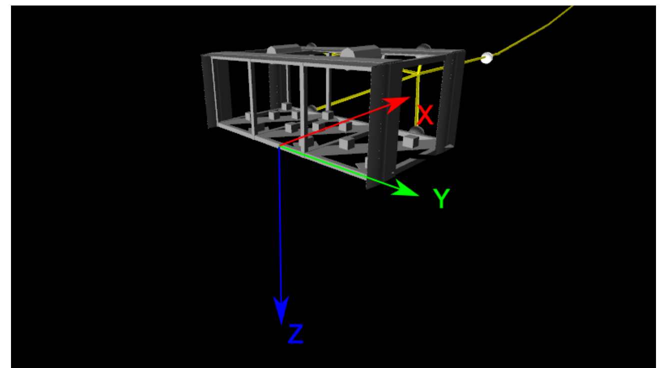
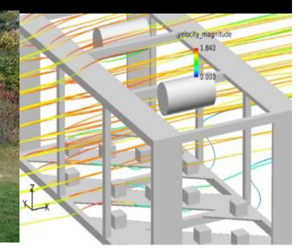
SAGEEP 2018

Underwater Dynamic Classification Technology





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1. White River Technologies, Inc.
2. Dynamic Systems Analysis Ltd.

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Marine UXO Classification

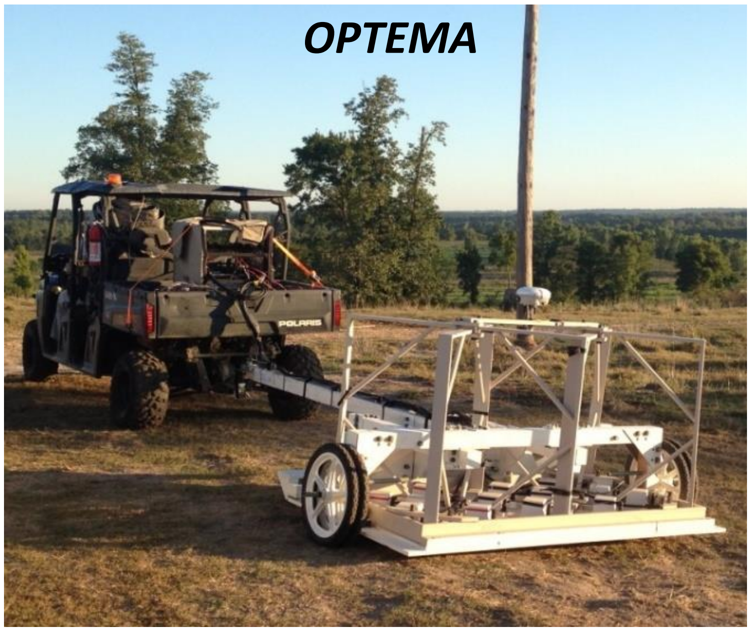
The marine UXO problem:

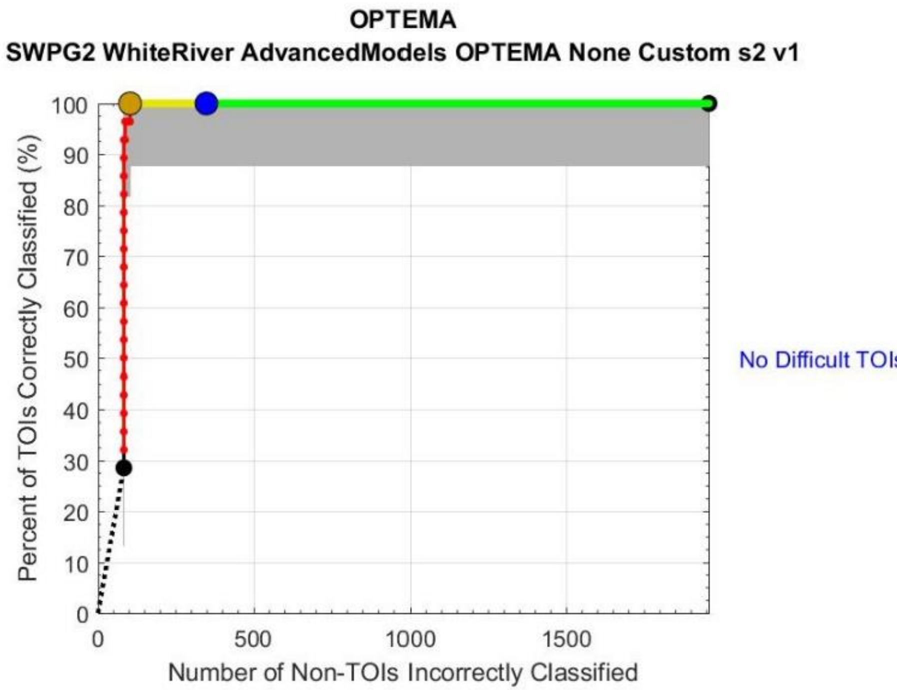
- Access to UXO is difficult; requires diver or ROV; targets obscured by marine growth or sediment
- Survey positioning quality significantly degraded underwater; limited availability of GPS methods
- Reacquisition is challenging due to access limitations compounded by positioning constraints

Current approaches:

- Advanced EMI very effective for land-based classification, but deployment underwater limited by increased standoff and positioning constraints

Background: Dynamic Classification



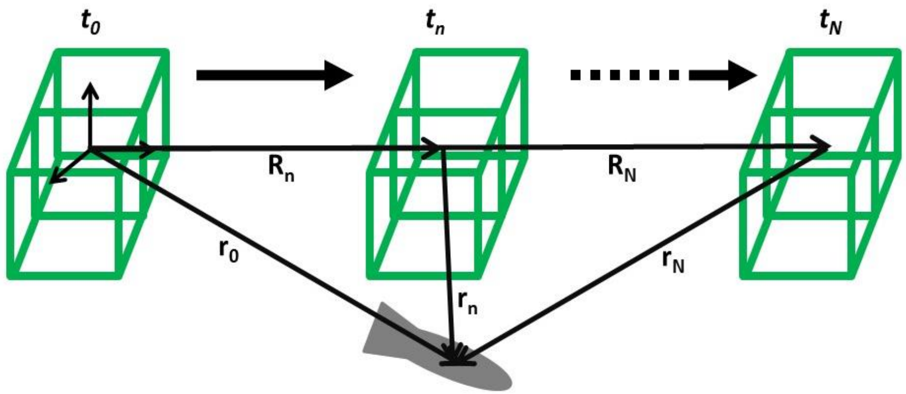


Dynamic classification methods based on those demonstrated successfully under MR-201225, benefits for underwater include:

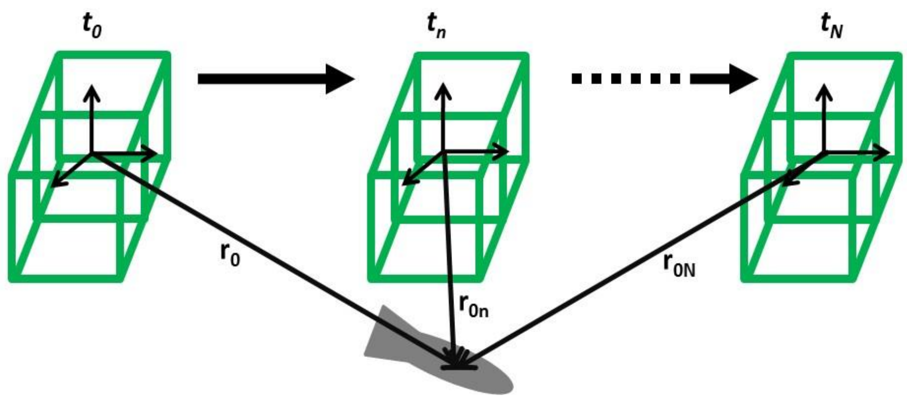
- One pass classification means no cued reacquisition
- Methods are particularly tolerant of positioning errors

