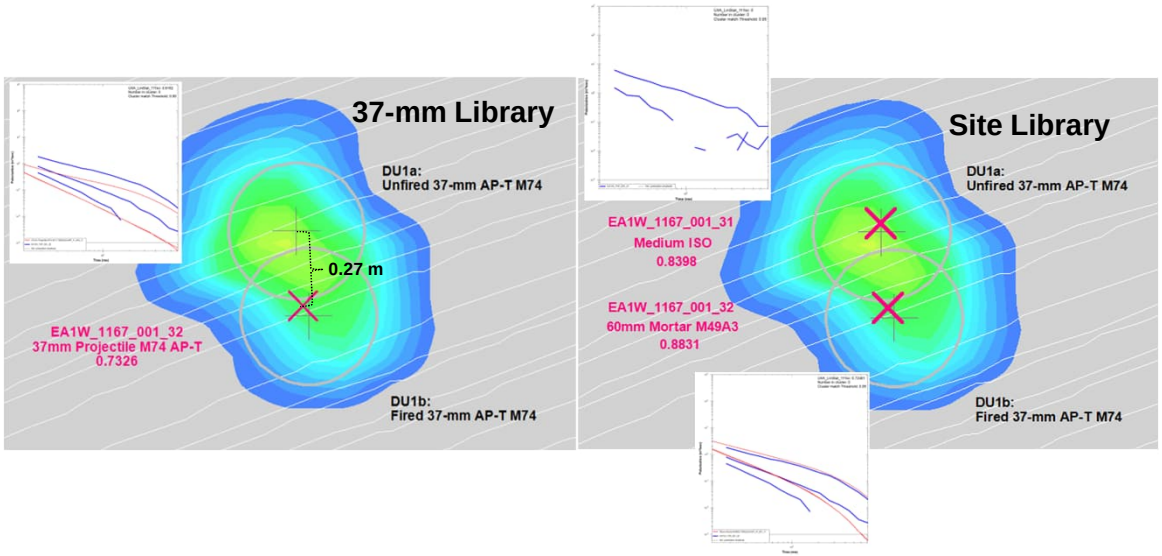
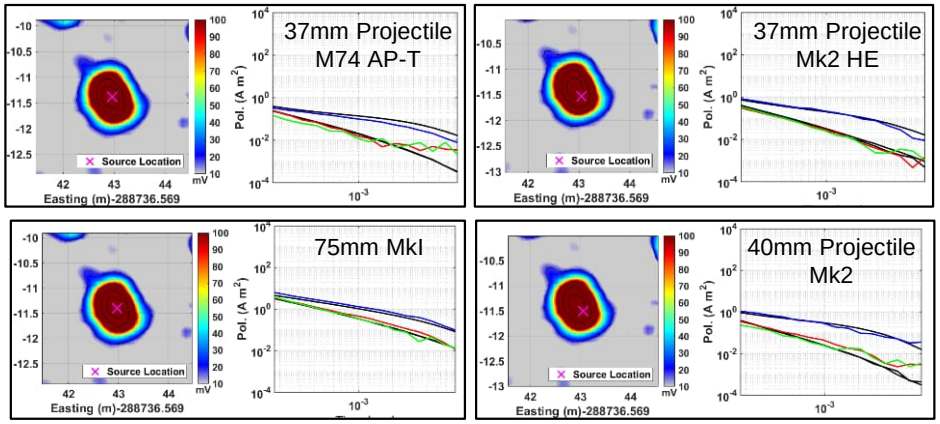
37-mm Projectile Real-World Results

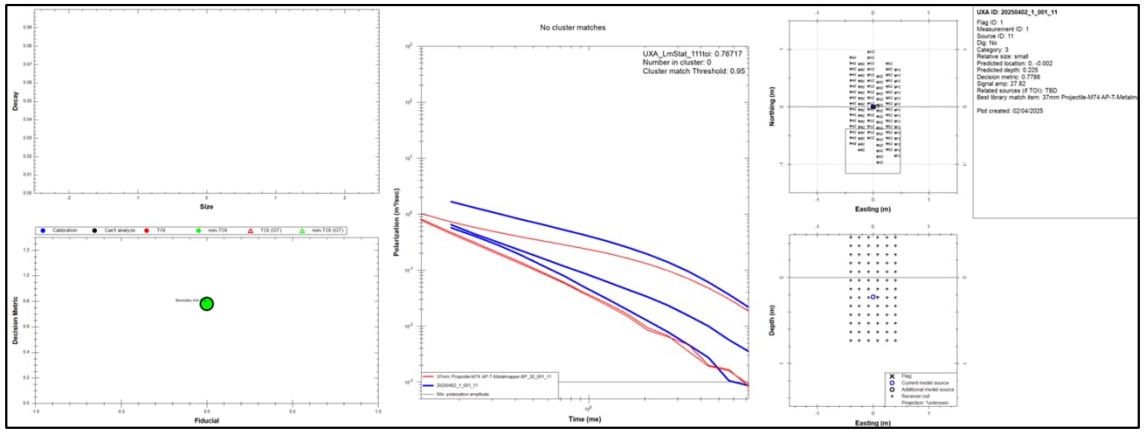
- UX-Analyze results
  - 37-mm library: single 37-mm source 0.7326
    - **Likely both 37-mms would be left in the ground!**
  - Site library: two sources
    - 60-mm M49A3 0.8831
    - Medium ISO 0.8398
    - **Likely, one 37-mm would be left in the ground!**
- EMClass results
  - 37-mm library: two 37-mm sources (M74 0.955 / MkII 0.954)
  - Site library: two sources
    - 75-mm projectile 0.976 (at geometric center of pair)
    - 40-mm projectile 0.926
  - **Duplicates removed as sources <25 cm apart,**
  - **Both should be recovered – dependent on dig procedure as related to size prediction and QC!**

