

Progress in Munitions Classification: Examples from Spencer Range, TN

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Evolution of processing capabilities driven by the ESTCP Live Site Program

2008 Camp Sibert, AL

- Identify single large target among smaller clutter and debris



2009 San Luis Obispo, CA

- Increased TOI target classes
- Significant topographic relief



2010 Camp Butner, NC

- Significant amount of clutter similar in size & shape to 37mm



2011 Camp Beale, CA

- Data requires a conservative approach



2011 Pole Mountain, WY

- Data support an aggressive strategy



2012 Spencer Range, TN

- multiple sensors deployed in both cued and dynamic modes

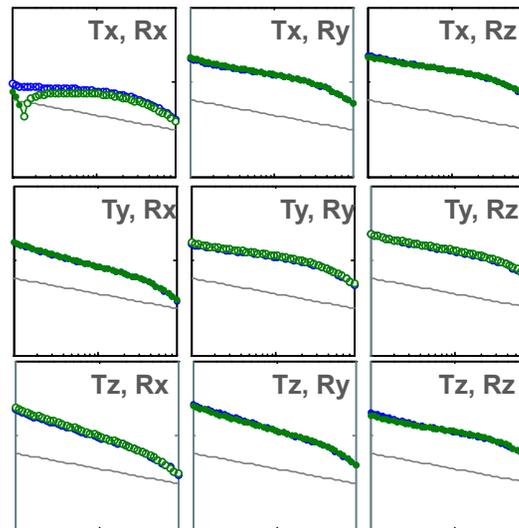


Standard processing flow for UXO detection and classification

1. Data Acquisition

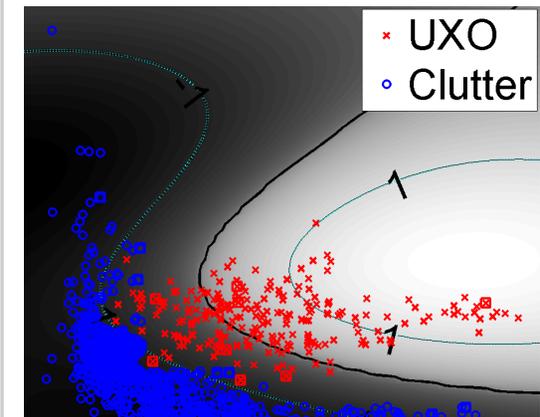


2. Feature estimation



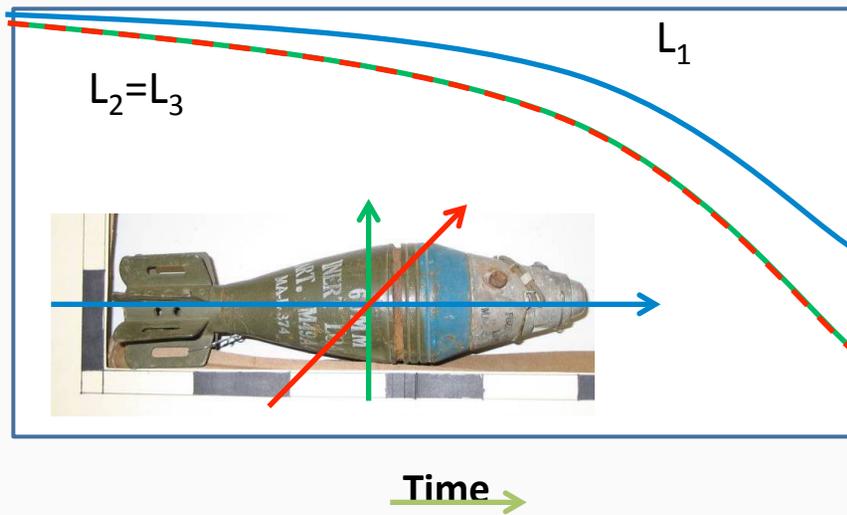
Feature vector

3. Classification

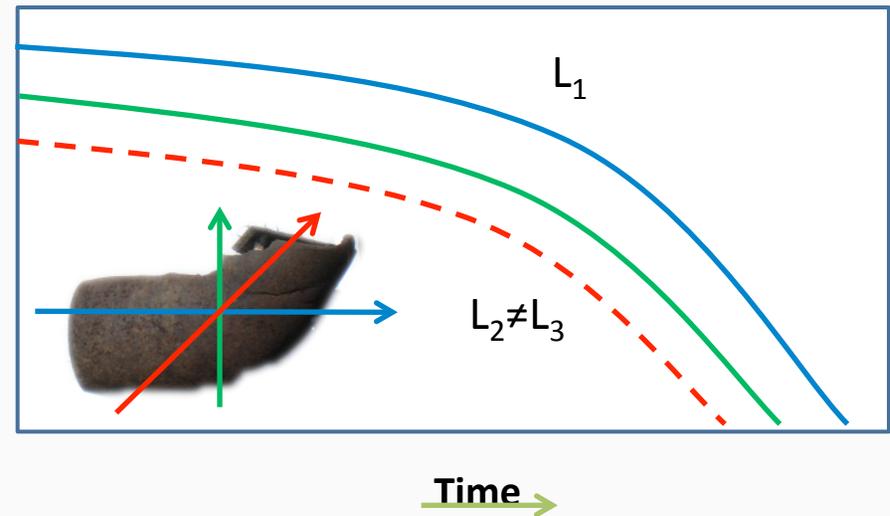


Feature Extraction: Target Polarizabilities

UXO



Non-UXO



UXO are generally distinguished by:

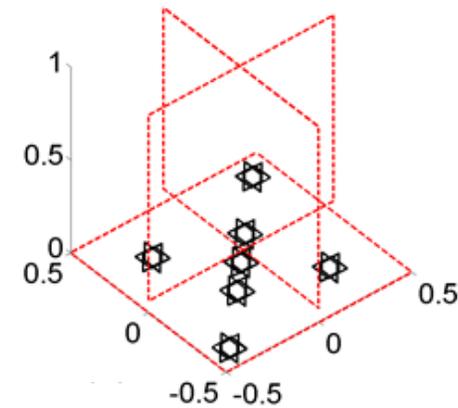
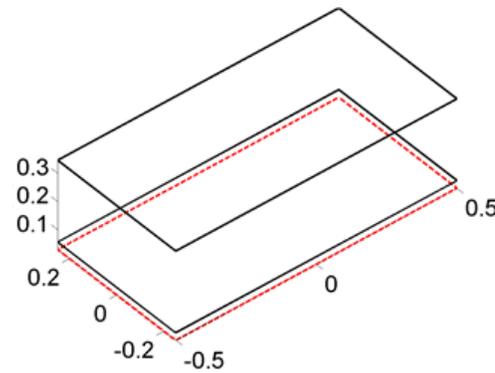
- large amplitude, slow-decaying primary (L_1) polarizability
- equal secondary polarizabilities ($L_2=L_3$).

