

# ESTCP Classification Demonstration Program

**Herb Nelson**  
**Program Manager for Munitions Response**  
**SERDP & ESTCP**



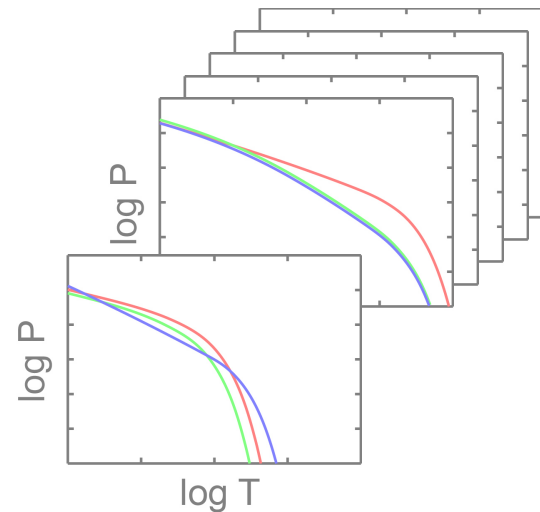
# Outline

- Classification Technology
  - ◆ Sensors
  - ◆ Analysis
  
- The ESTCP Demonstration Program
  - ◆ Goals
  - ◆ Demonstration Sites
  - ◆ How We Conduct the Demonstrations
  - ◆ How We Report the Results
  - ◆ Demonstration Results
  - ◆ Emerging Conclusions

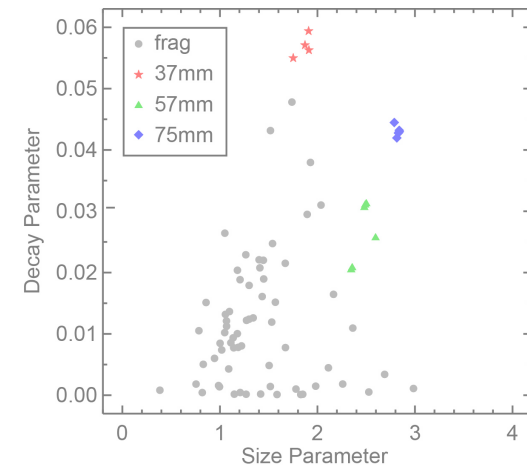
# Stages in the Classification Process



1. Measure target responses with suitable sensor
  - Classification-specific EMI



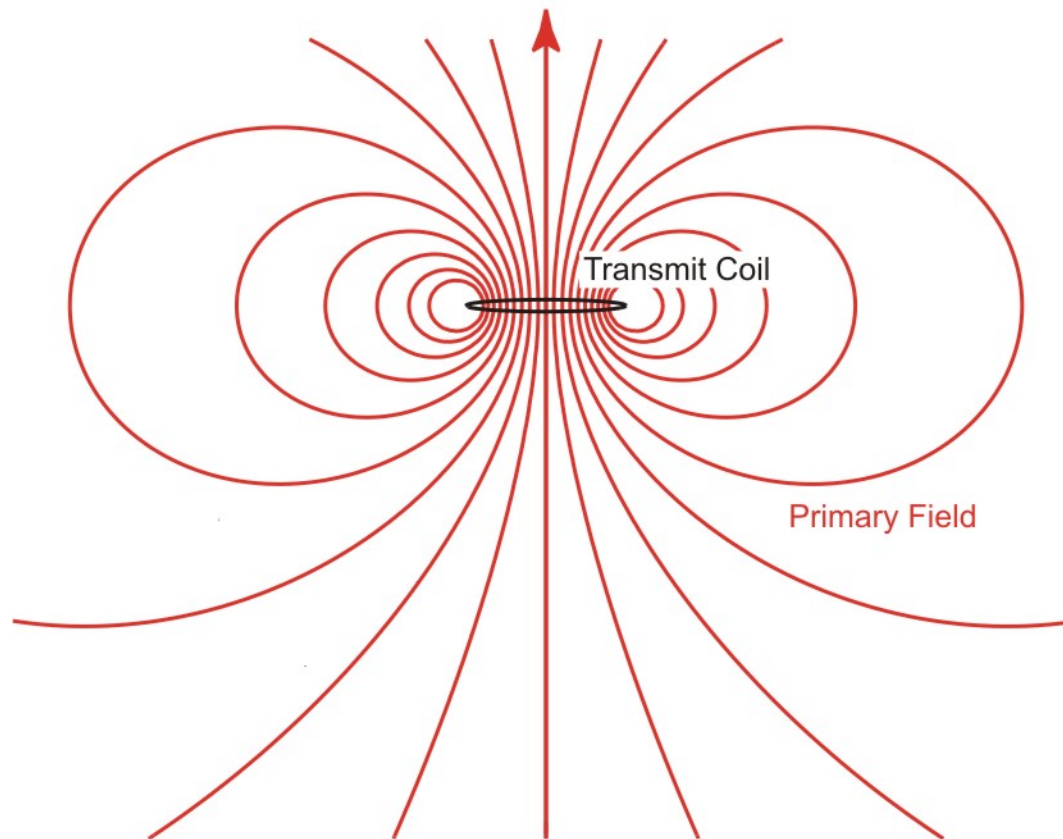
2. Extract target features from the measured responses
  - Data Inversion
  - Target polarizabilities



