Classification of Small TOI in Highly Cluttered Areas

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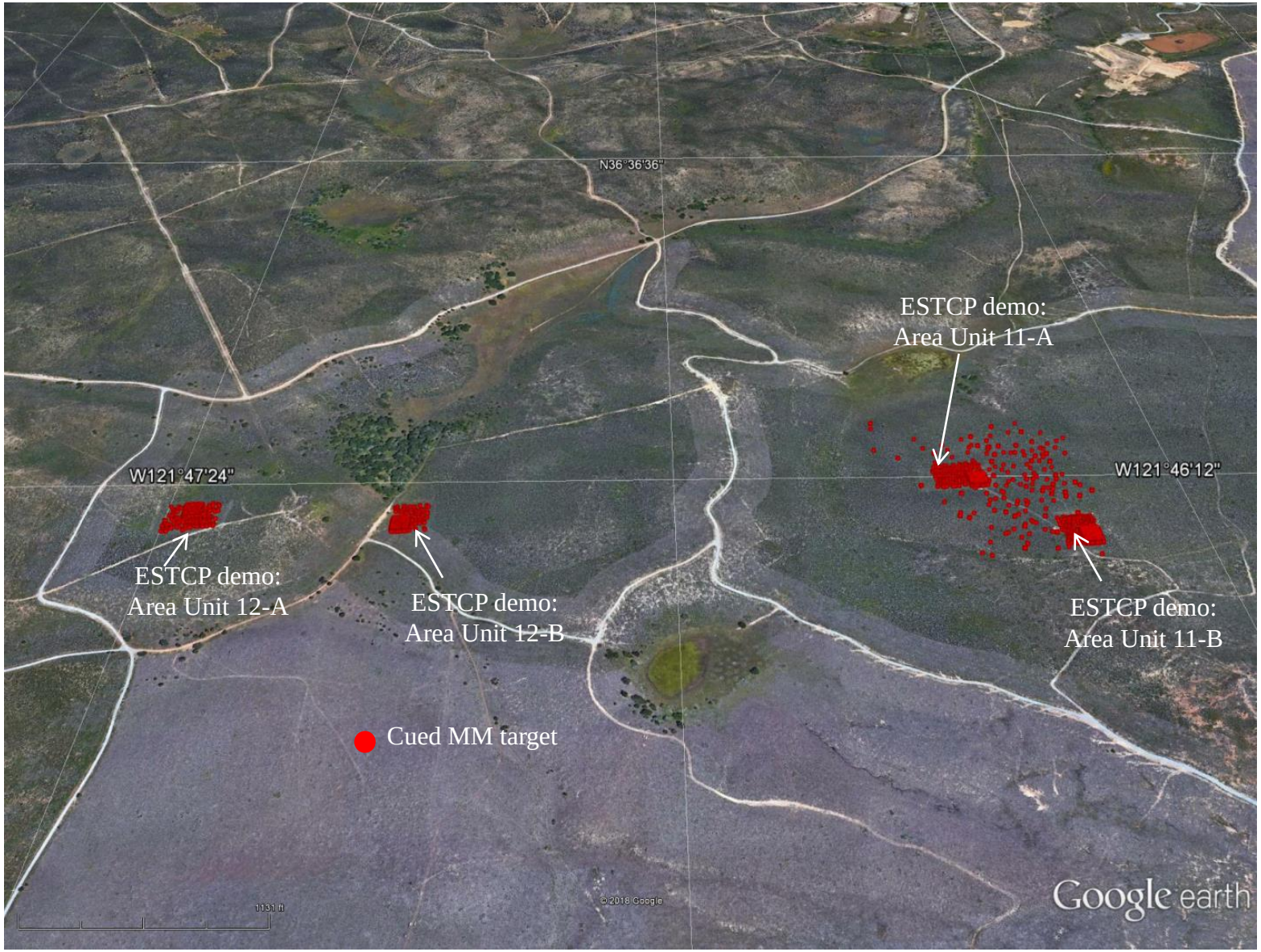
Outline

- ESTCP demo site at Fort Ord, CA
- EMI data inversion and classification approaches
- Ft. Ord TOI-s
- Results
  - ROC curves
  - Lessons learned
  - Comparisons between classification performances
- Conclusions

ESTCP demo site at Fort Ord, CA



Objectives:

- Classify all large munitions, such as 155mm projectiles, to a depth of 2 feet.
- Demonstrate if all TOI can be confidently classified within low to highest metal anomaly density areas at Fort Ord, CA.

Fort Ord Soil

- Consists marine sandstones with iron concentrations.
- No Noticeable impact on the EMI sensor data .

Fort Ord, CA TOI

Main goal

Classify all large (>106 mm) TOI to a depth of 2 feet.

Keep at least 90% clutters in ground

Secondary goal:

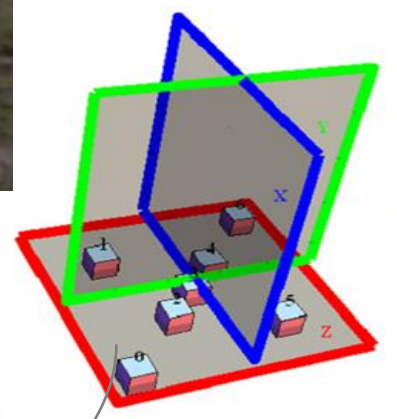
Classify all TOI-s.

Keep at least 75% clutters in ground

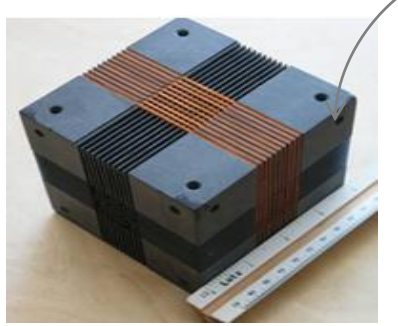
TOI	20 mm	ISO	37mm	35 mm	40mm	60 mm	ISO M	75 mm	81 mm	105mm	4.2 inch	155 mm
#	3	4	11	3	87	1	7	185	3	1	3	33

EMI sensor

- **The sensor has 3 T_x-s & 7 R_x cubes**
- **Multiple angle illumination**
- **Good spatial resolution**
- **Operates in both cued and survey modes**
- **Receives vector field**



Rx cube



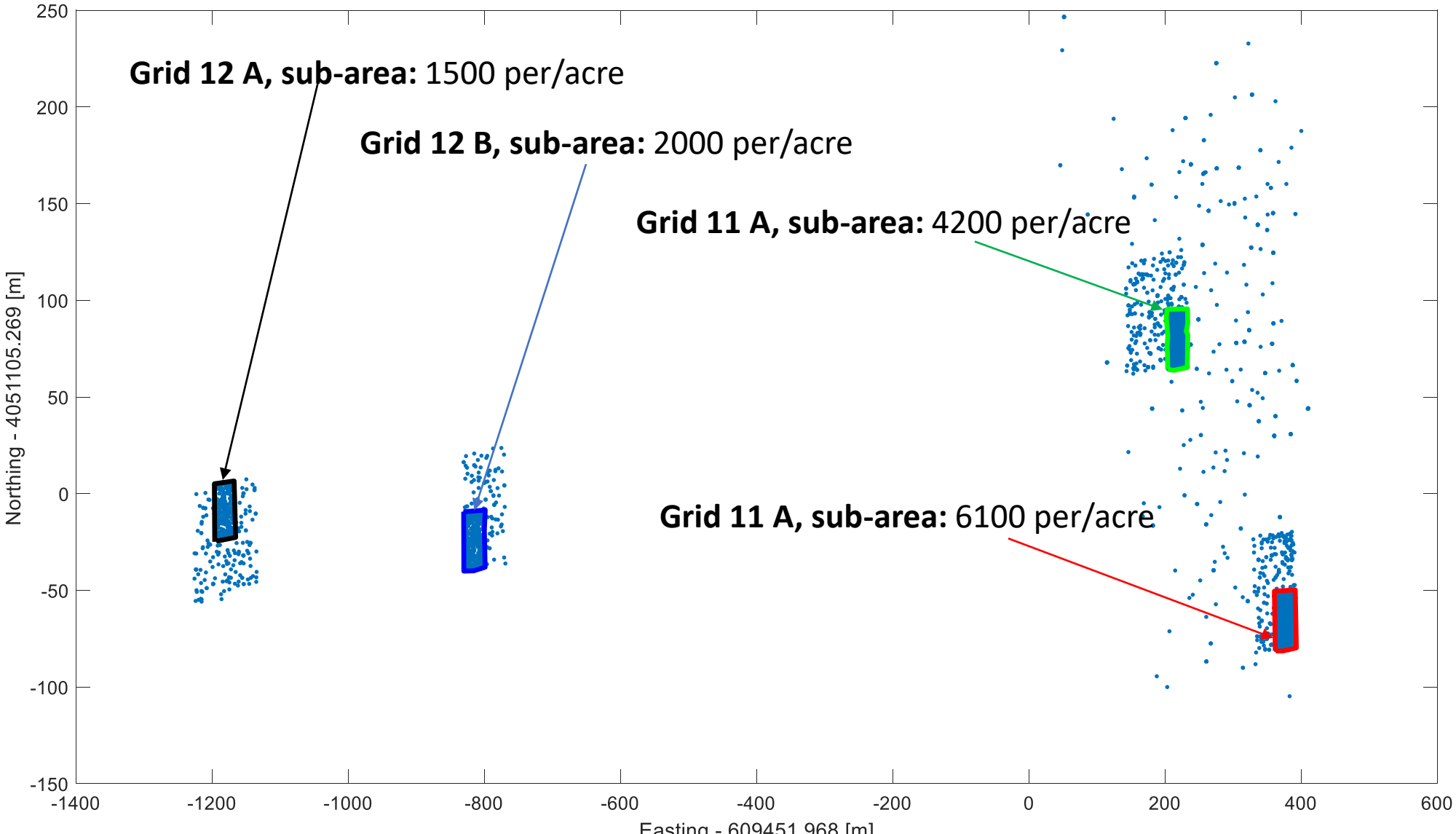
T_x coils:

3 orthogonal 1 m × 1 m rectangular loops

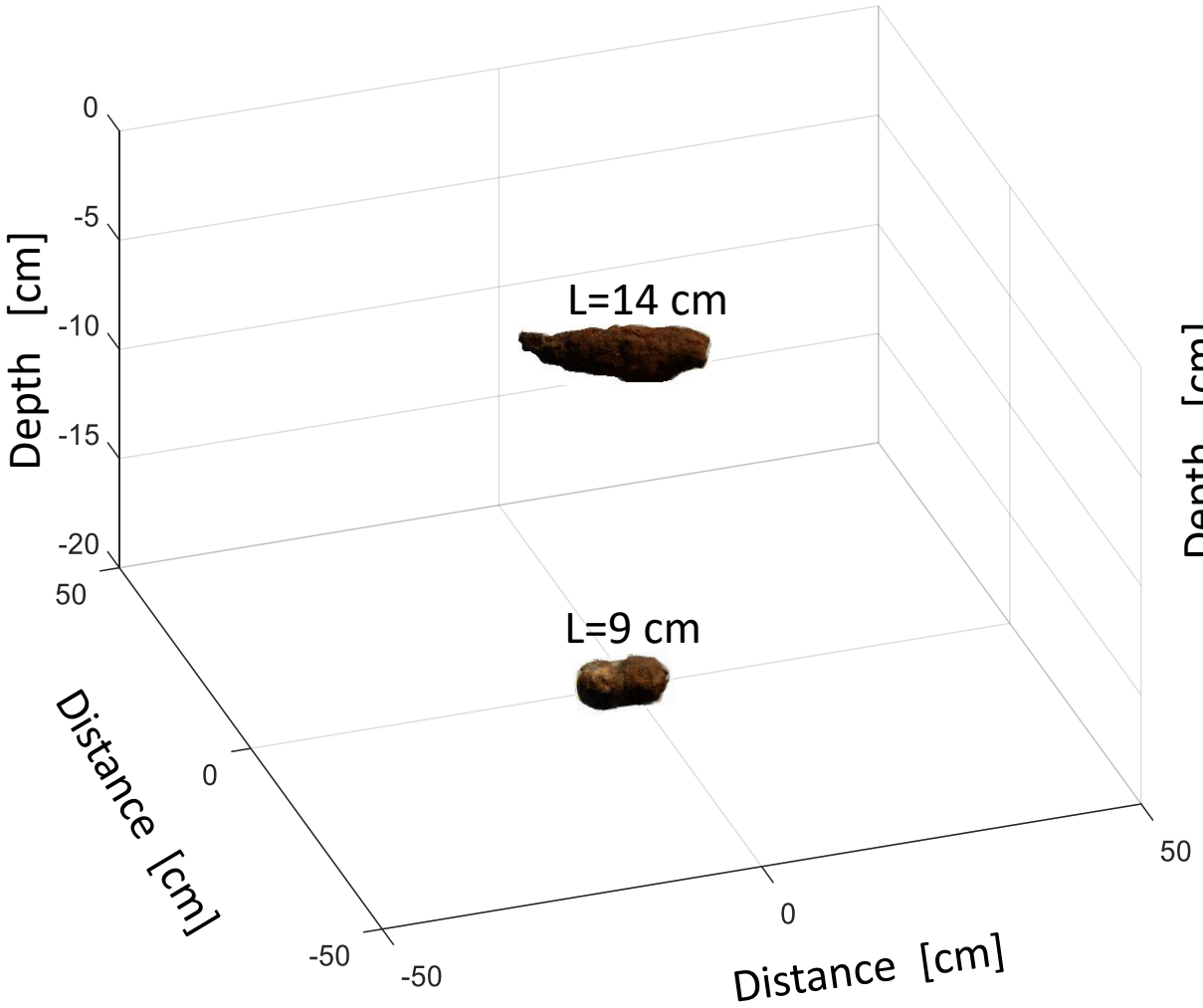
Receivers:

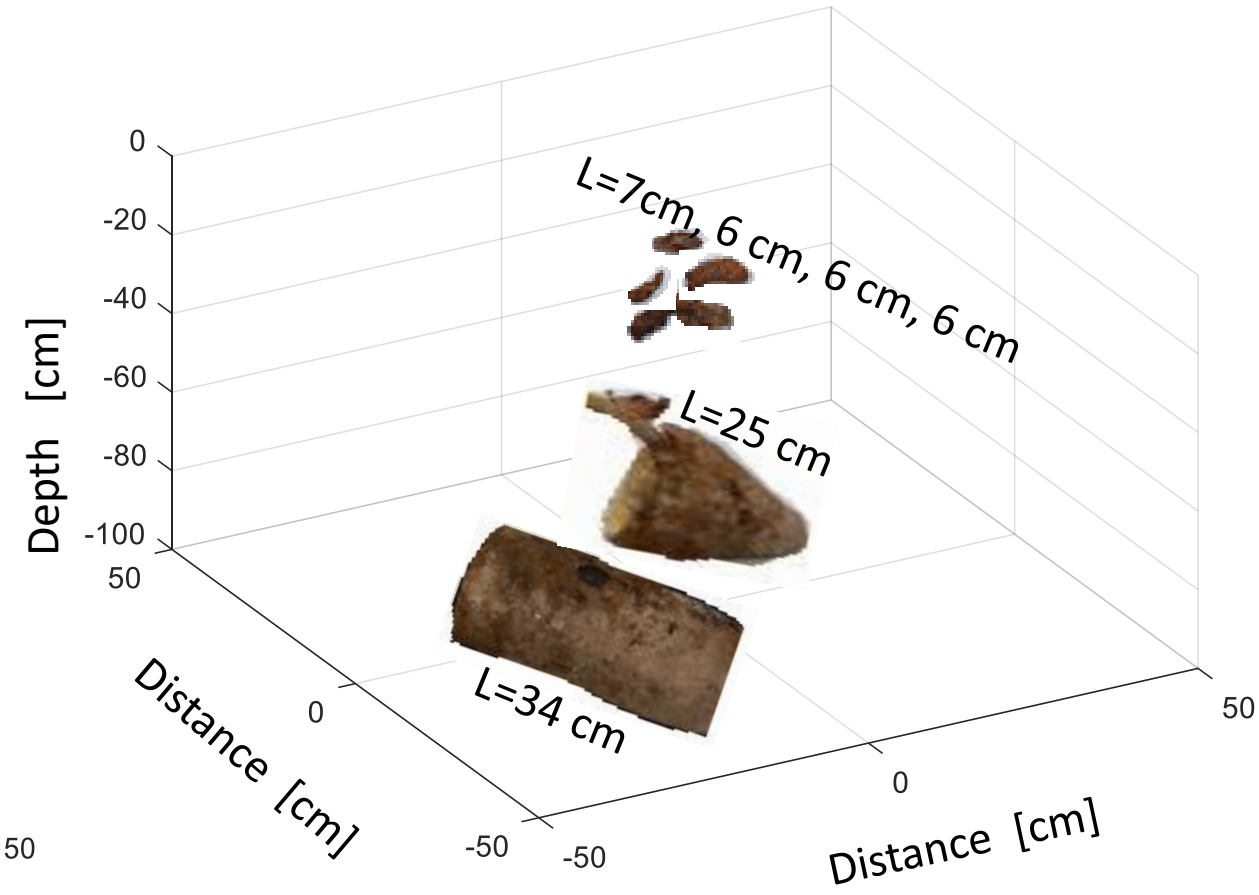
7 tri axial receiver cubes

Target density at Fort Ord, CA



Multi targets





Forward Models

ONMVS

- The scattered EMI field is approximated as magnetic field from **groups of interacting dipoles** using an ortho-normalized function expansion:

$$\mathbf{H}(\mathbf{r}) = \sum_{q=1}^{Q} \bar{\bar{\psi}}_q(\mathbf{r}) \cdot \boldsymbol{b}_q ,$$

where $$\bar{\bar{\psi}}_q(\mathbf{r}) = \bar{\bar{G}}_q(\mathbf{r}) - \sum_{k=1}^{q-1} \bar{\bar{\psi}}_k(\mathbf{r}) \cdot \bar{\bar{A}}_{qk} ;$$

- First it determines b_q from the measured data **without solving** a linear system of equations, then it backs up $\mathbf{m}_i$
- Uses total ONVMS/effective polarizabilities for classification

Multi dipole mode

- The scattered EMI field is approximated as superposition of magnetic fields from each individual dipoles, using the Green's dyadic function:

$$\mathbf{H}(\mathbf{r}) = \sum_{i=1}^{N_v} \bar{\bar{G}}_i(\mathbf{r}) \cdot \boldsymbol{m}_i$$