Classification Approach: 2D vs. 3D

2D Method



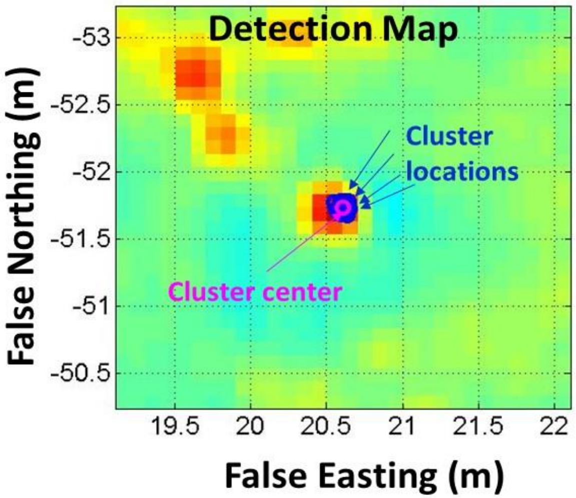
3D Method

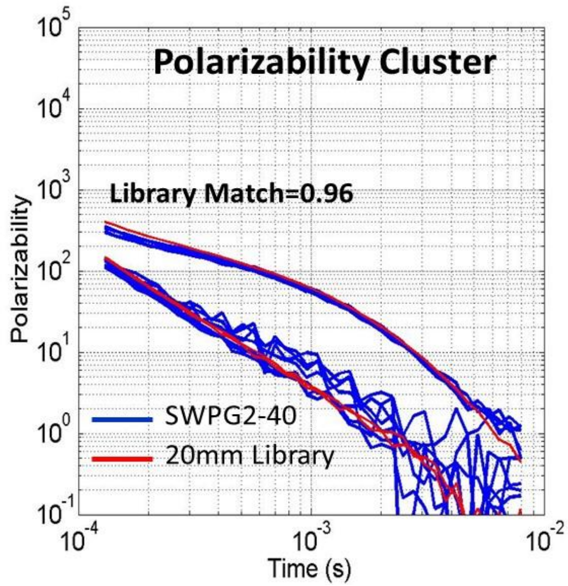


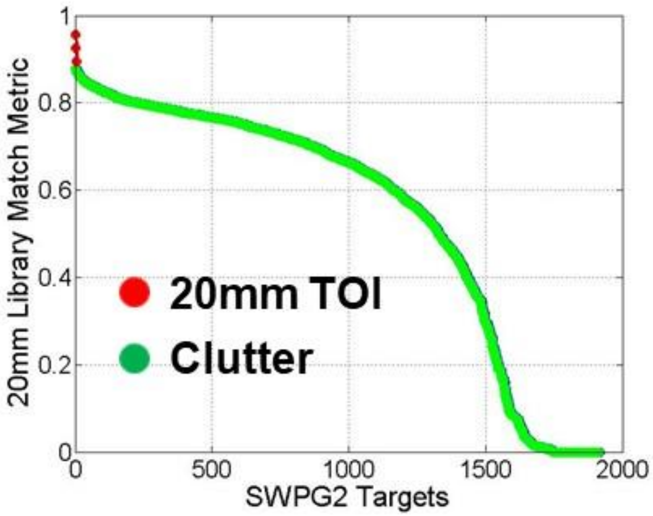
Position error tolerance: 3D EMI

- Each sensor position provides complete data for inversion of polarizabilities
- Polarizability "clusters" obtained from multiple sensor locations
- No need to accurately track relative position vectors, $\mathbf{R_n}$
- May be useful for underwater towed operation where towpoint surge could reduce accuracy of relative position tracking over short distances