3. Classify targets based on the features
  - Statistical classifiers
  - Library matching

# Electromagnetic Induction Sensors

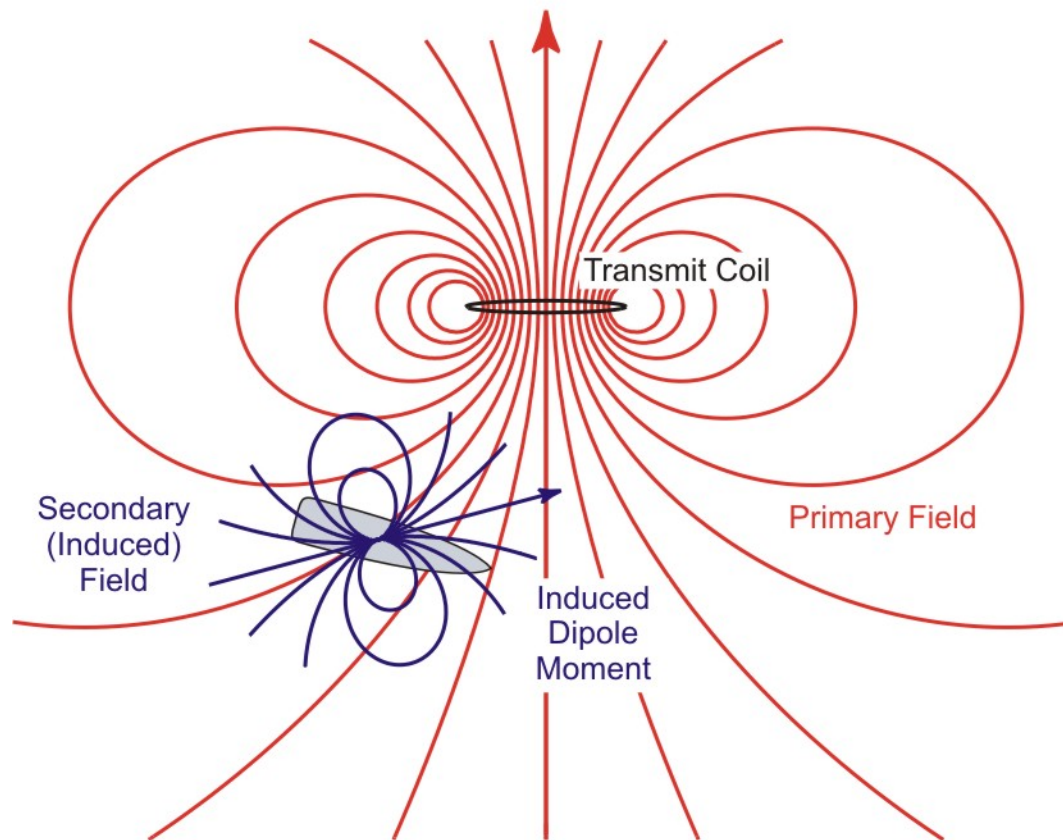
Typical Electromagnetic Induction Sensor



**Excitation Pulse**

# Electromagnetic Induction Sensors

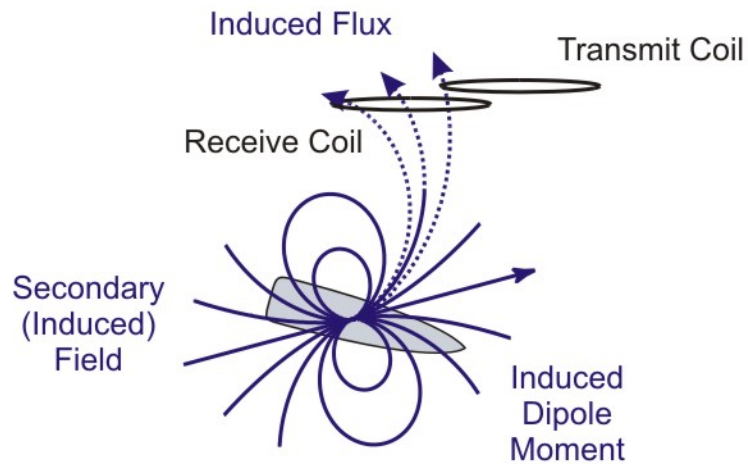
Typical Electromagnetic Induction Sensor



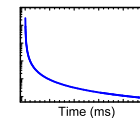
**Induced Target Response**

# Electromagnetic Induction Sensors

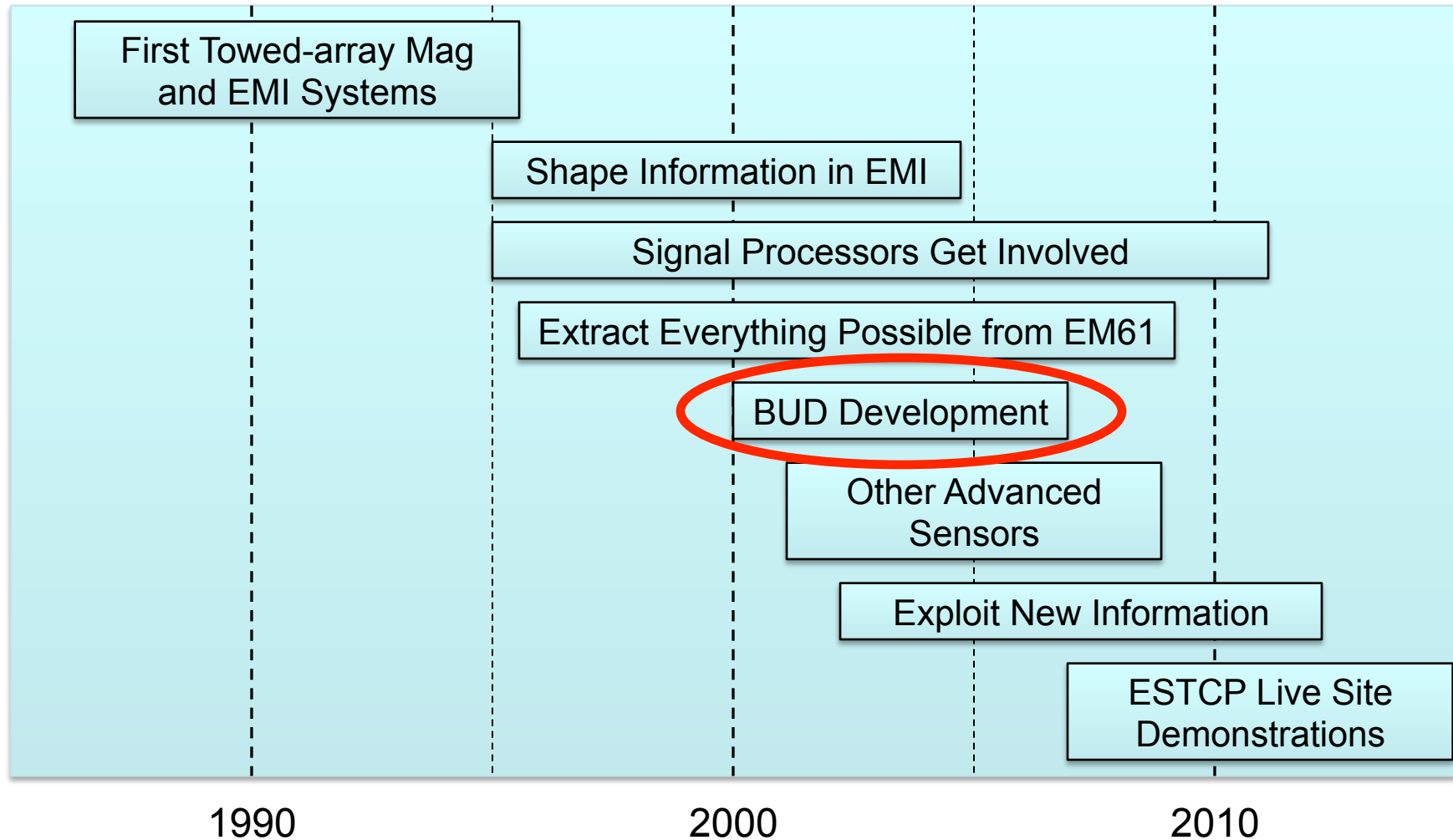
Typical Electromagnetic Induction Sensor