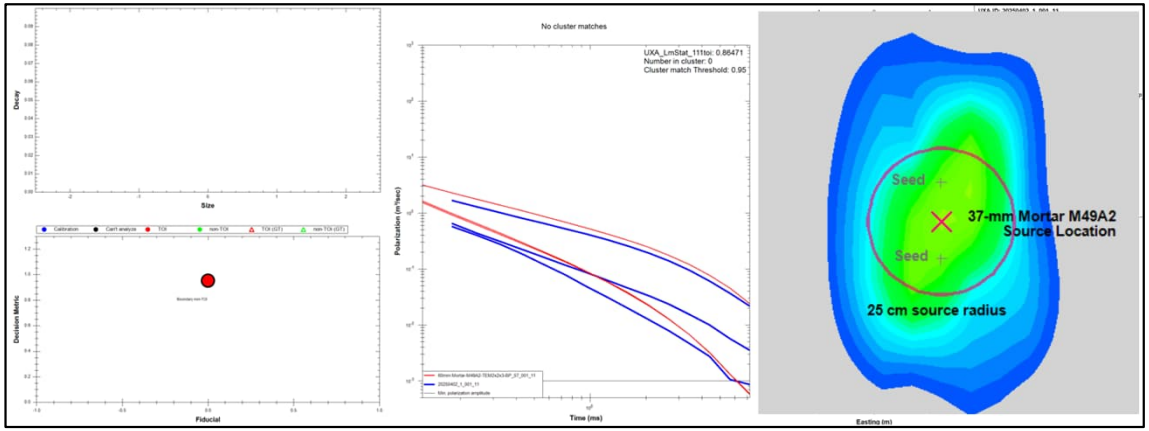




37-mm Projectile: UX-Analyze Synthetic Results

- 37-mm Library
  - Single 37-mm M74 AP-T source 0.7788
  - **Both 37-mms would be left in the ground!**
- Full DoD Library
  - Single 60-mm Mortar M49A2 source with 0.9522 confidence
  - Source at mid-point; 13 cm offset between items
  - **Both 37-mms should be recovered using proper dig procedures**





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Putting It All Together…

- **ISO + Shell Casing:** good results even in most complex case – metrics met, and all seeds should be recovered.
  - Majority matched to a small ISO
  - Each test had one match to a 60-mm mortar
- **ISO + ISO:** did (Site 1), or should (Site 2), result in all seeds being recovered.
  - Orientation/offset between items effect results
  - Possible no find result at separation of 10”
  - Inconsistent size predictions
- **Library:** makes a difference in results
  - Site-specific library average 0.9606, ISO library average 0.9324
- **Mode of collection:** has effect on outcome
  - Dynamic cued: all resolved into single source; 60-mm (average 0.9638) or ISO (average 0.9483)
  - Dynamic classification: 81% single source (average 0.9557) and 19% two sources (average 0.9193)
- **Classification software:** significant differences in 37-mm test results
  - If results substantiated, items with a potential explosive hazard could be left in the ground
- **UXA Synthetic Testing:** Generally good correlation between real-world and synthetic tests.
  - Option for exploring complex scenarios

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Next Steps

- Questions we hope to answer:
  - Is there an offset distance between similarly shaped items where resolution of a single source would result in non-recovery of one of the items?
  - Why are the EMClass and UXA results so different for 37-mms?
  - Do test results degrade as the max depth of reliable classification is approached?
- More real-world testing planned (supplemented with synthetic testing)
  - ISO + Wire: ISO at 12” bgs
  - ISO + ISO: increased offsets (up to 14”) to 12” bgs
  - Tests with medium ISOs
  - Mk5 (zinc) and Mk23 (steel) practice bomb tests
  - Mk1 and Mk2 grenade tests
  - Comparison of results between software platforms

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Thank you for attending this episode of…

Complex Seed Wars

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