EM61 Versus Advanced EMI Sensors

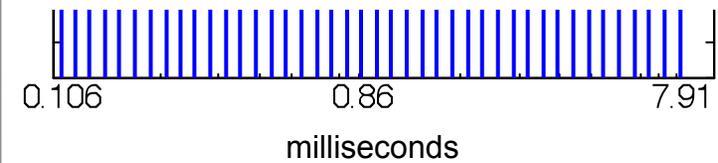
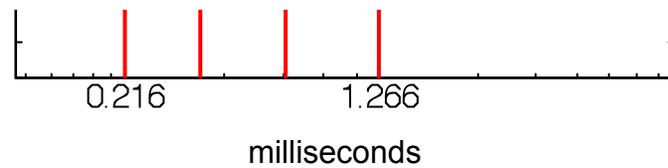
Sensor



Geometry

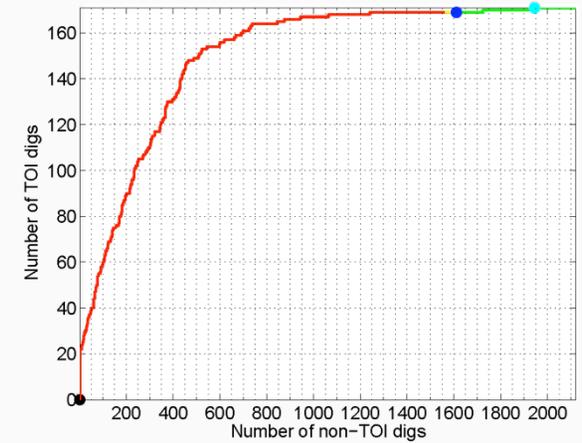
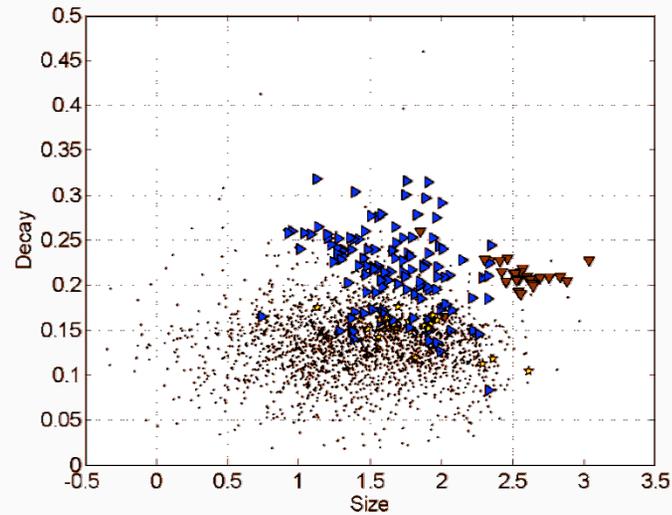


Time

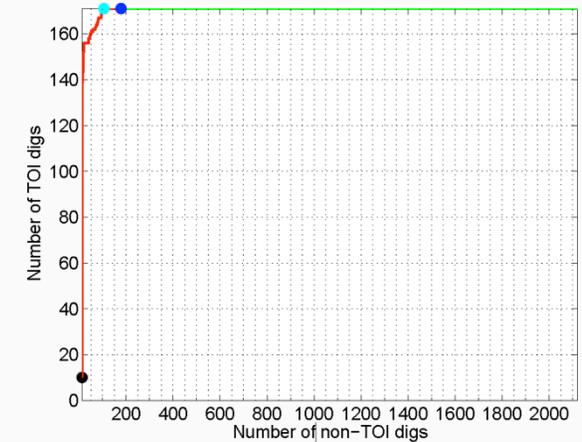
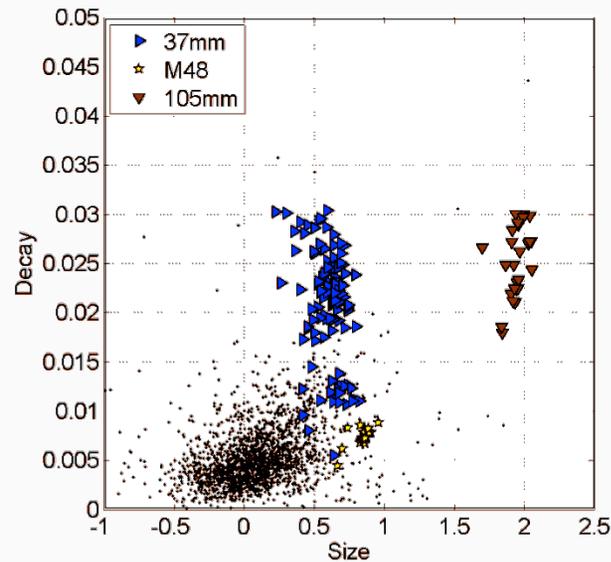