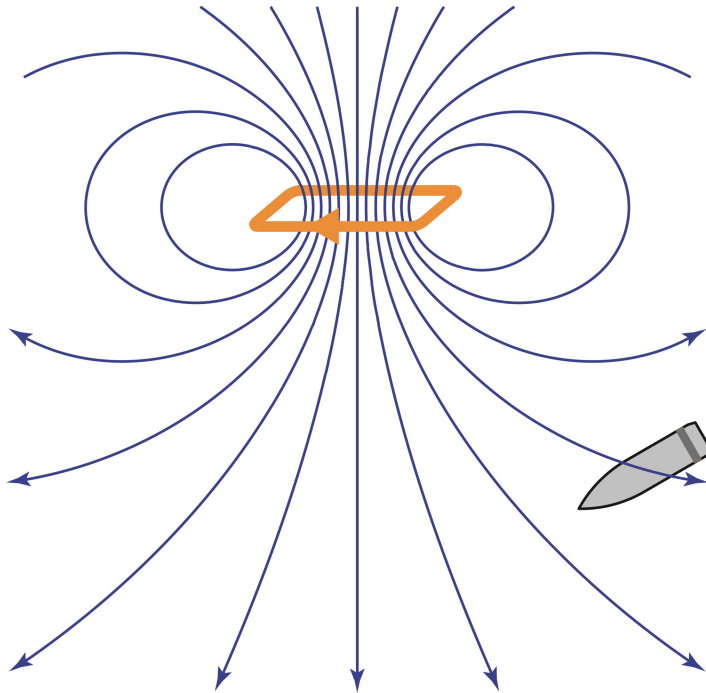
**Sense Induced Field**



# Research & Development in This Area

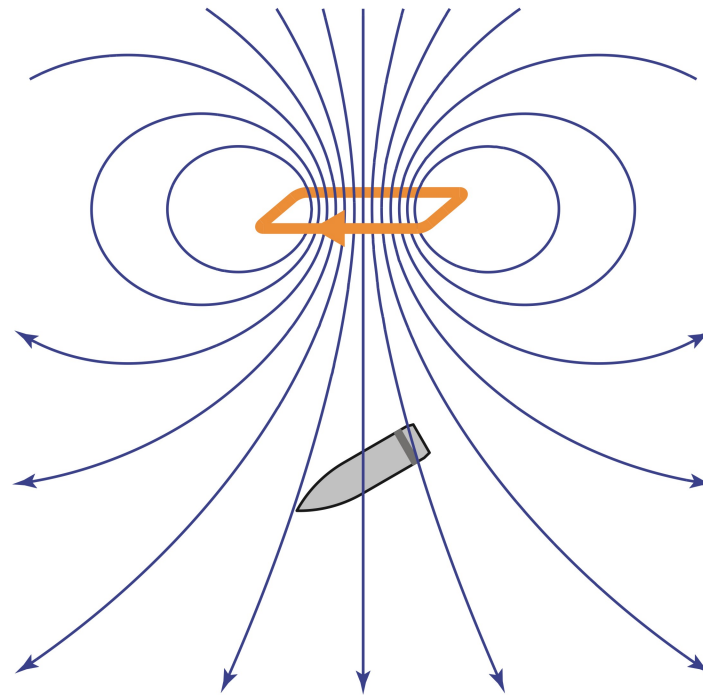


## Multiple Measurements Are Required to Completely Characterize a Target with a Single-Axis Sensor

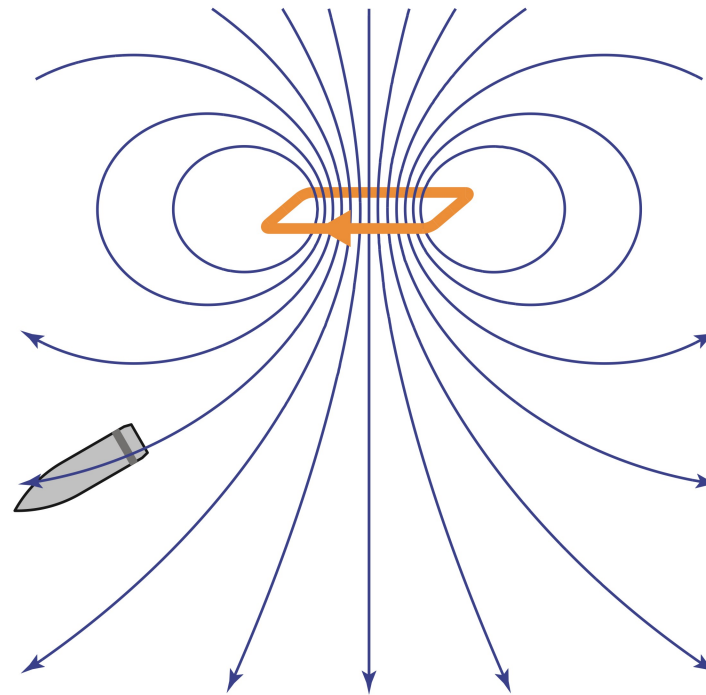




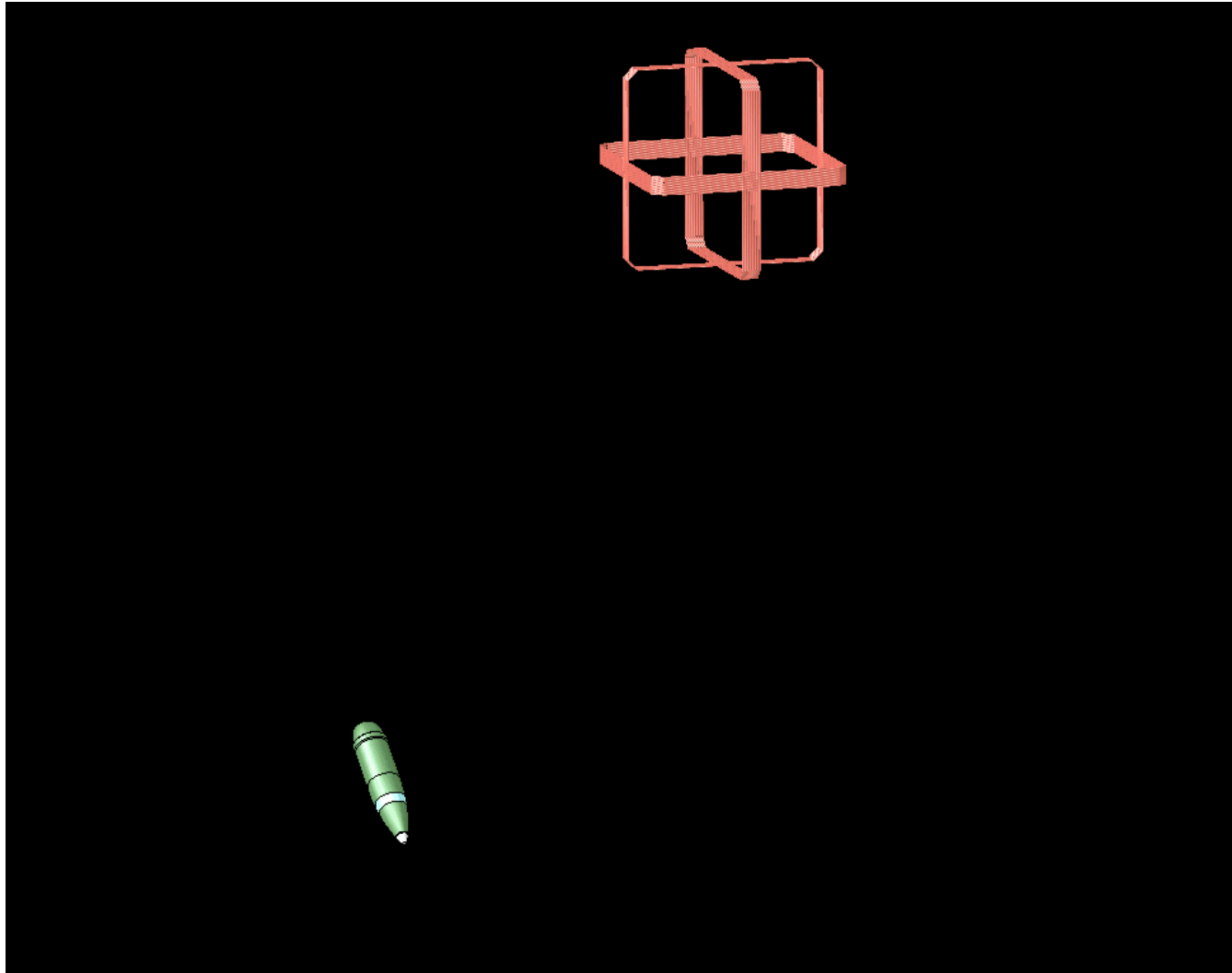
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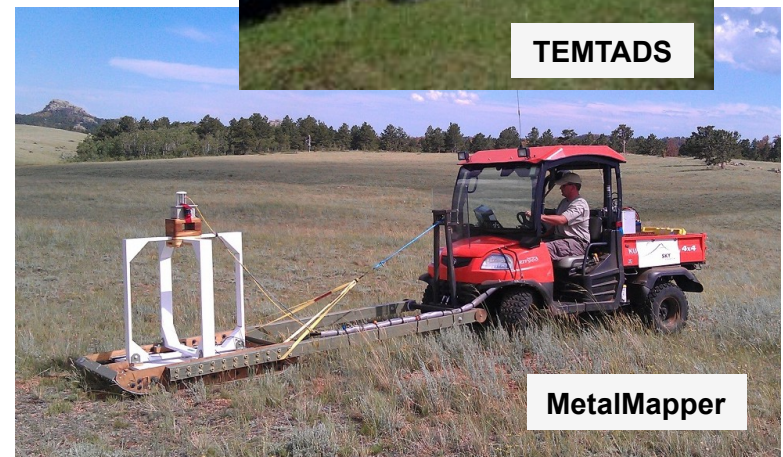


# Advantages of a Multi-Axis Sensor



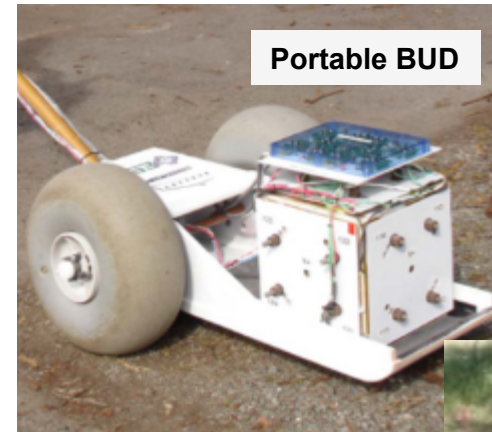