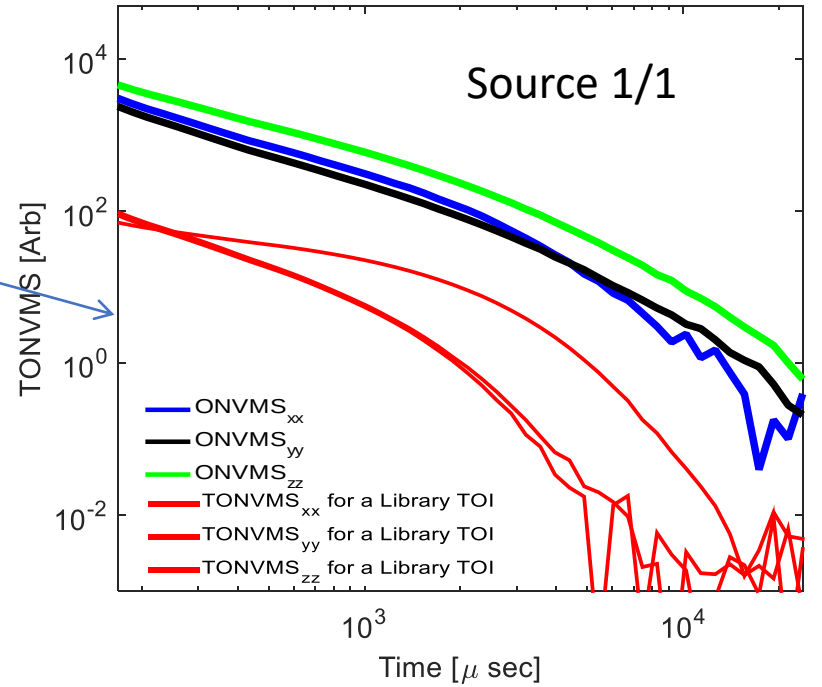
where

$$\bar{\bar{G}}_i(\mathbf{r}) = \frac{1}{4\pi R_i^3}\left(3\vec{R}_i\,\vec{R}_i - \bar{\bar{I}}\right) ; \quad \vec{R}_i = \mathbf{r}_i - \mathbf{r}$$

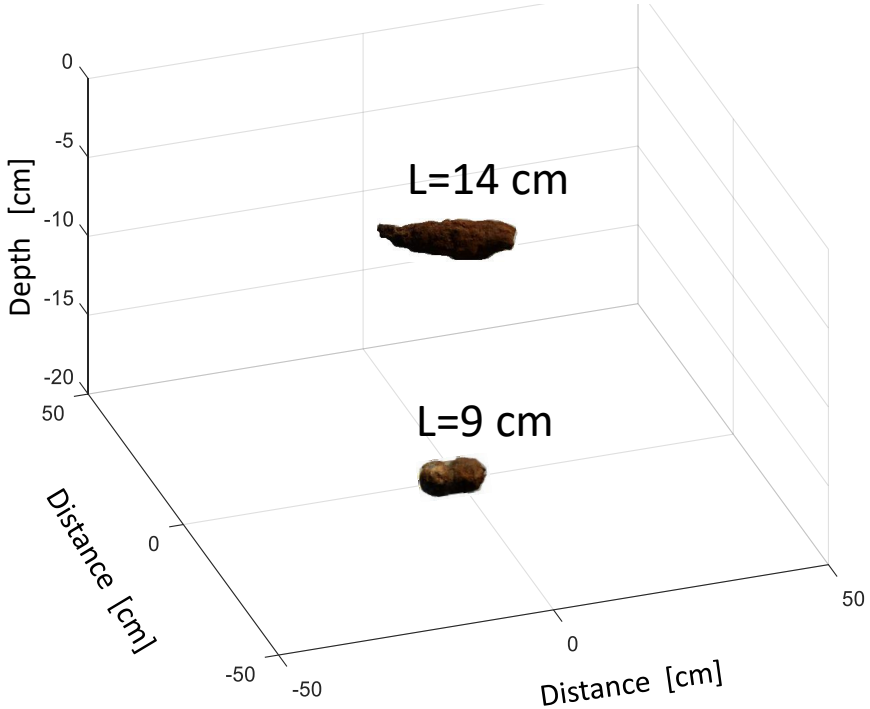
- $\mathbf{m}_i$ are determine from the measured data **by solving** a linear system of equations.
- Uses **individual dipoles** for classification