Need for purpose built UXO classification sensors

EM61-MK2

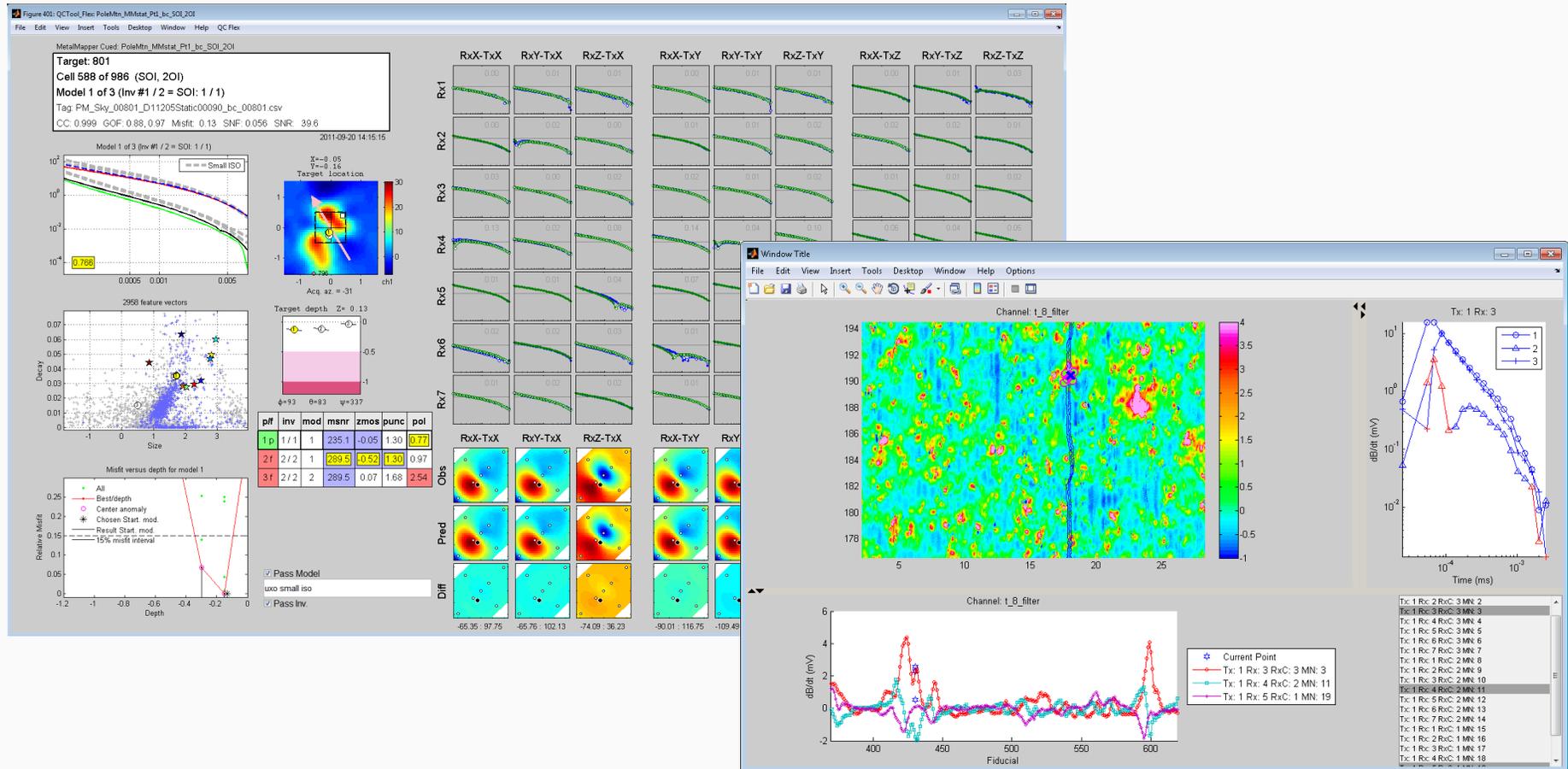


TEMTADS



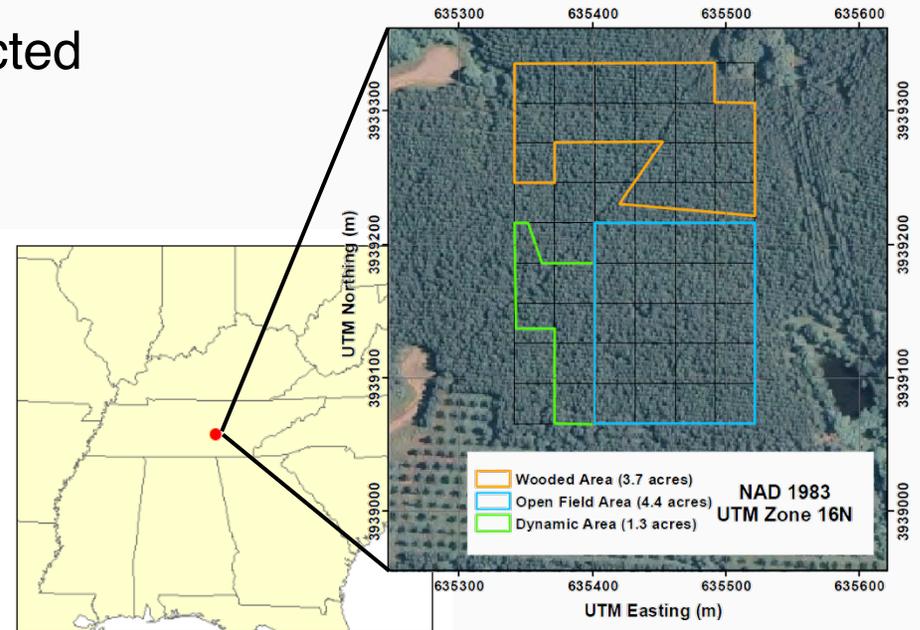
Software tools for Classification

- Dedicated software tools required for efficient, reliable classification
- UX-Analyze
- UXOLab



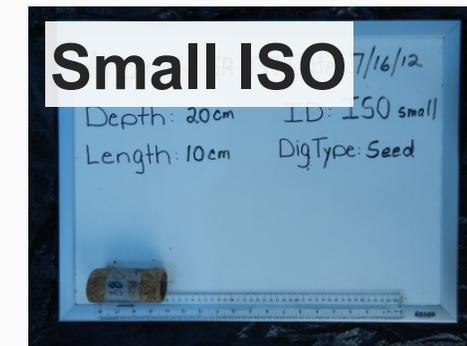
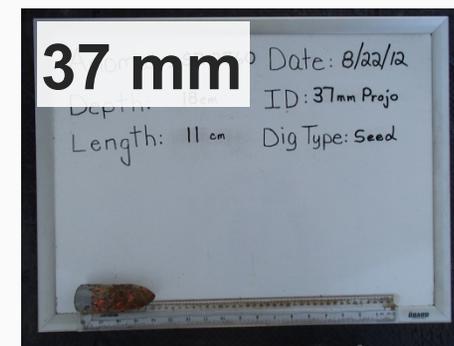
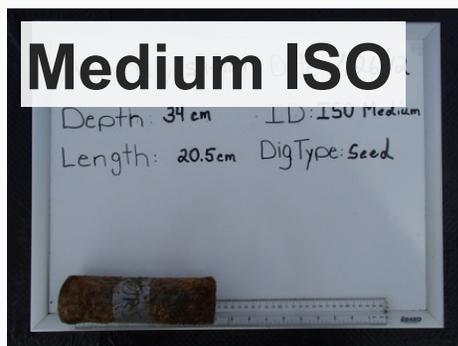
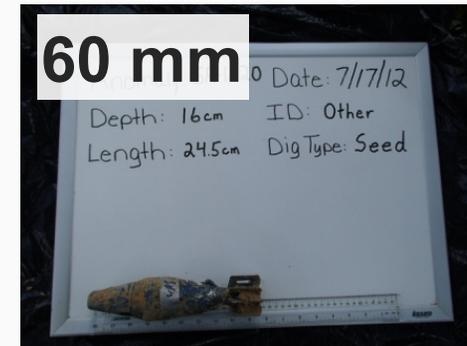
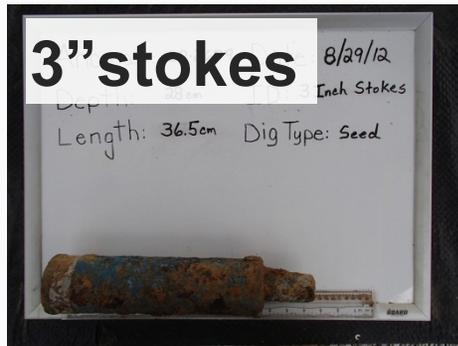
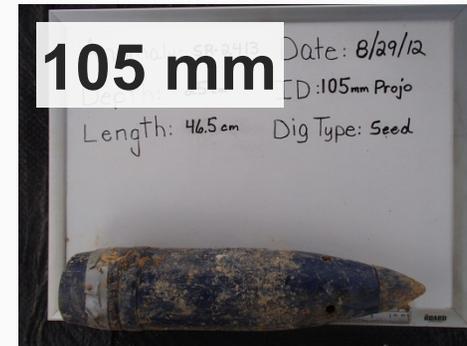
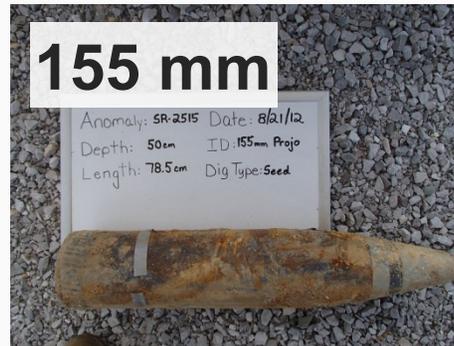
UXO Classification at Spencer Range

- Apply practical UXO classification techniques to all EMI data sets collected
- Evaluate discrimination performance using both cued and portable EMI sensor data