Polarizability Cluster: Classification Decision



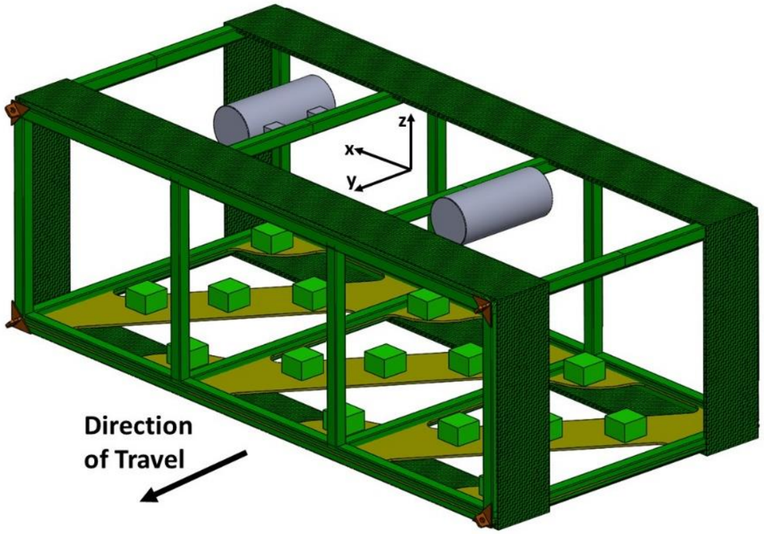




3D Dynamic classification decision flow:

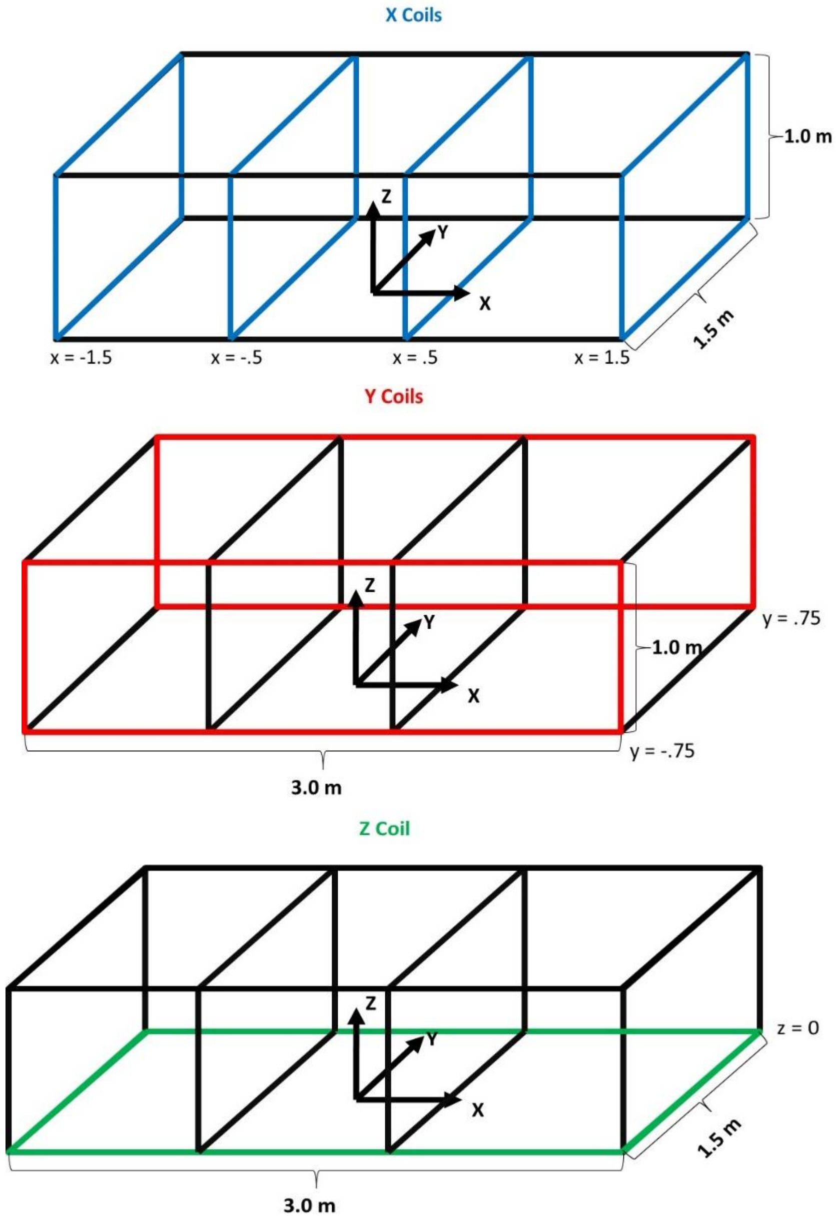
- Library match performed on polarizability cluster
- Average of cluster locations (cluster center) provides location estimate
- Targets ranked based on library match value