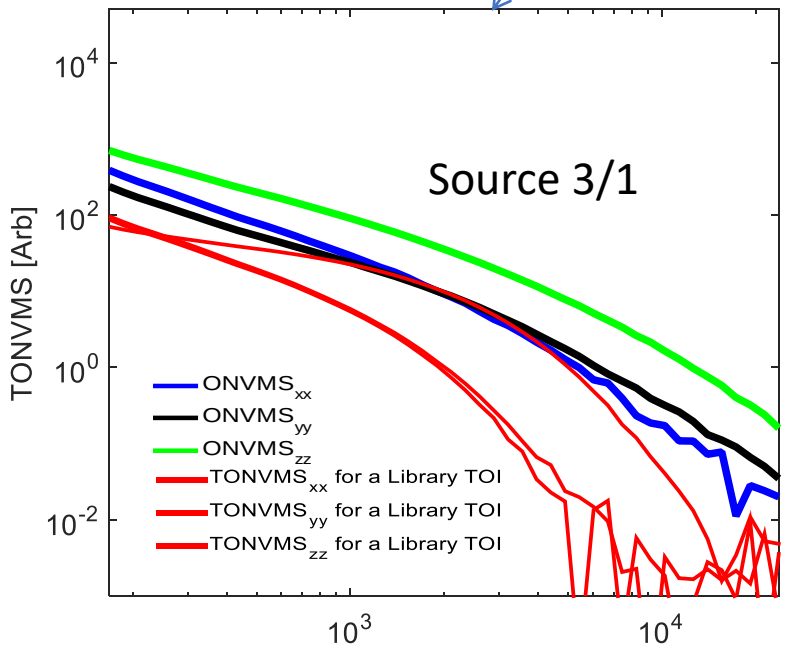
Data inversion

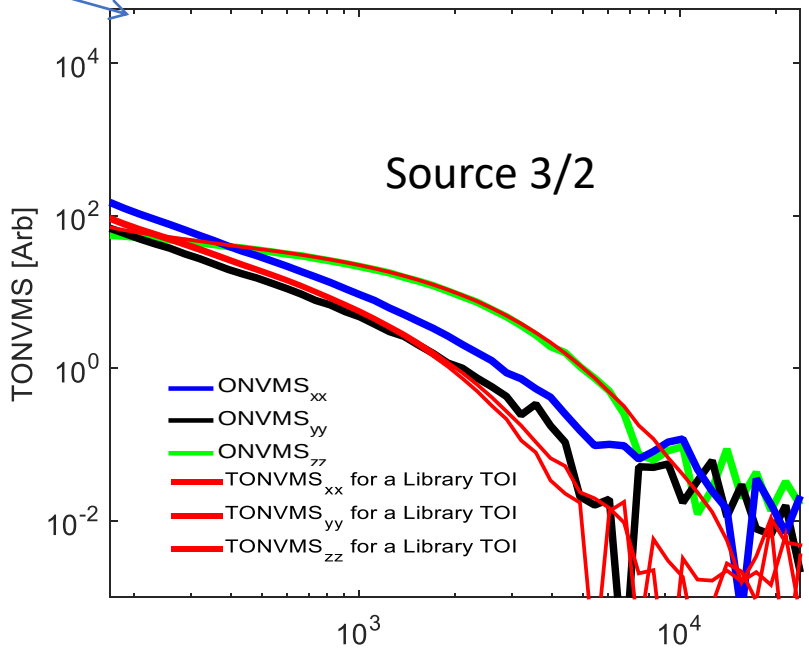
One source inversion result



Multi source inversion results

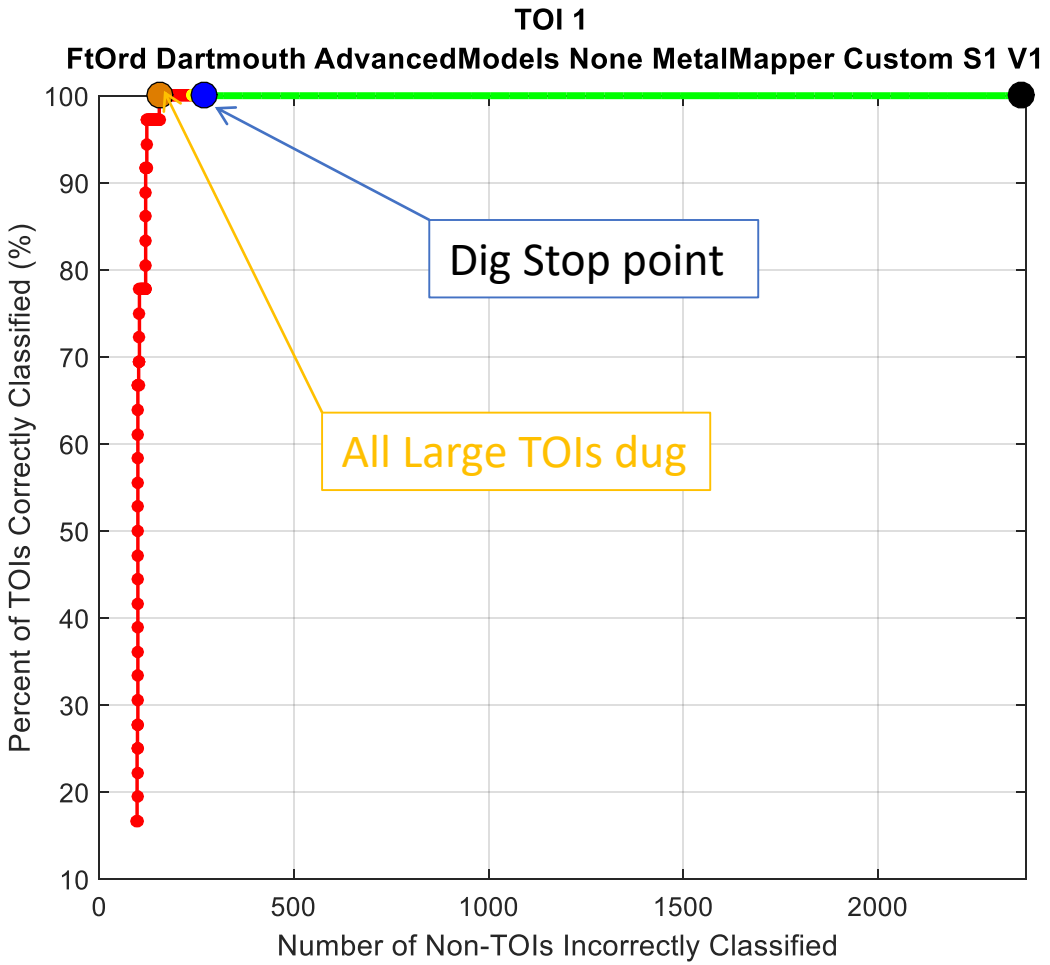






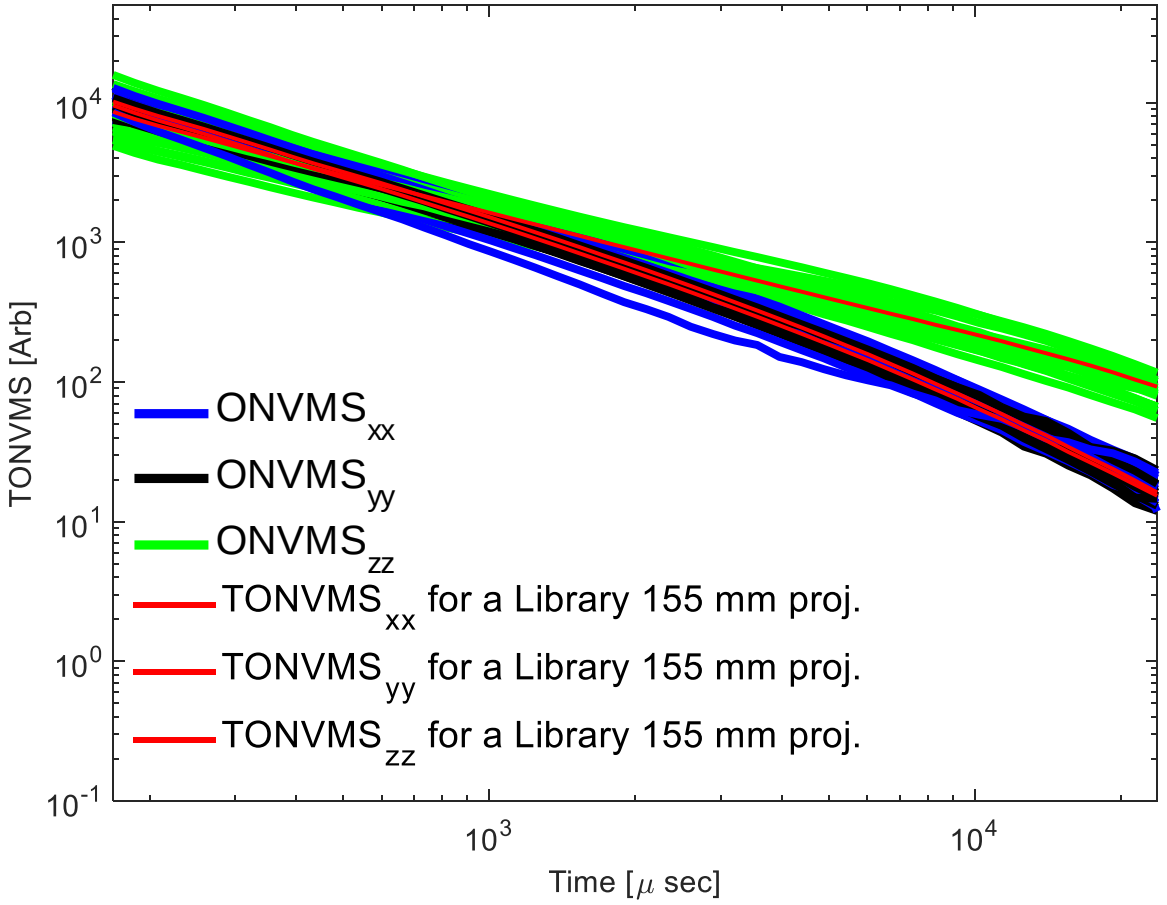
Fort-Ord, CA classification result

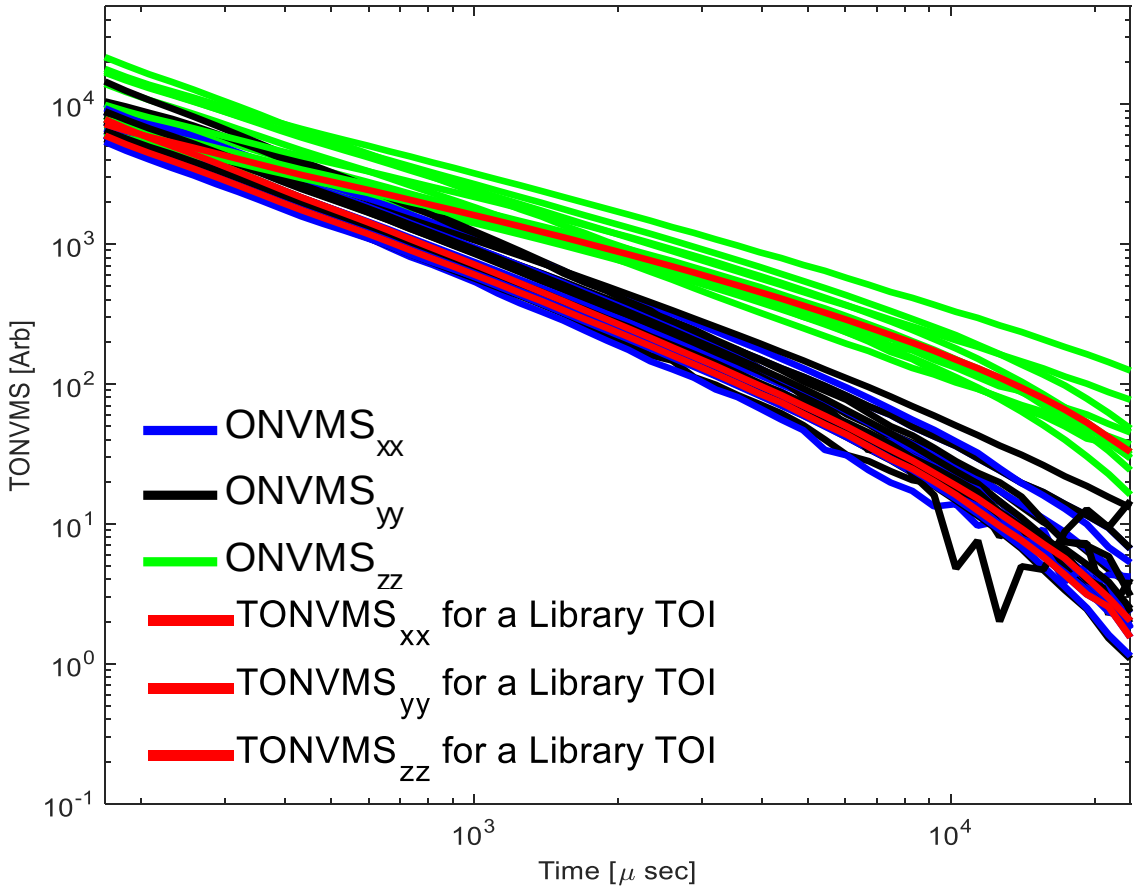
The primary objective : Classify all large munitions, such as 155mm projectiles, to a depth of 2 feet.