# Advanced EMI Sensors

- New **UXO-specific** EMI technologies developed and tested under SERDP & ESTCP
- All digital electronics, measuring complete eddy current decay cycle
- Multi-axis, multi-coil data more completely defines target parameters



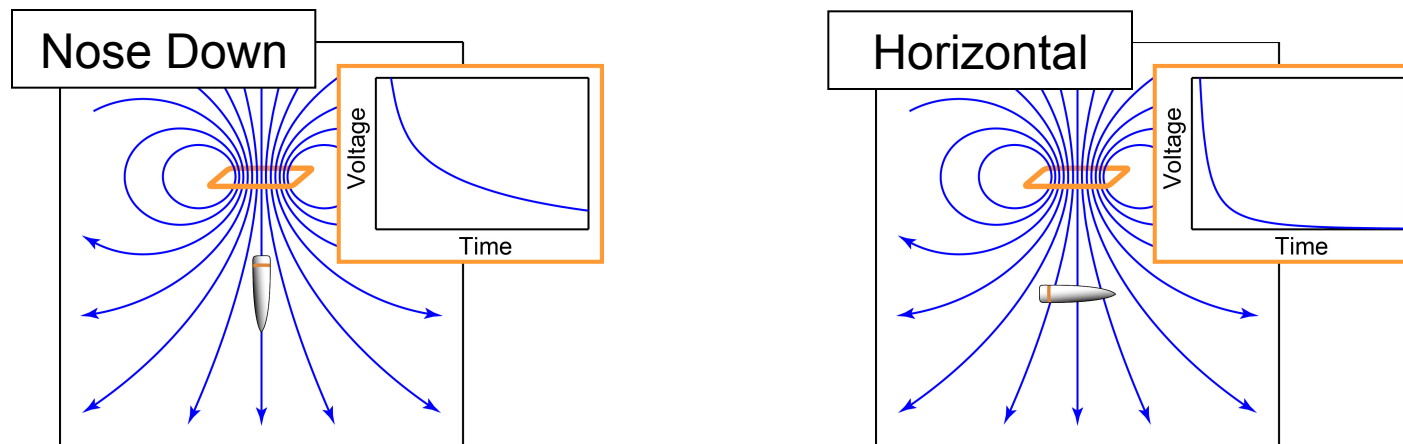
# Advanced EMI Sensors

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# EMI Signals

- + EMI response signal determined by target properties
  - ◆ Size and Shape
  - ◆ Material type and thickness