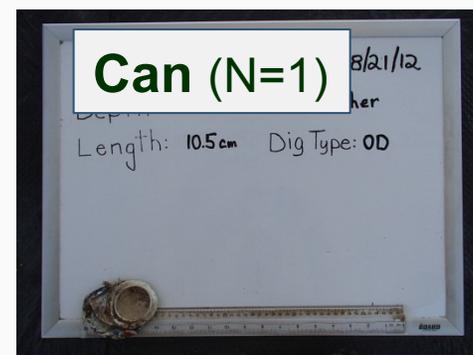
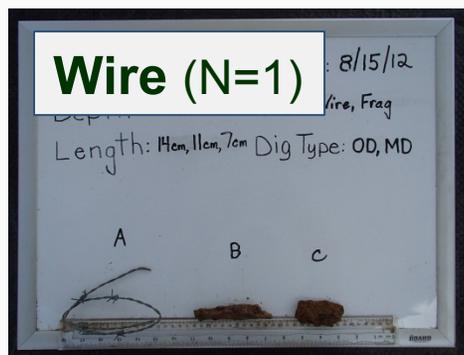
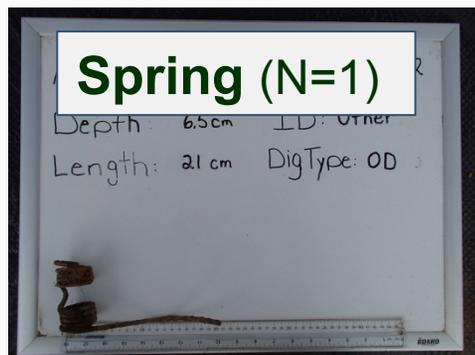
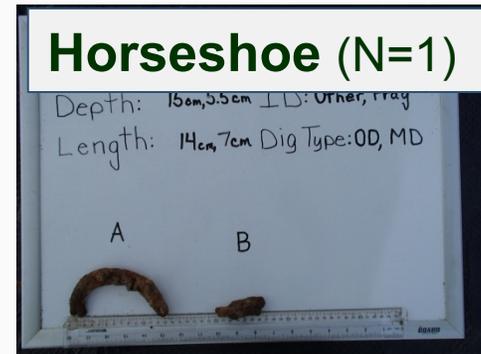
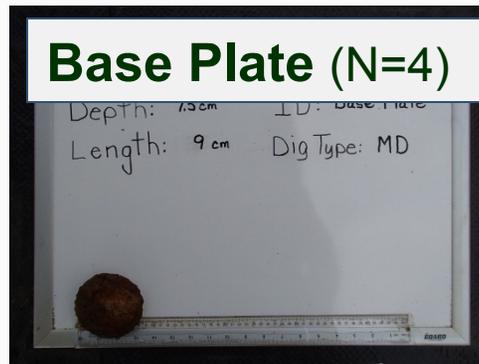
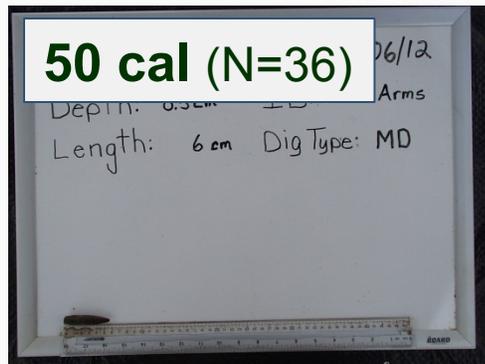
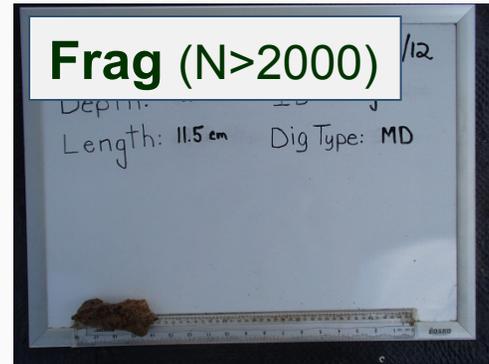
UXO Classification at Spencer Range

Targets of Interest



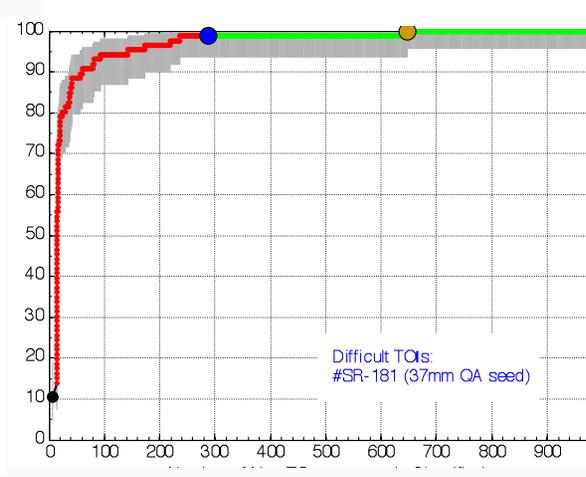
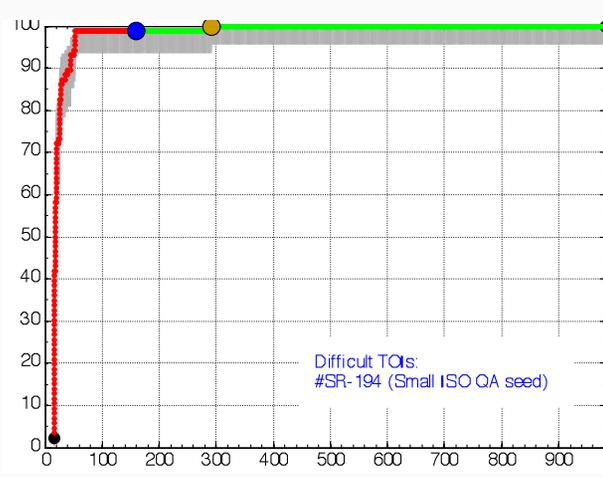
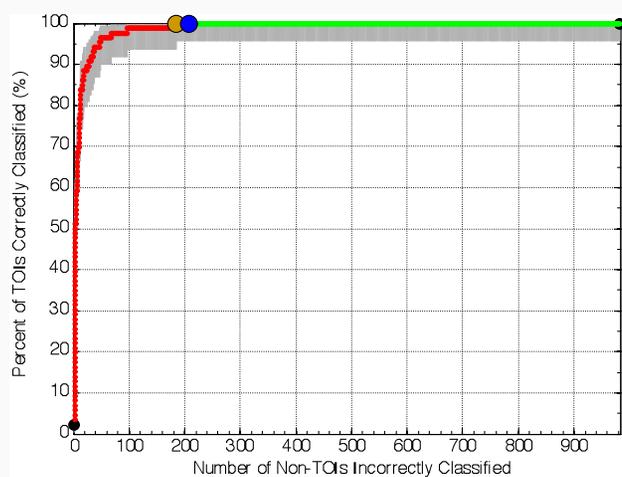
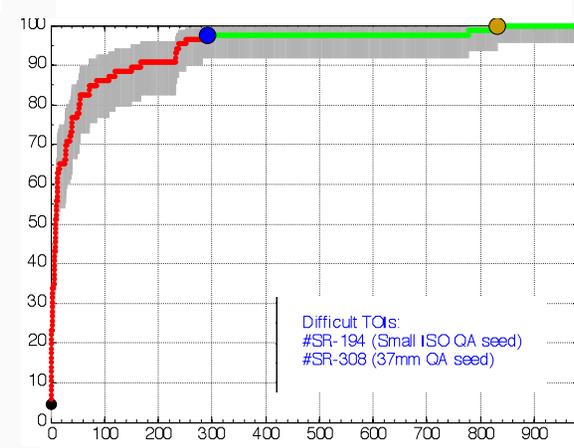
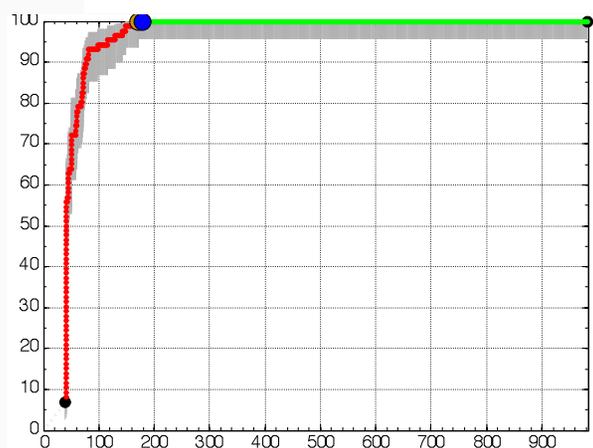
UXO Classification at Spencer Range