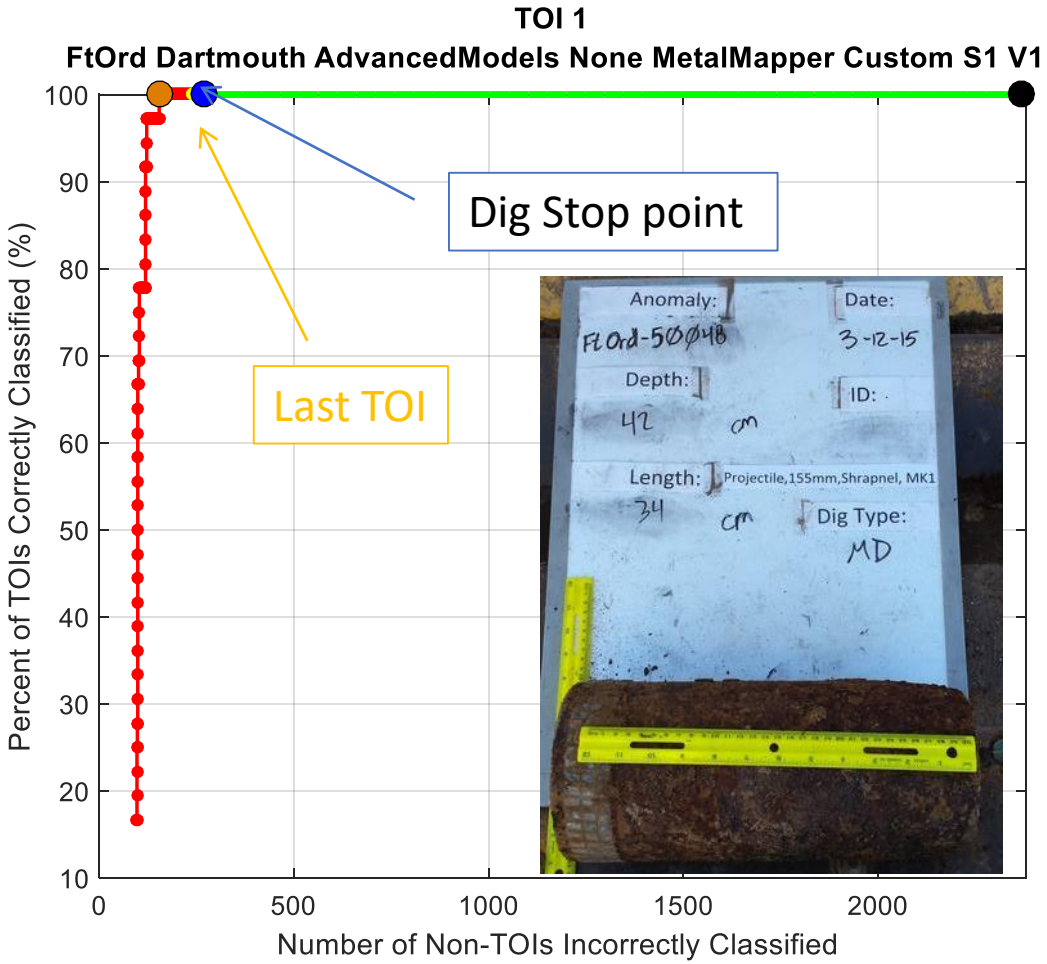
- The primary objective was achieved.
- At the dig stop point classification analyst was able to achieve:
  - 100 % efficiency
  - 90 % false positive rejection rate.

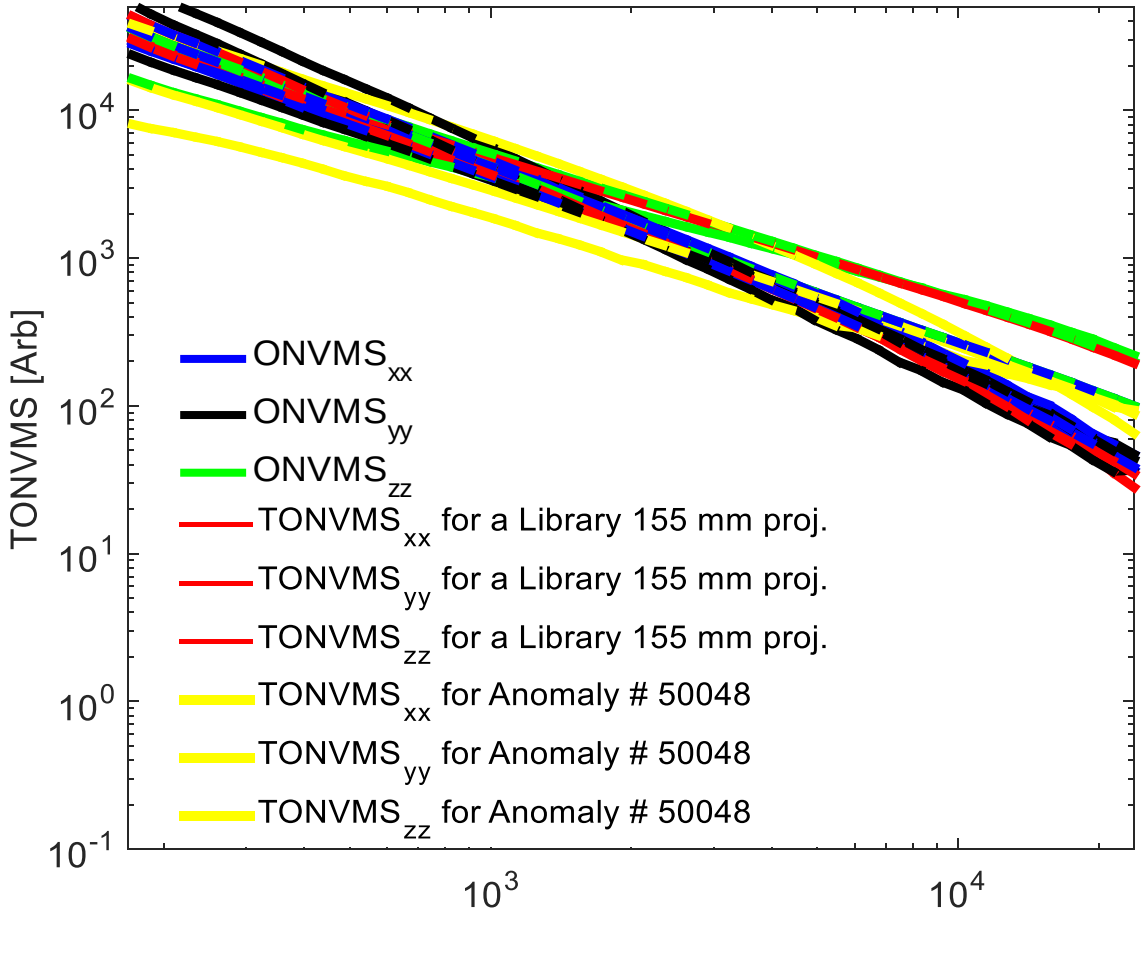
Extracted Classification features for Fort-Ord, CA Large TOIs to a depth 2 feet