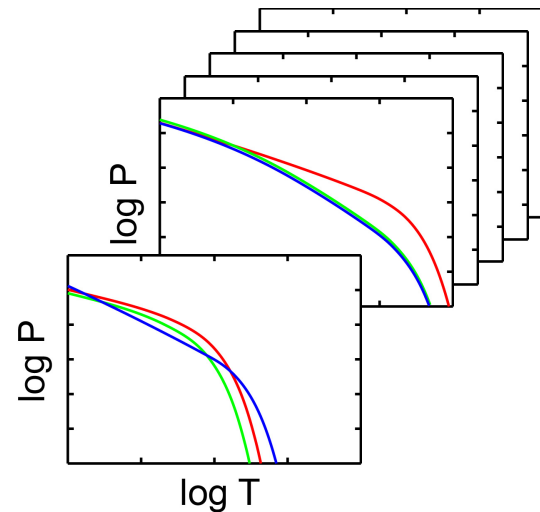


- Muddled by response variation with target location and orientation relative to primary field
  - ◆ Signal strength varies as sixth power of range

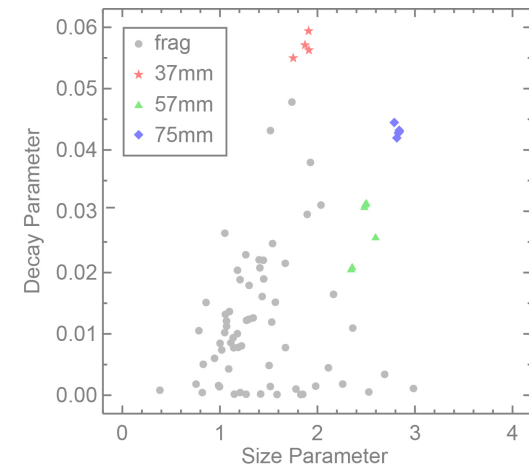
# Stages in the Classification Process



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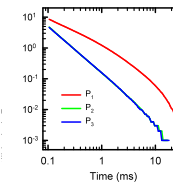
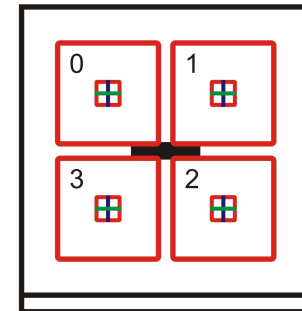
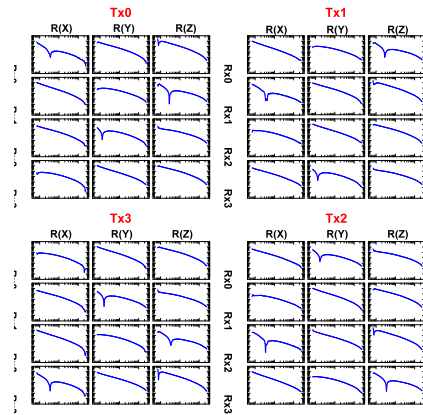


2. Extract target features from the measured responses
  - Data Inversion
  - Target polarizabilities



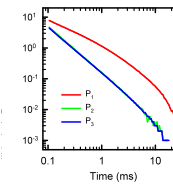
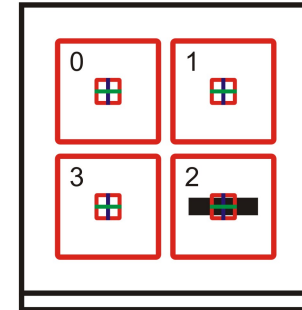
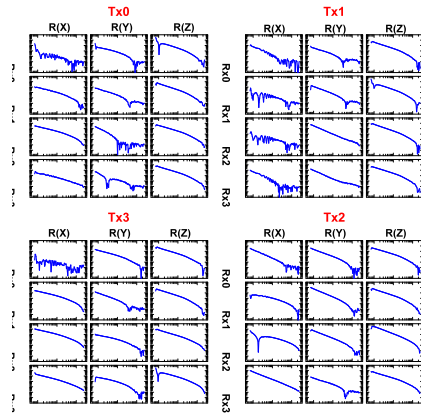
3. Classify targets based on the features
  - Statistical classifiers
  - Library matching

# Measured Decays Convolve Intrinsic Response with Relative Position and Orientation

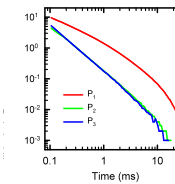
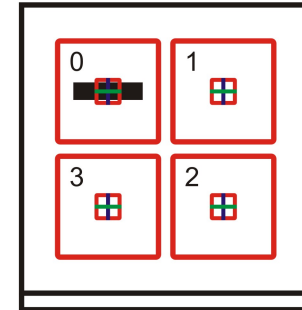
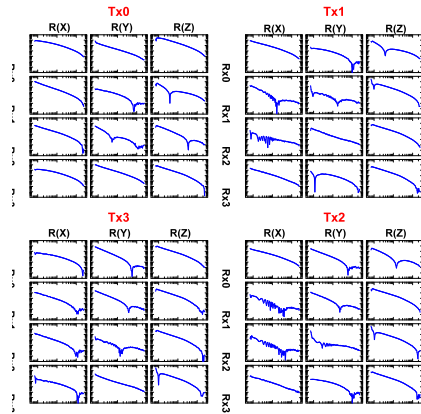




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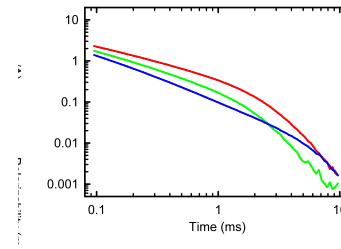
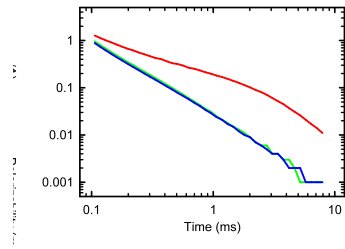