- **Non TOI**
 - Labelled as non-harmful, non-UXO



Cued MetalMapper results from Spencer Range

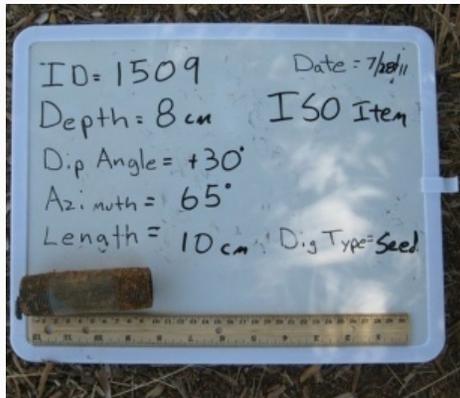
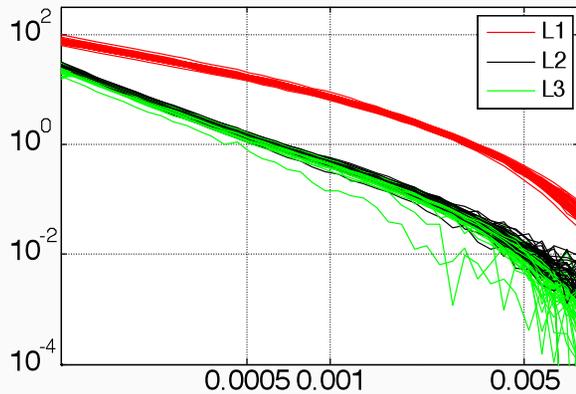
Results by industry geophysicists



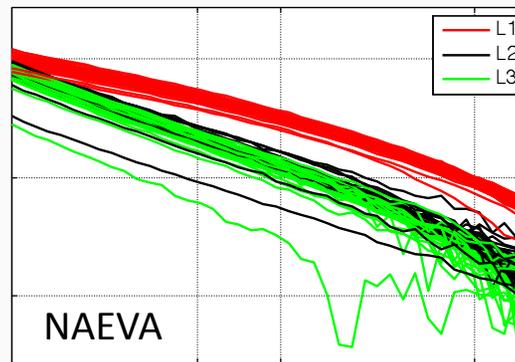
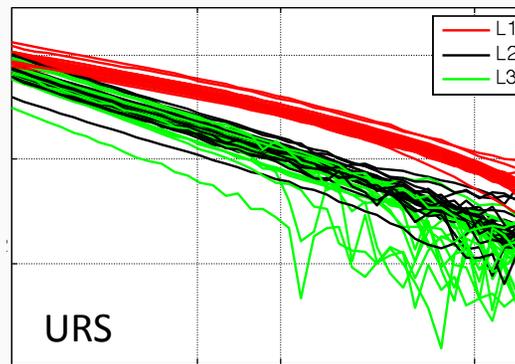
Understanding Variations in Data Quality

- Variation in quality of recovered polarizabilities for ISO

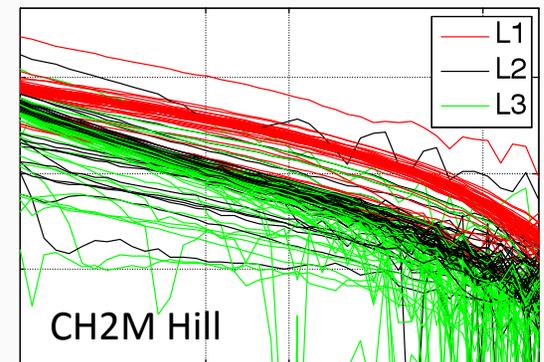
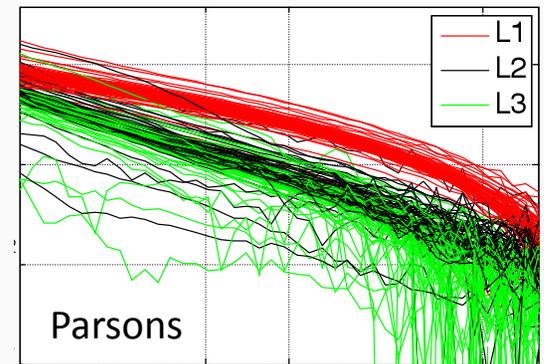
Pole Mountain



Spencer Range

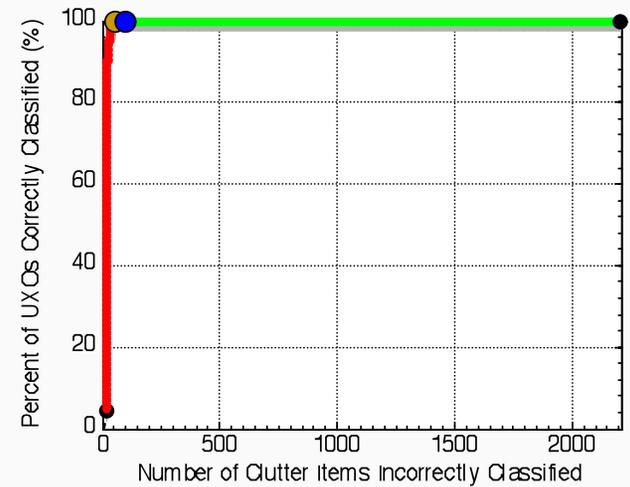
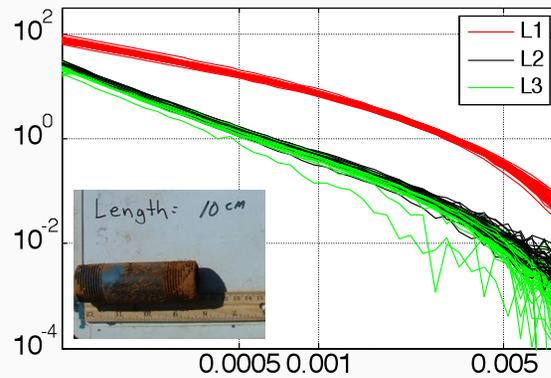


Camp Beale

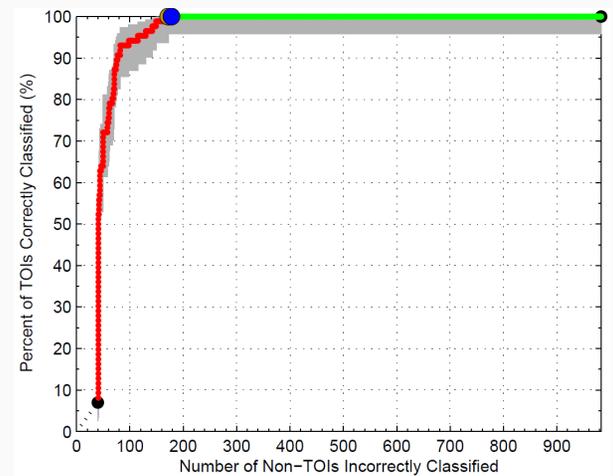
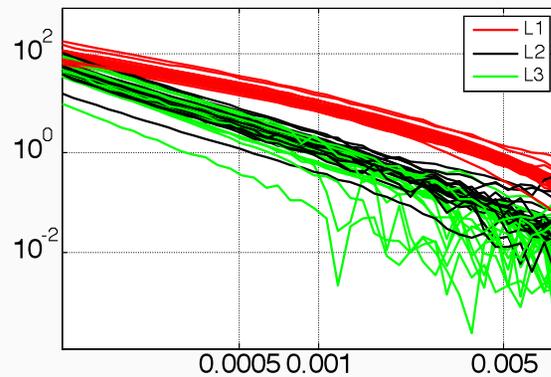