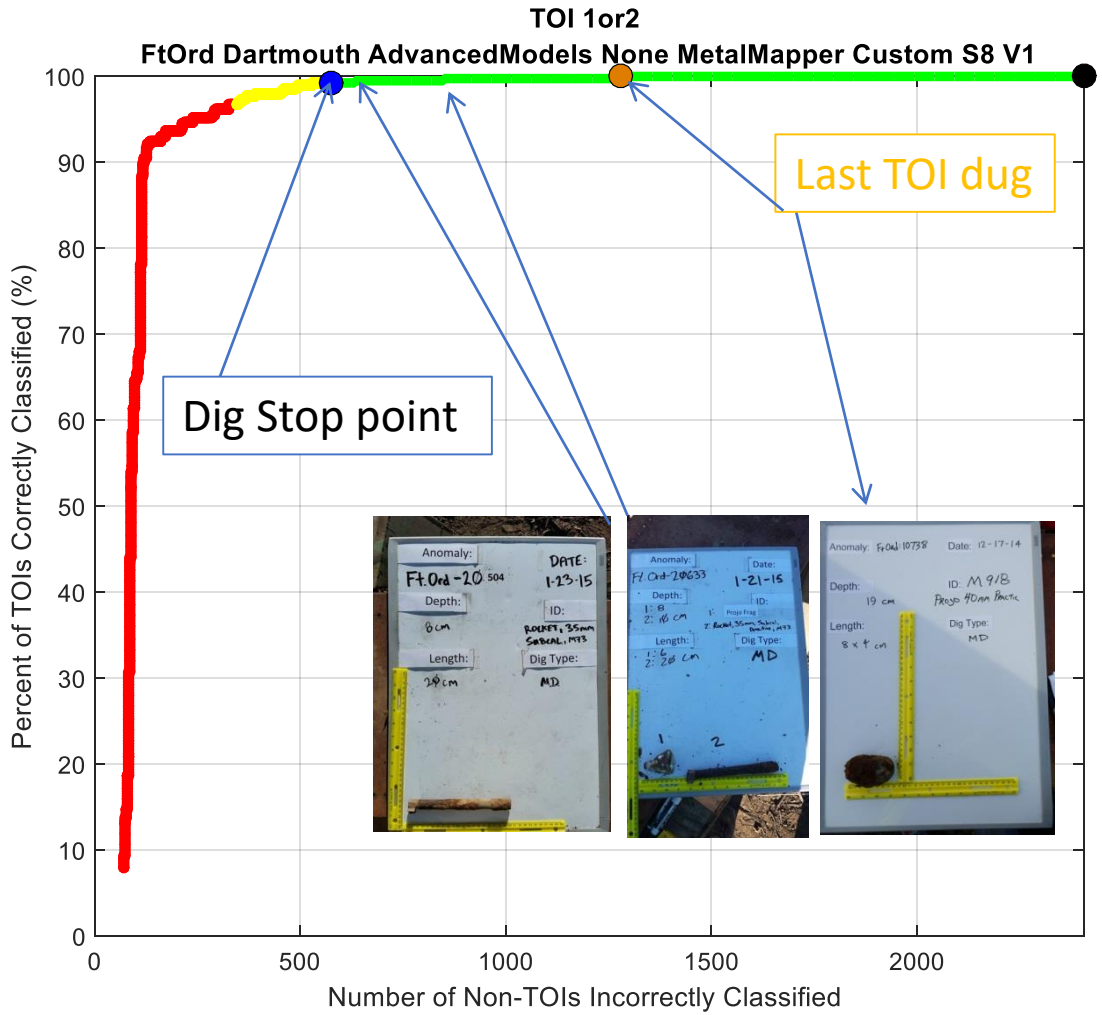
Inversion's Robustness





Fort-Ord, CA classification result

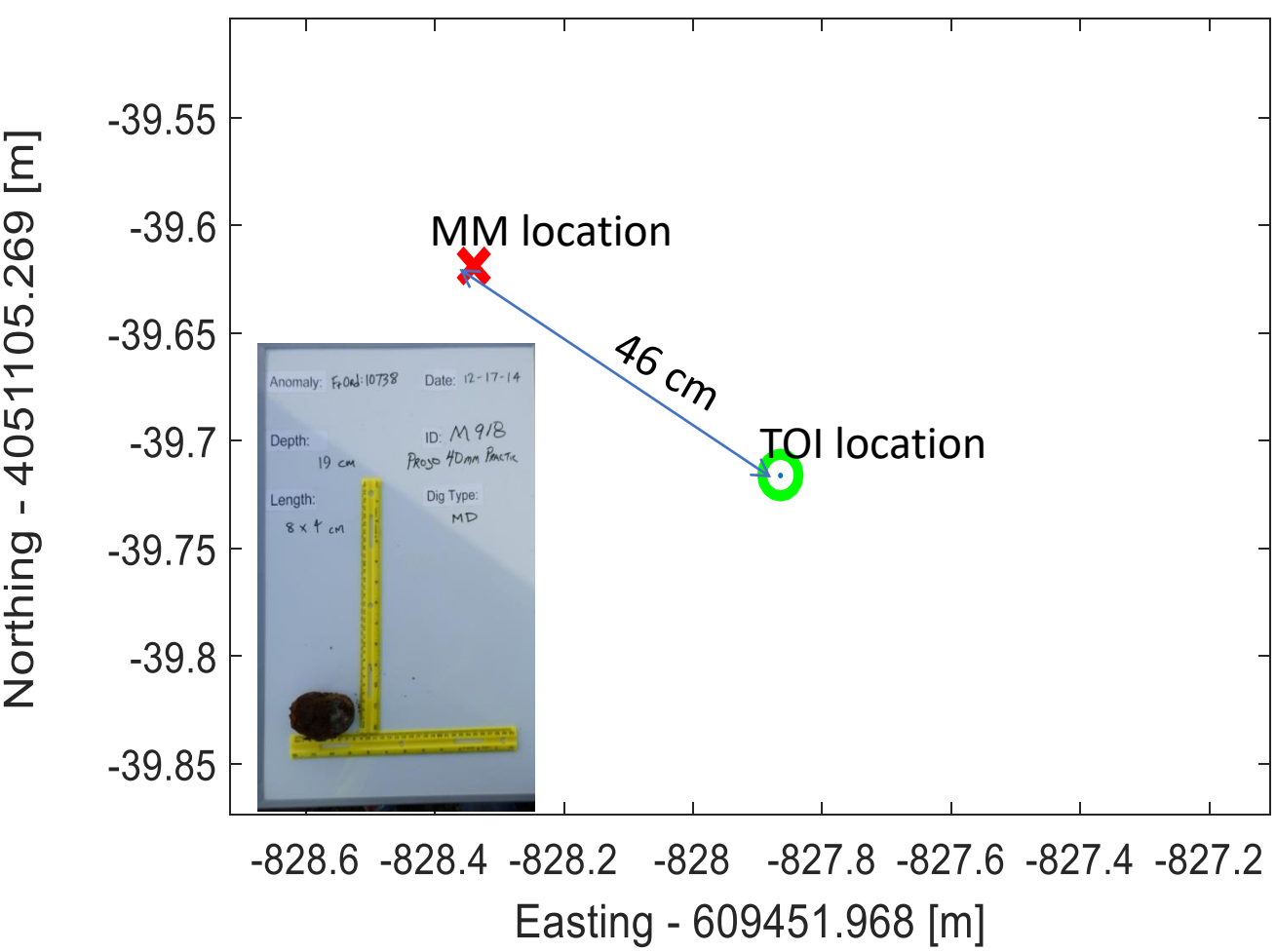
The secondary objective : Classify all type munitions within low to highest metal anomaly density areas.

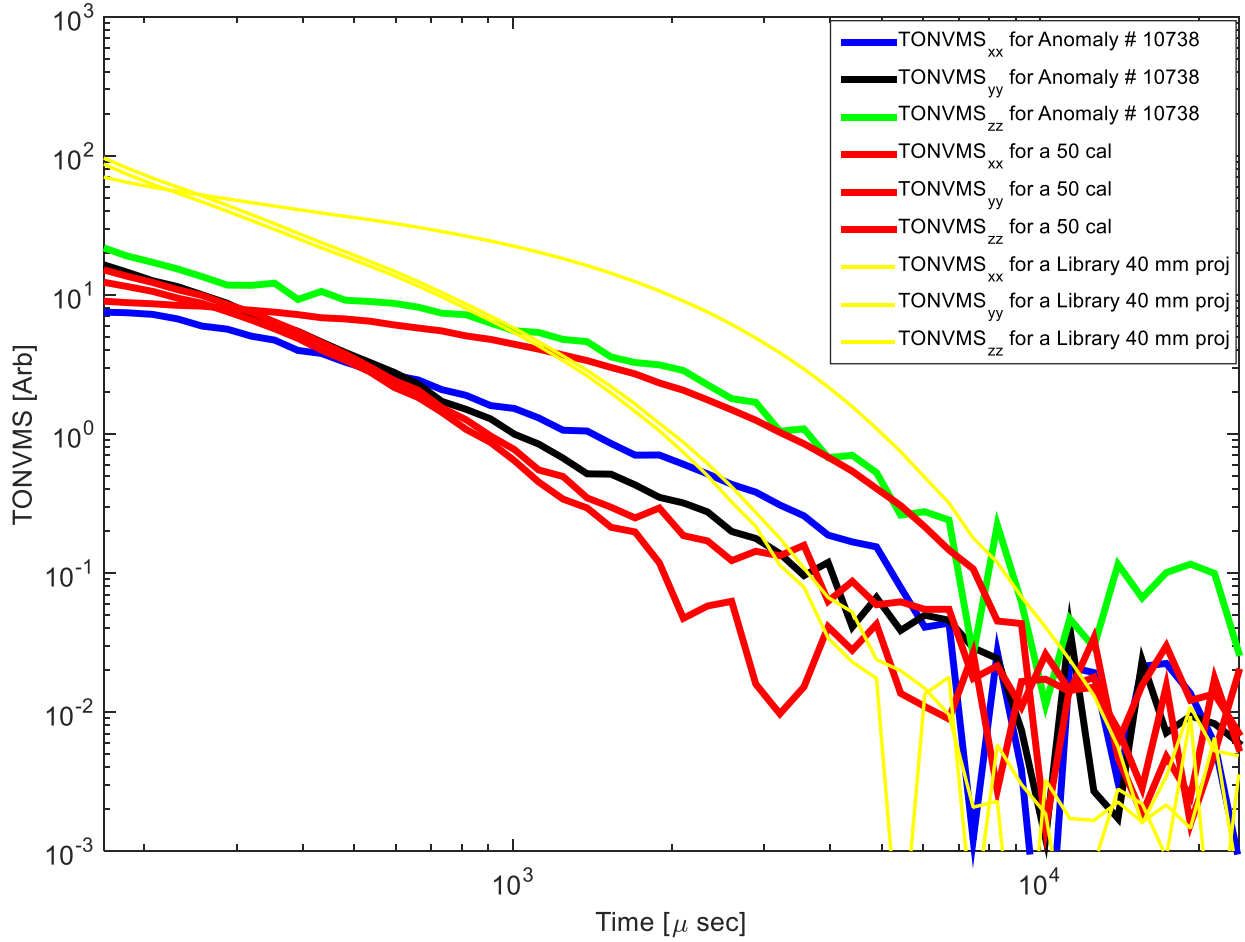


- All, but three small, TOIs were classified correctly.
- At the dig stop point classification analyst was able to achieve:
  - 99.2 % efficiency
  - 76 % false positive rejection rate.