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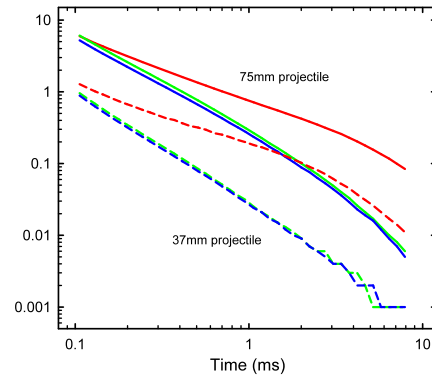


# Polarizabilities → Classification

Intrinsic responses (polarizabilities) along target's principal axis directions fully characterize EMI signal



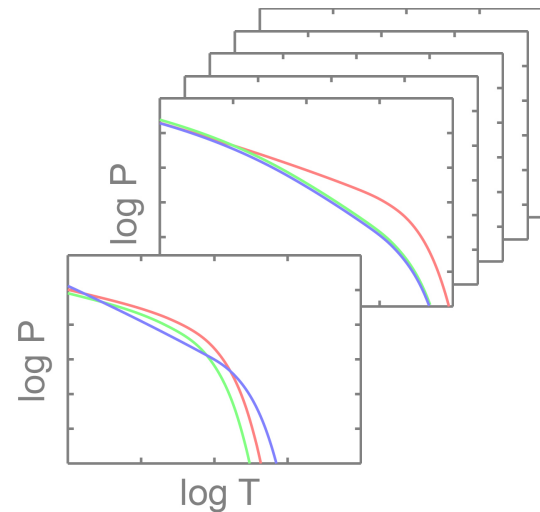
# Size Comparison



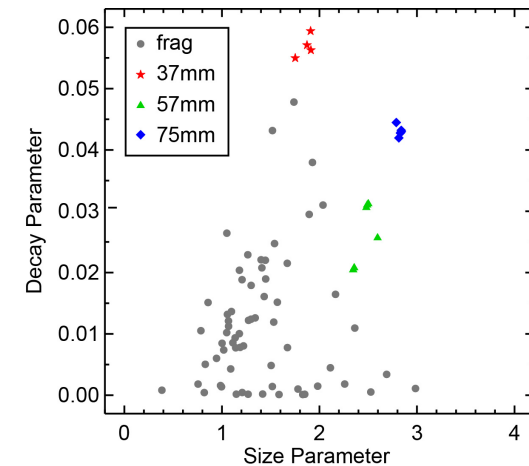
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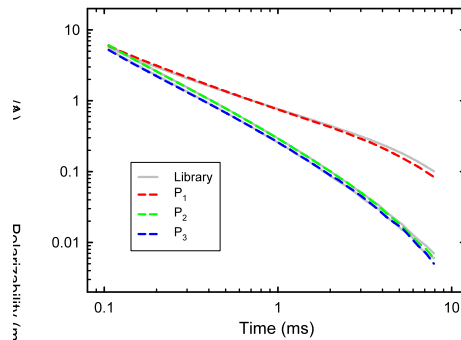
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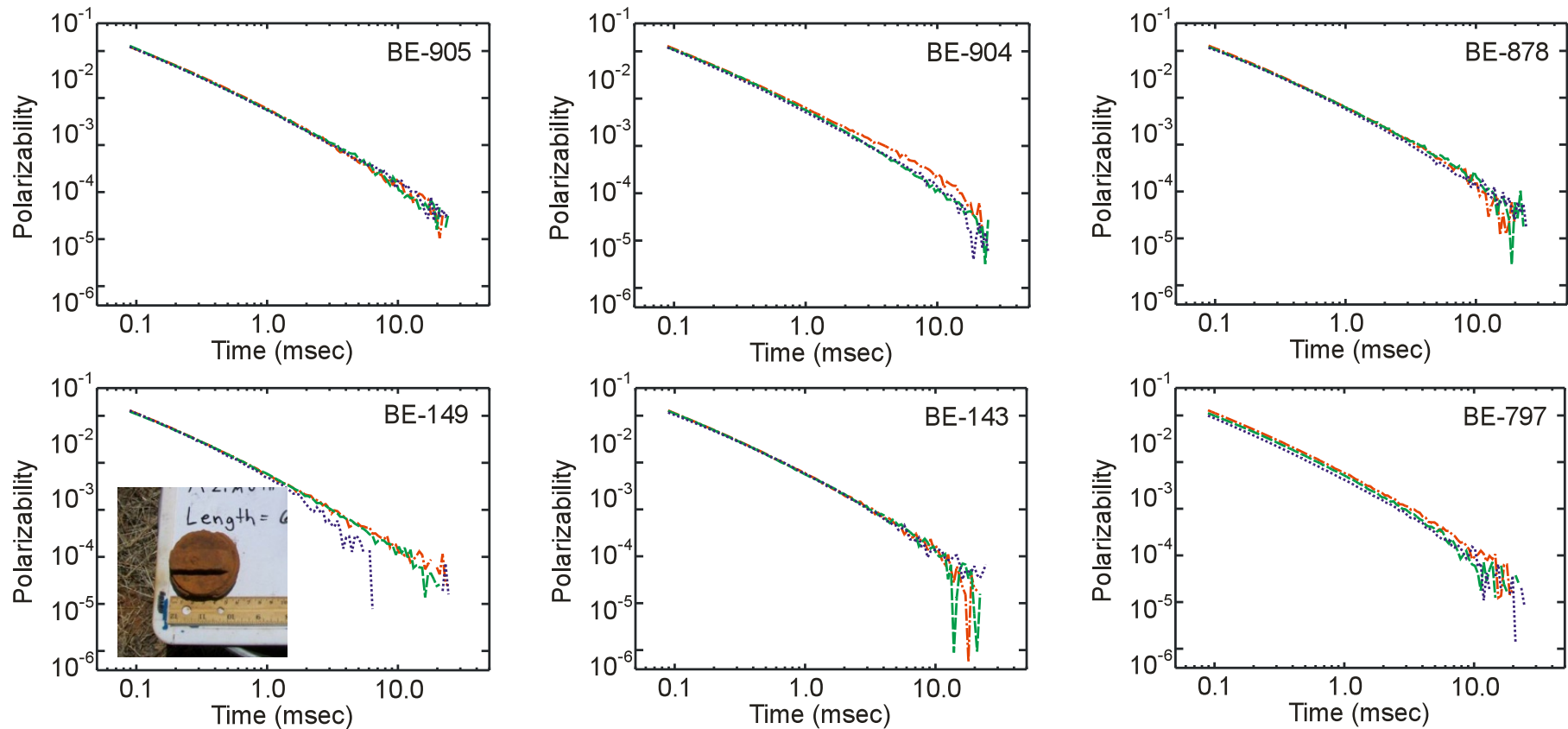
# How Do You Get Classified as a TOI - 1