Technology Transfer: Industry Partner Results

Pole Mountain



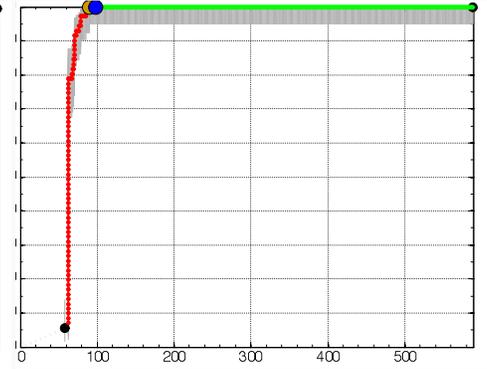
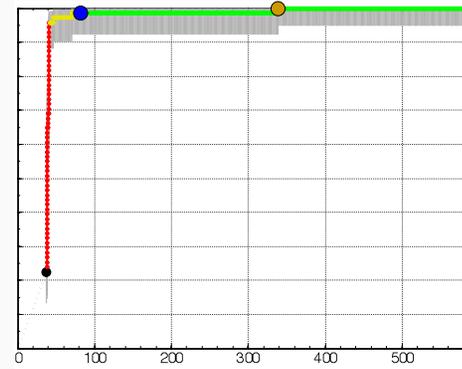
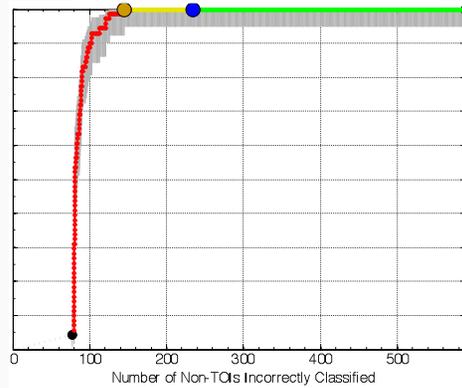
Spencer Range



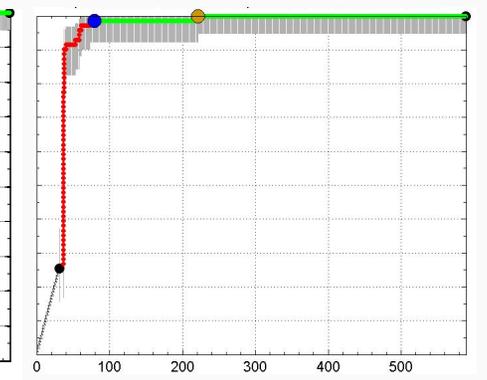
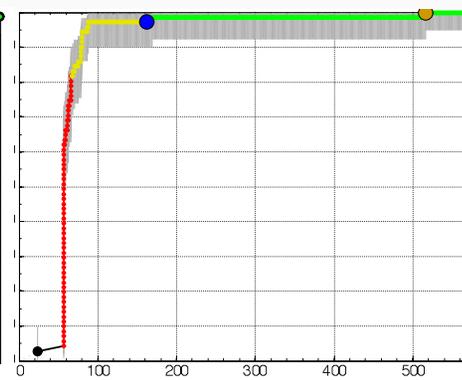
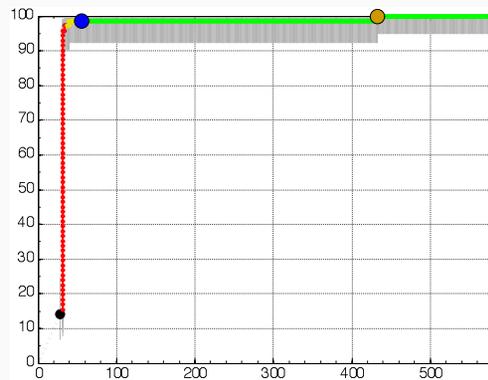
Cued Portable Sensor results from Spencer Range

- Man-portable sensors data analyzed by SAIC, Dartmouth and Black Tusk Geophysics

TEMTADS 2x2



MPV



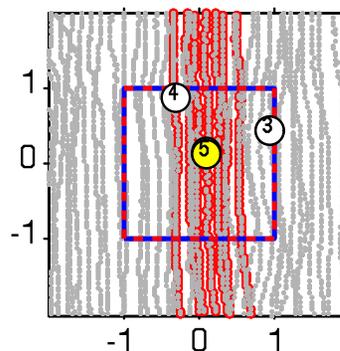
note: same target missed by each analyst

Cued Interrogation Issues

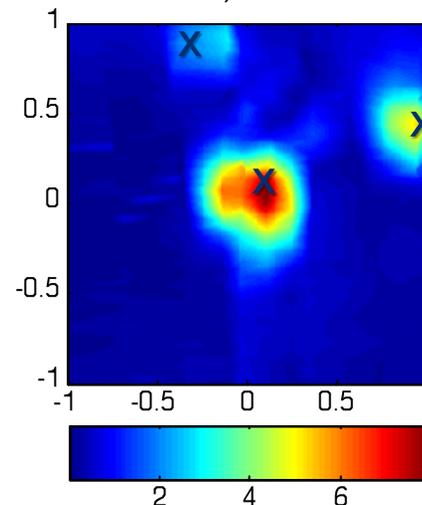
- Cued interrogation survey requires additional time and cost
- Need to rely on DGM map using EM61-MK2
 - Difficulties resolving multiple targets in close proximity
 - Geologic noise
 - Inaccuracy of EM61-MK2 picks lead to multiple recollects of cued data

Example: Spencer Range

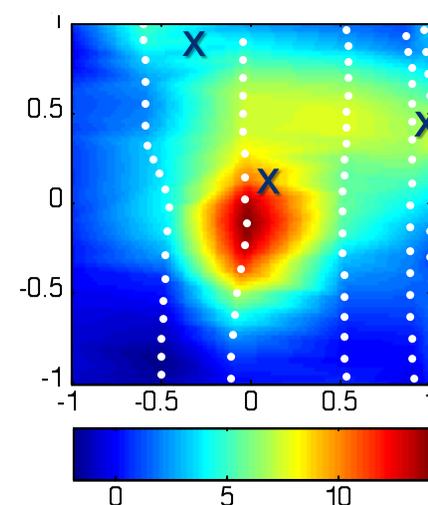
Dynamic MetalMapper coverage



Dynamic MetalMapper
Channel 5, Vector Sum



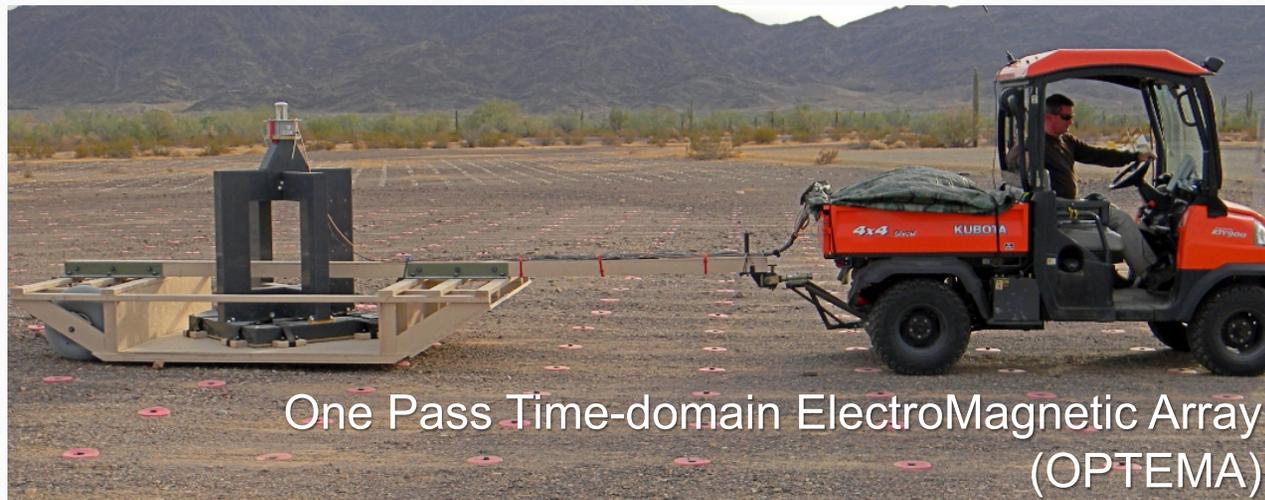
Geonics EM61-MK2
Channel 1



Combined Detection and Classification with Advanced EMI Sensors

Challenges and questions:

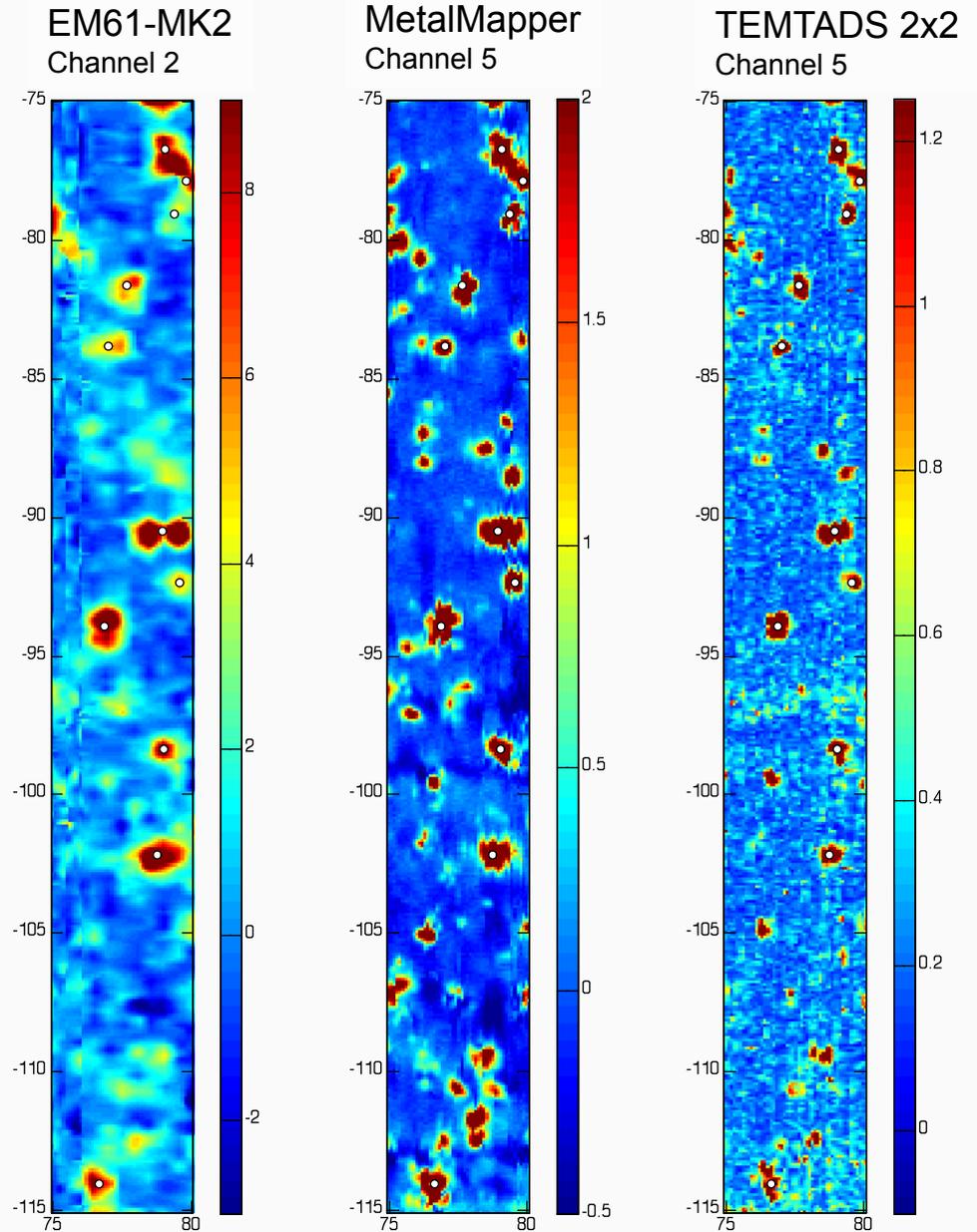
- How does production rate compare to EM61?
- Increased sensitivity to near surface clutter
- Collecting dynamic data with sensors designed to be deployed in a cued mode in difficult terrain
- Reduction of data quality relative to cued surveys
 - positioning, smaller time window, fewer “looks” at target (dynamic MM)



One Pass Time-domain ElectroMagnetic Array
(OPTEMA)

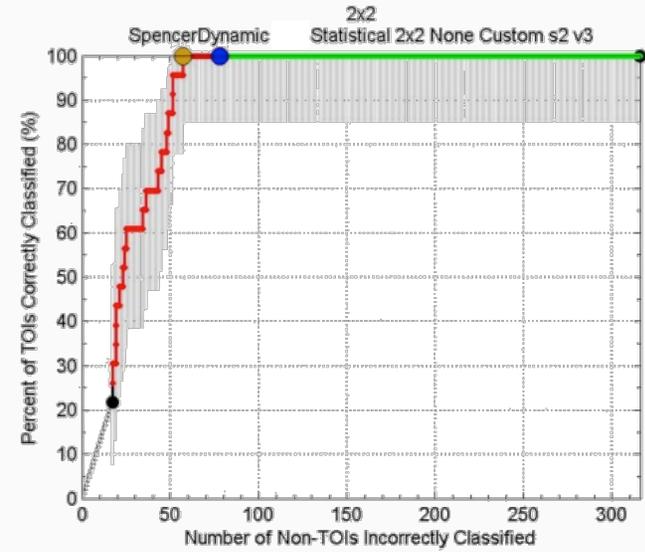
Dynamic Data Collected at Spencer Range

- The vector sum of receivers are plotted.
- Advanced EMI instruments produce higher resolution maps for target picking