Leeson 1: Placement of a sensor near to an anomaly continuous to be a problem

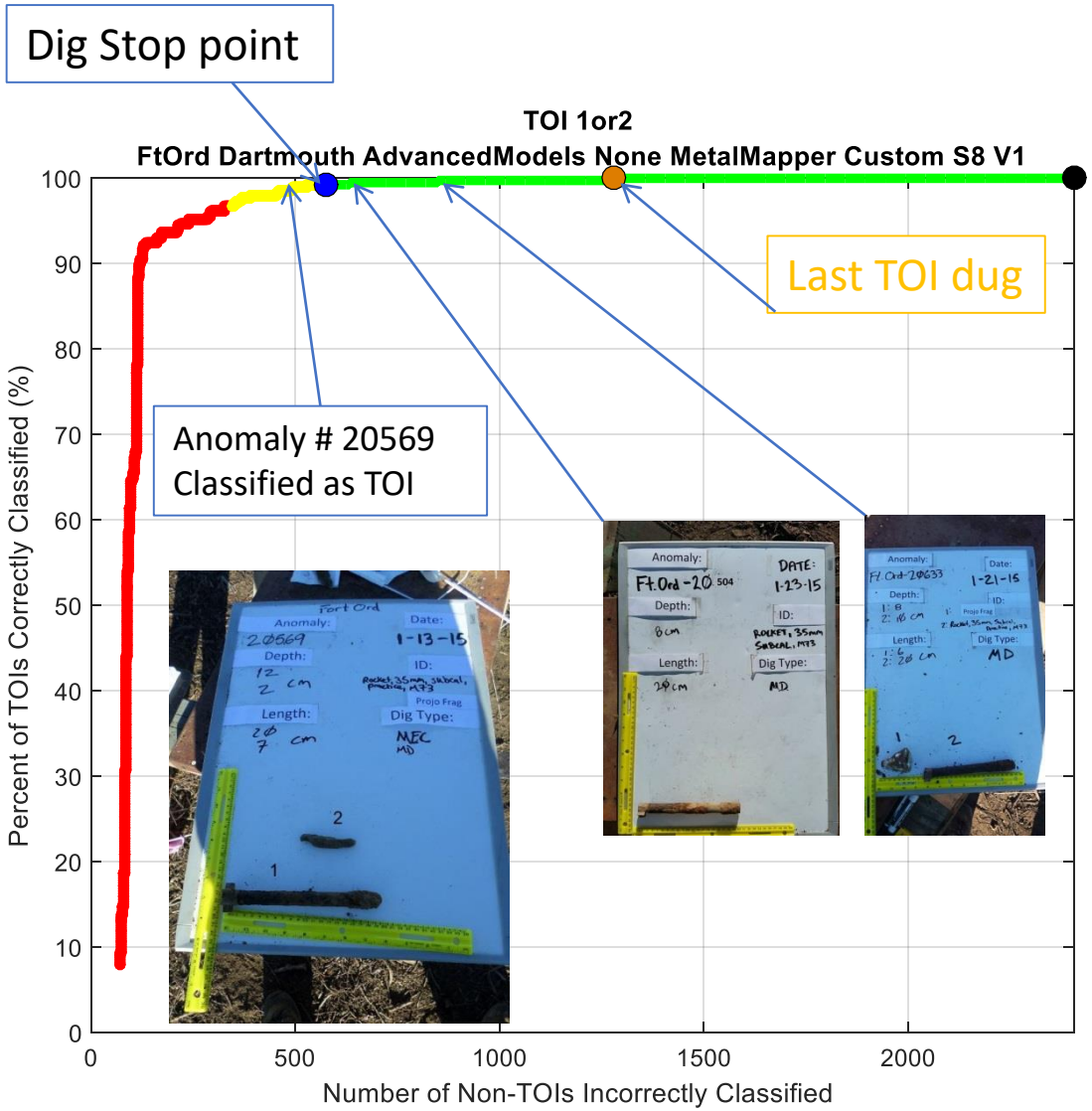
Anomaly #10738

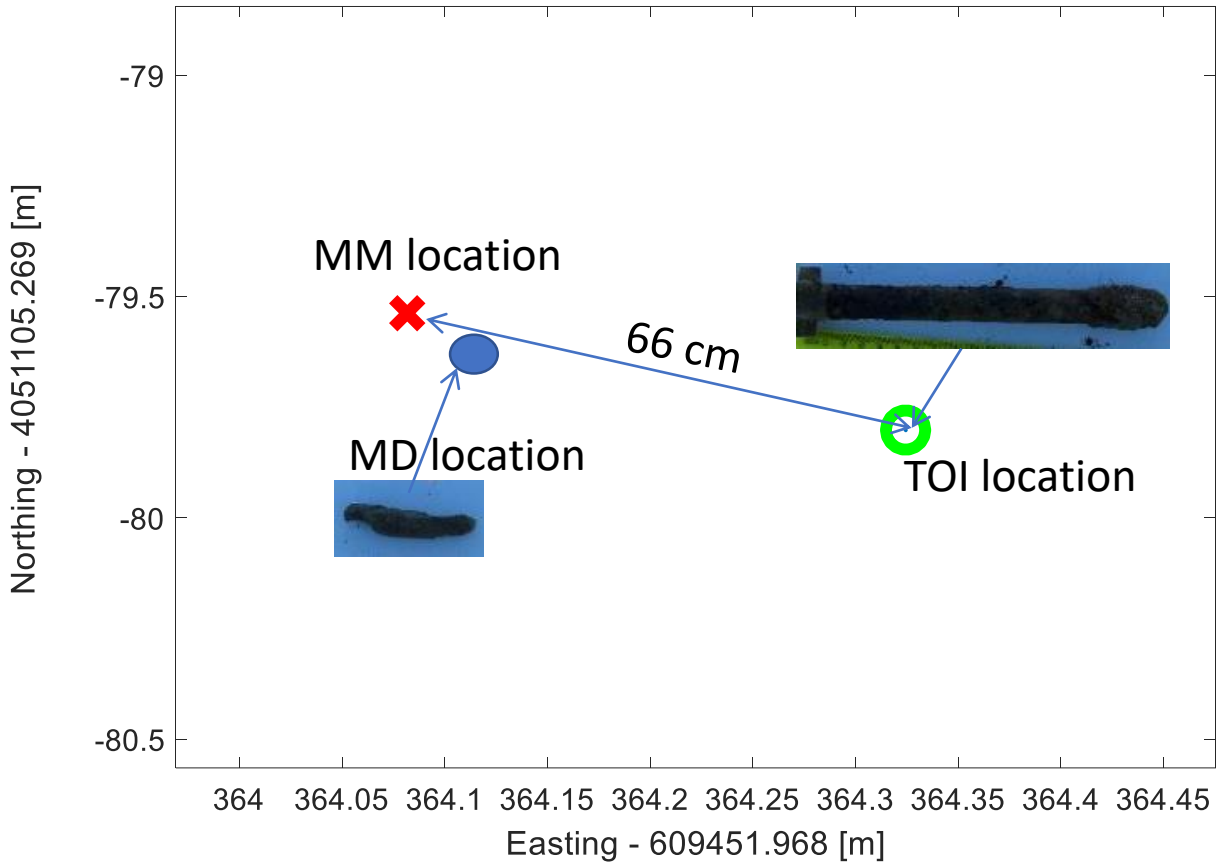




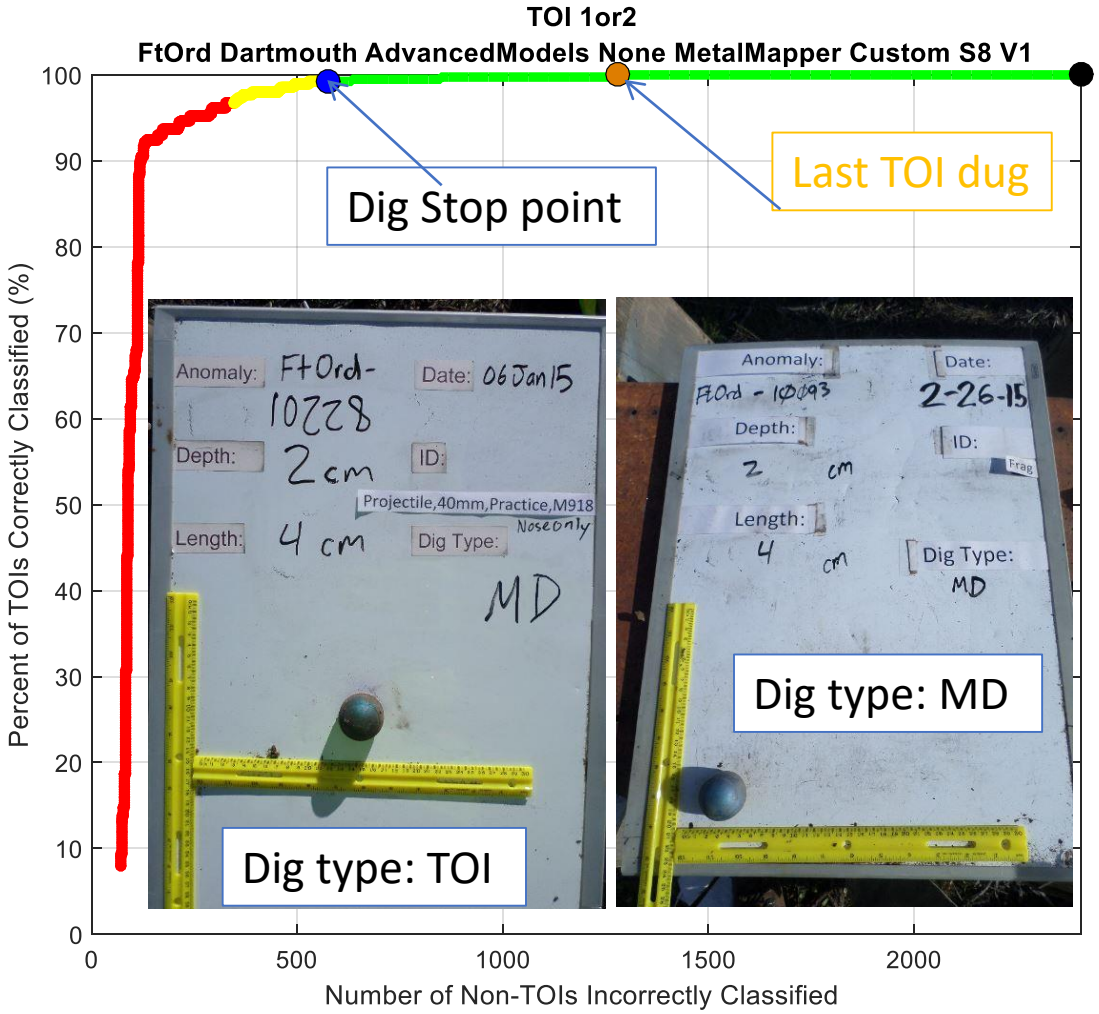
Leeson 2:Complete library is needed

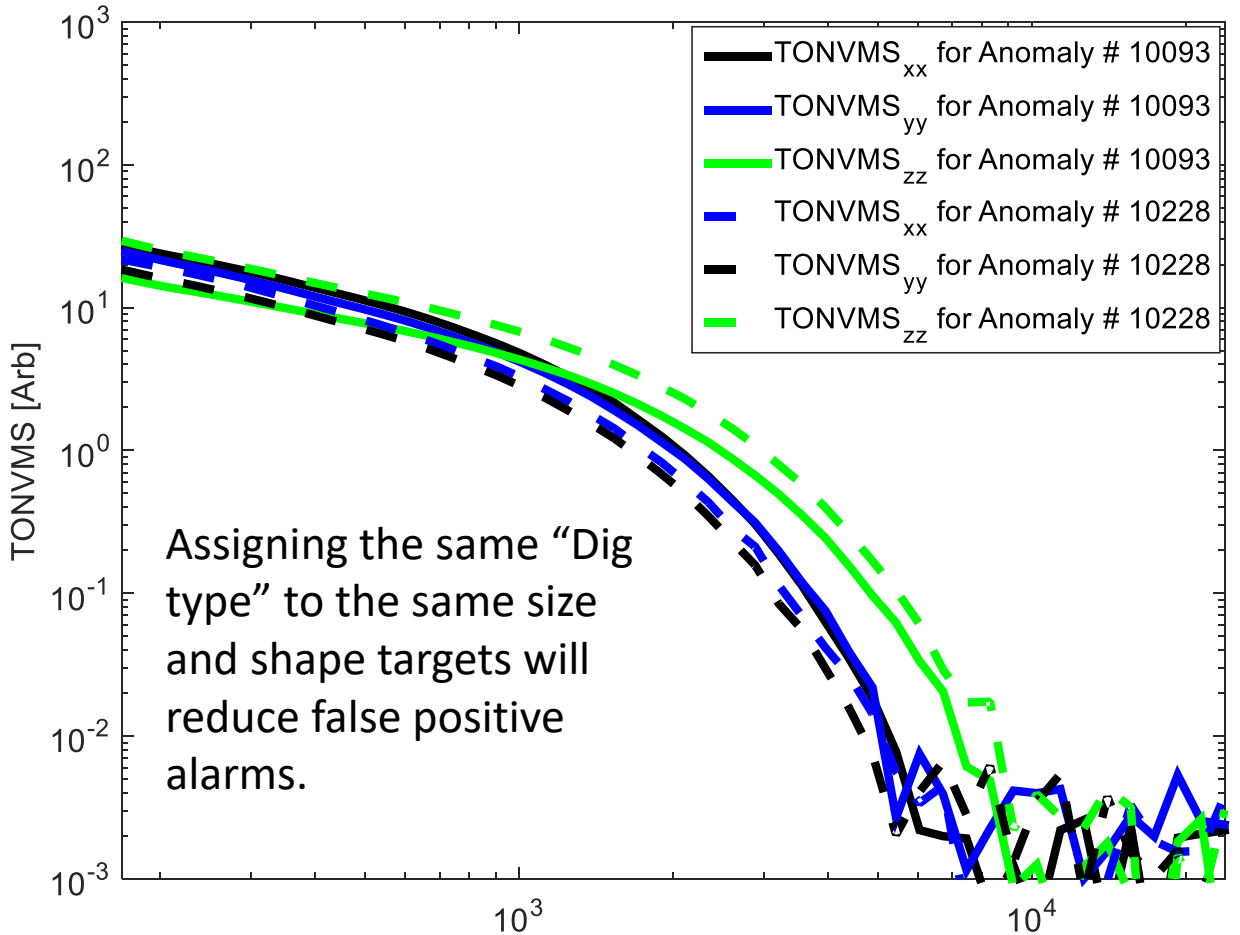
Anomaly #20504, 20633



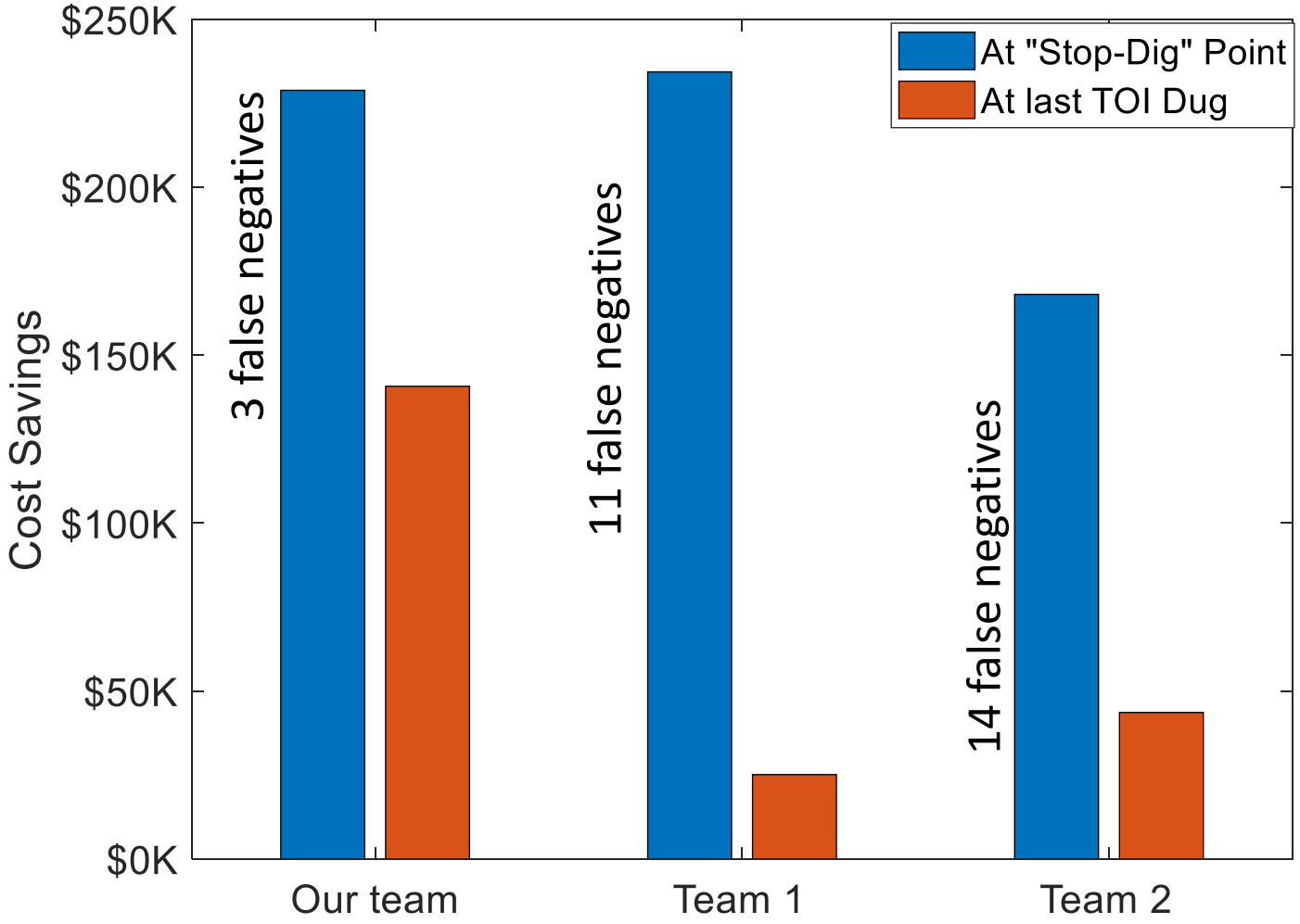


Lesson 3. Documenting the intrusive results is an important





Cost Savings



The cost savings was calculated as $125 times the number of clutter items after the last TOI dug.

Conclusions:

- The advanced classification methods are applicable for highly cluttered sites.
- Our approach was able to classify all large TOI as well as majority of small TOI on the site.
- There were three false negatives, which were due to
  - sensor-to-target separation distances;
  - insufficient library data;
- The independently scored classification results showed that our classification approach was able to provide superior classification result.

Acknowledgments:

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