Match a Munition in the Library



# How Do You Get Classified as a TOI - 2

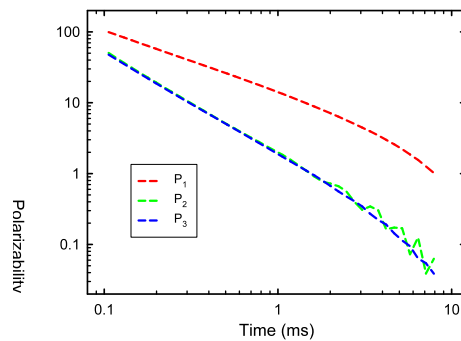
Be Part of a Cluster of Similar Items That Turn Out to Be TOI



6 of 25 in cluster

# How Do You Get Classified as a TOI - 3

Be Big and Symmetric

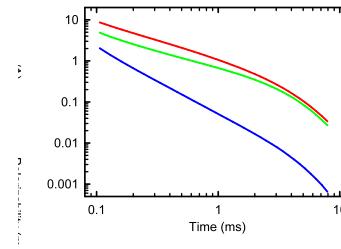
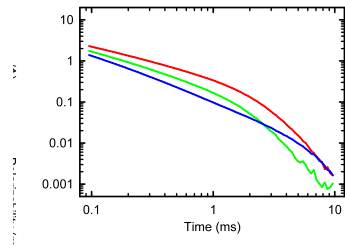




# How You Get Classified as Clutter

No Symmetry

Known Clutter Item

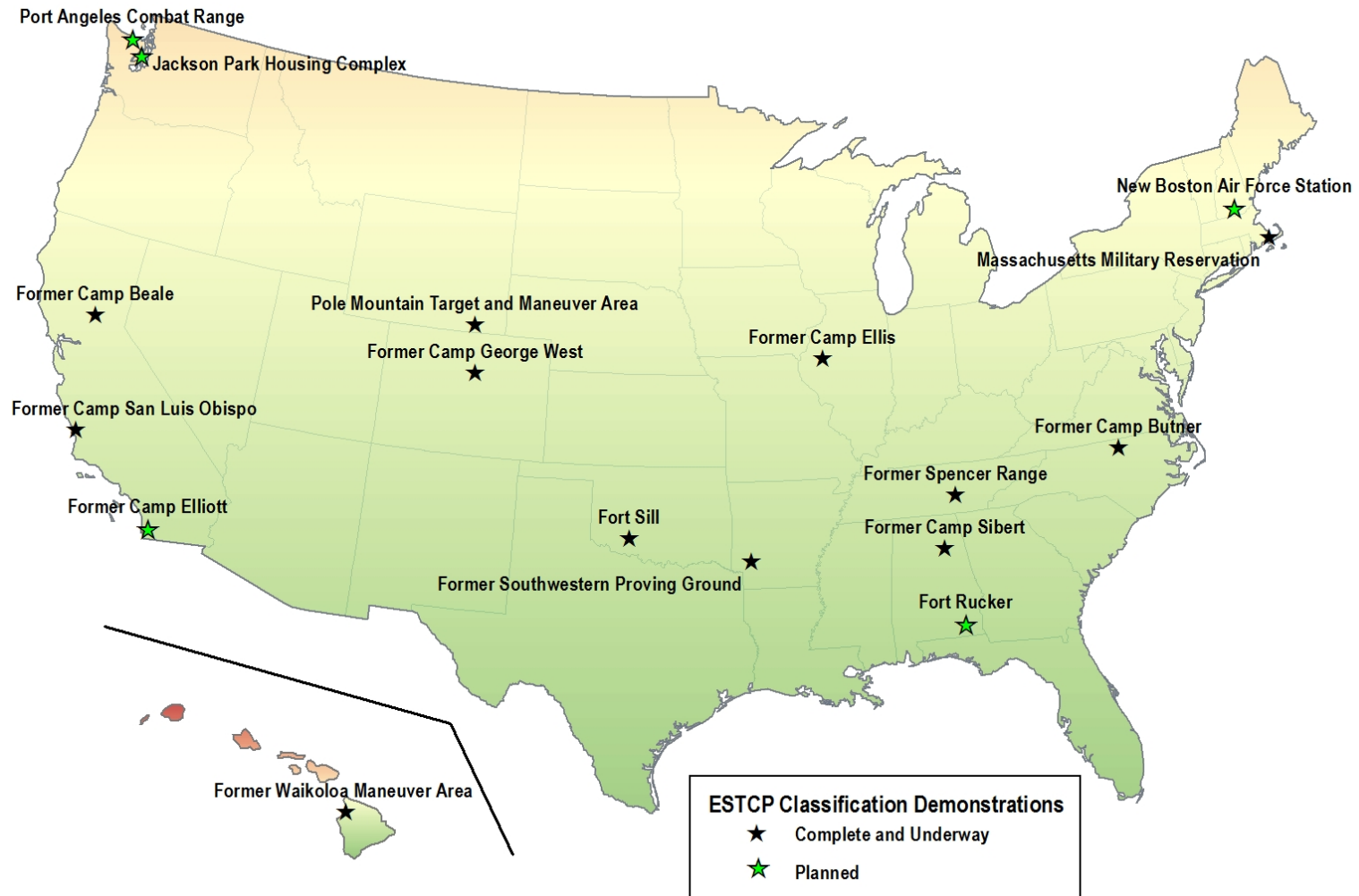


## ESTCP Classification Demonstrations

- Goal: Validate Discrimination Technologies
  - ◆ Establish performance capability as function of site conditions
  - ◆ Establish operational procedures and costs
  - ◆ Documentation and Quality Control
  - ◆ Train government and contractor community
  - ◆ Gain regulatory acceptance
- Multiple Live Sites Required
  - ◆ Munitions type
  - ◆ Site conditions
- Engagement
  - ◆ Regulators
  - ◆ Stakeholders
  - ◆ Site Managers
  - ◆ Industry



# Classification Demonstration Sites



## How We Go About This

- Identify the site
- Seed the site for process validation
- Geophysical surveys – identify anomalies
- Cued surveys over the anomalies
- The analysts work with data collected over each anomaly
  - ◆ Extract parameters
  - ◆ Use those parameters to classify each anomaly
  - ◆ Construct a ranked anomaly list
  - ◆ Determine a threshold
- Then we dig them all to see how they did