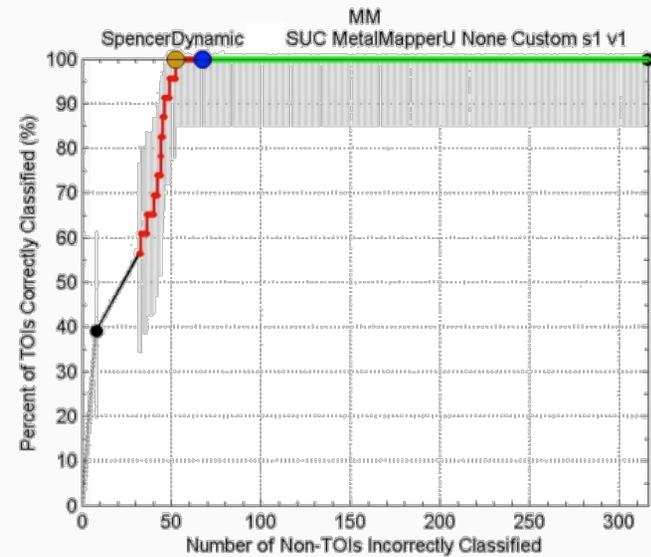


Classification using Dynamic Data Only

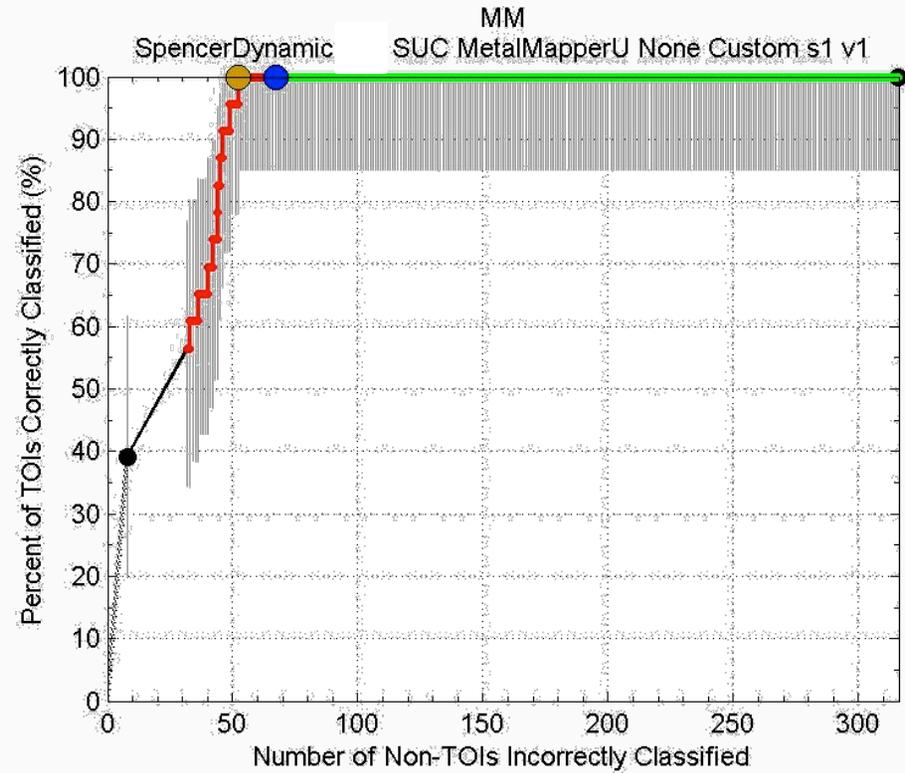
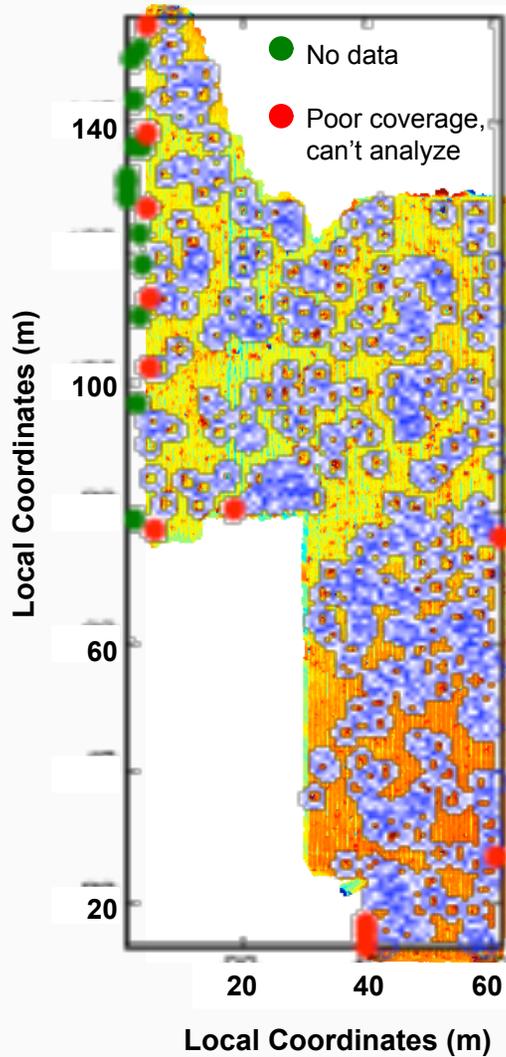
**TEMTADS
2x2**



**Metal
Mapper**



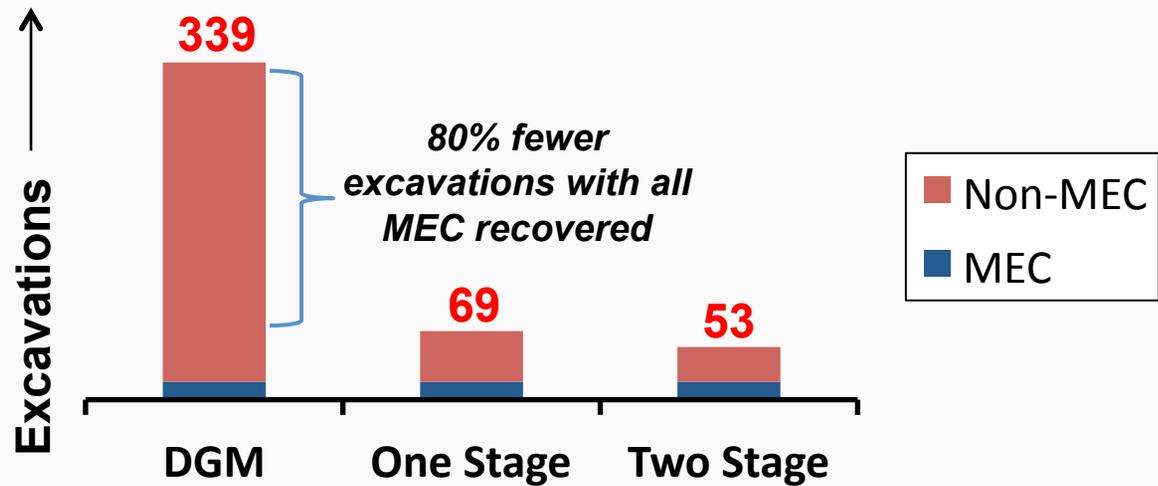
Analysis of Spencer Range MetalMapper Dynamic Field Data



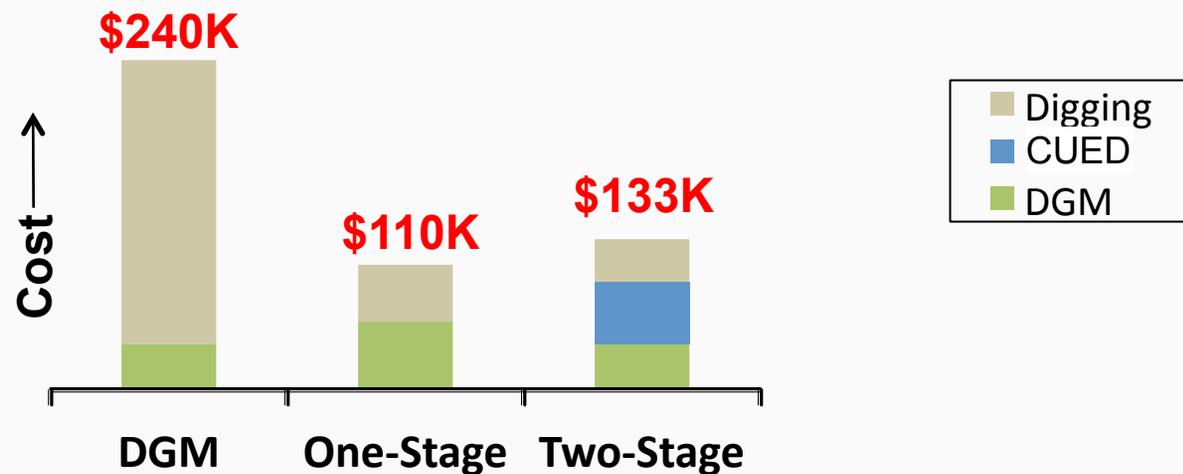
- Some difficulty with coverage of anomalies on edge of survey area

Reduction in Excavations and Cost Resulting from advanced classification

Spencer Range
MetalMapper
Performance



Spencer Range
MetalMapper
Costs



Conclusions

- All advanced EMI sensors deployed at Spencer Range generated excellent classification results
- Production contractors produced promising classification results for cued MetalMapper data at Spencer Range.
- Combined detection and classification with advanced EMI sensors performed very well at Spencer Range.
 - ~80% reduction in clutter digs required

Acknowledgements

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The University of British Columbia
Geophysical Inversion Facility



SERDP
DOD • EPA • DOE



ESTCP



Black Tusk
GEOPHYSICS