# Ranked Anomaly List

**Initial Ranked Anomaly List**

Anomaly ID	Dig on First Pass	Type	Comment
2498	Y		Unable to extract reliable parameters
247	Y	105 mm	
1114	Y	4.2 in	High likelihood TOI
69	Y	155 mm	
811	Y	81 mm	
313	N		Unable to classify
883	N		
...	N		
...	N		
...	N		High likelihood not TOI
...	N		
...	N		
...	N		
...	N		
...	N		
...	N		
...	N		

First Pass Threshold

**Final Ranked Anomaly List**

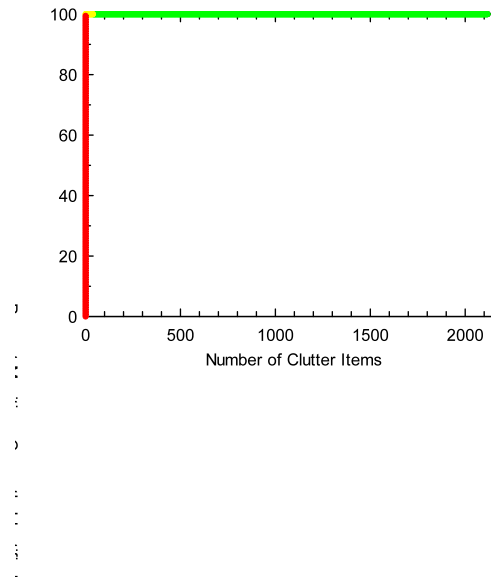
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811	Y	81 mm
313	Y	105 mm
883	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	
...	N	

Final Threshold

# Performance Evaluation

## Receiver Operating Characteristic (ROC) Curve

Rank	Comment
1	
2	High confidence munition
3	
...	Can't make a decision
...	Can't make a decision
...	
...	
...	High confidence non-munition
...	
...	
...	
...	
...	
...	
...	
N	

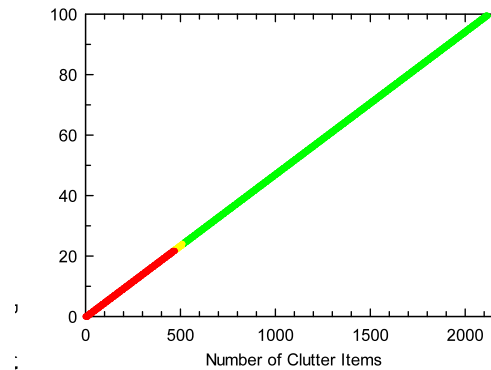


correctly classified as non-hazardous

# Performance Evaluation

## Receiver Operating Characteristic (ROC) Curve

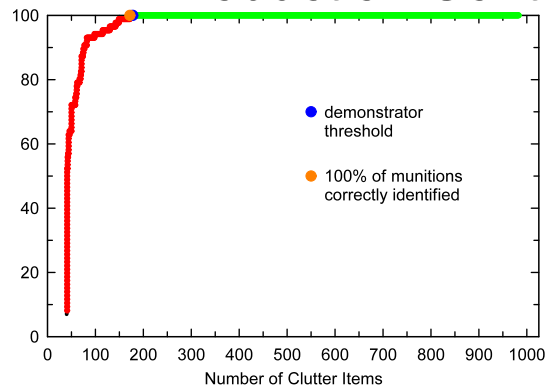
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...	
...	
...	
...	
...	
...	
N	



correctly classified as non-hazardous

# Former Spencer Range, TN

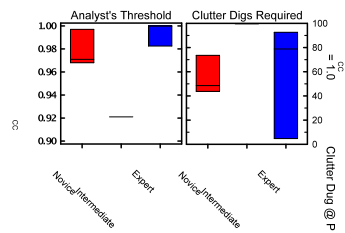
## Production Contractor Analysis of MetalMapper Data



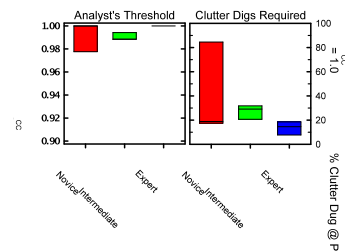


# Performance Improvement

Camp Butner - 2010



Spencer Range 2012

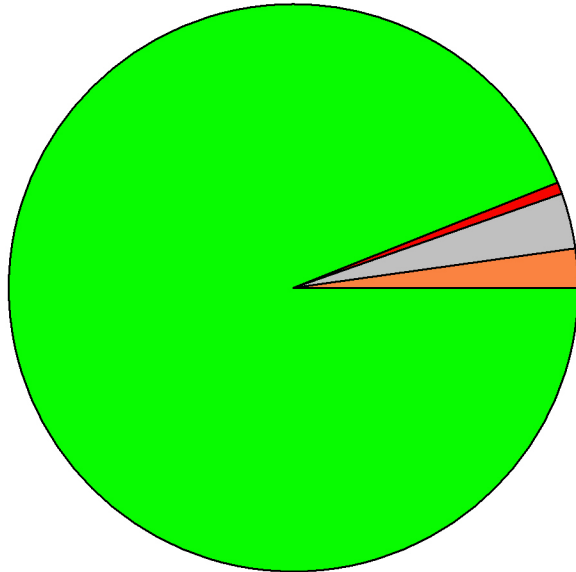


# Emerging Conclusions From the Demonstration Program

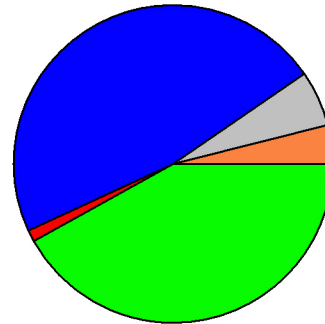
- Classification has been successful at a wide variety of sites using both vehicular-towed and portable advanced sensors
- Munitions as small as 37-mm projectiles have been successfully classified – 20mms are being tested now
- MetalMapper has similar depth performance to an EM61. The smaller, portable sensors are more limited.
- Classification has been successfully employed with anomaly densities as high as 800 per acre
- There is a learning curve for analysts

# Potential Savings At a 100-acre Site

Current Practice

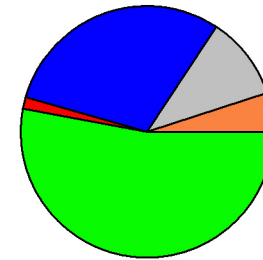


75% Reduction of Clutter



44% Savings

Dynamic Survey Using Advanced Sensor



55% Savings

- QC Seeds
- Detection Survey
- Cued Data
- Dig UXO & Seeds
- Dig Clutter



**For More Information**

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