Underwater Dynamic Classification Concept

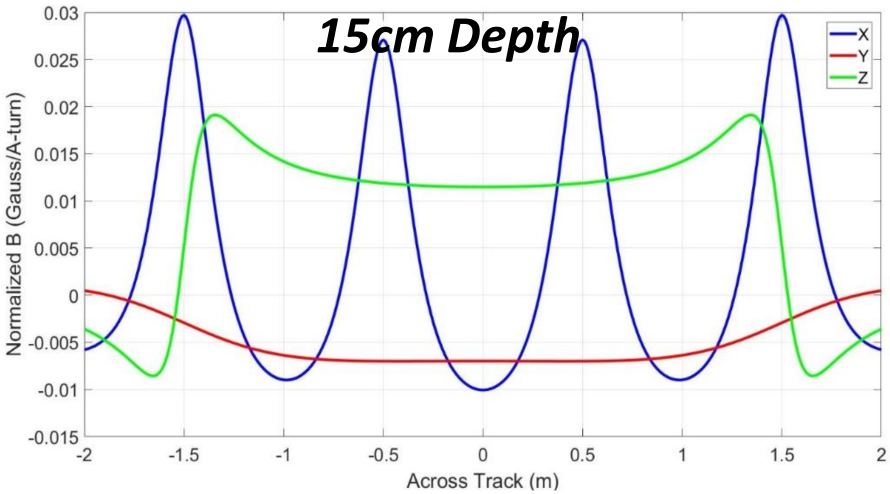


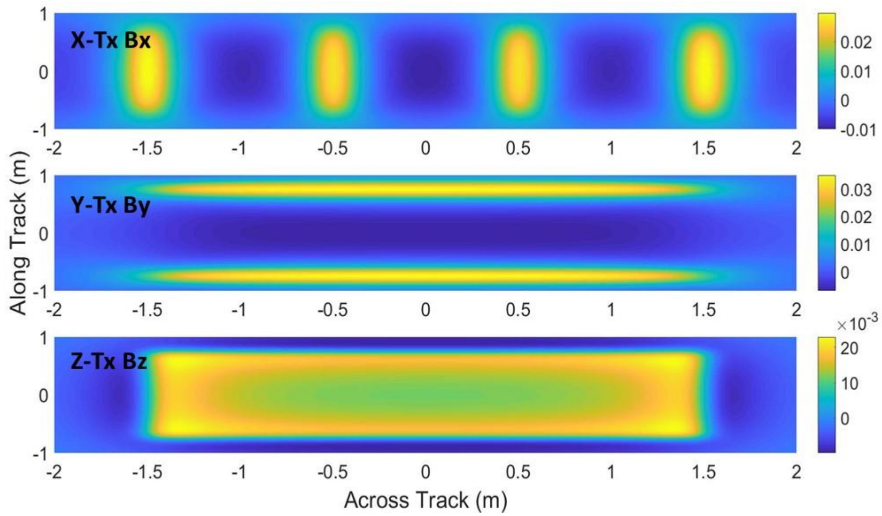
Sensor Design:

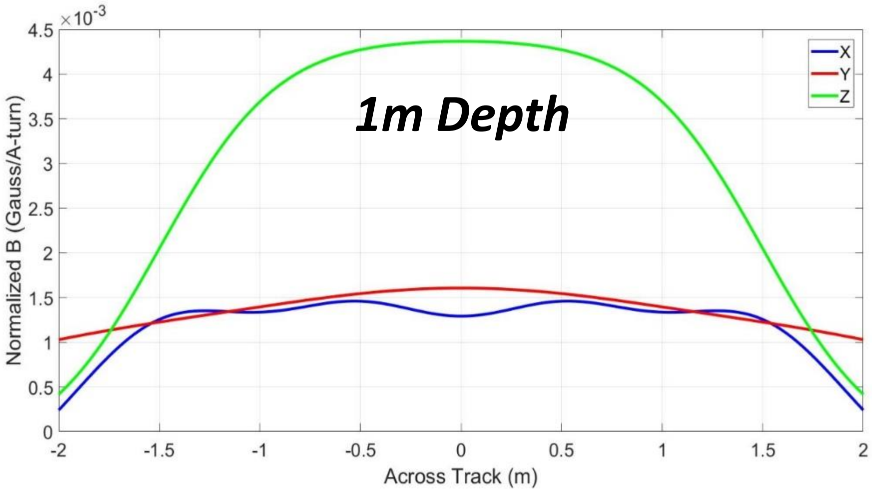
- Enables 3D classification approach
- Optimized for increased standoff range
- Extended for towed survey swath of 3m

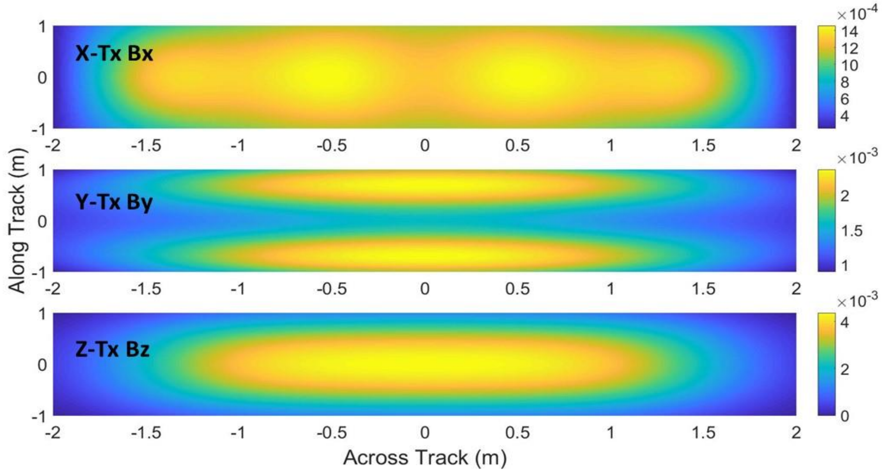


Transmitter Field Optimization



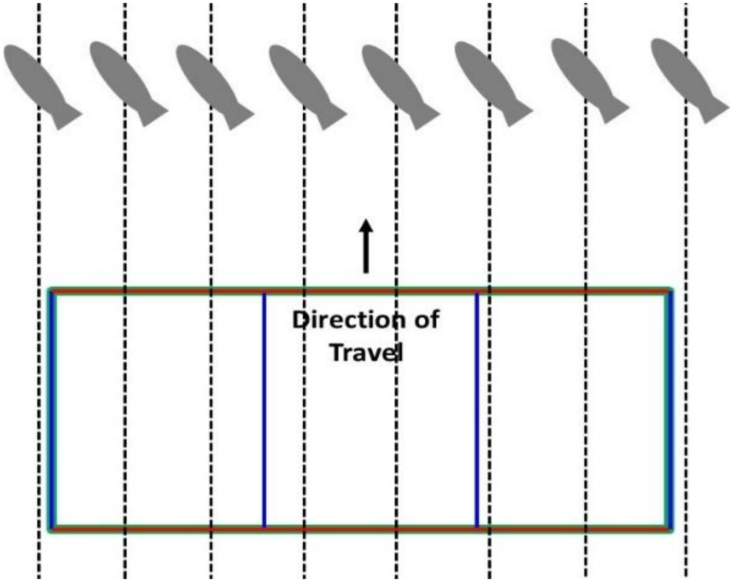






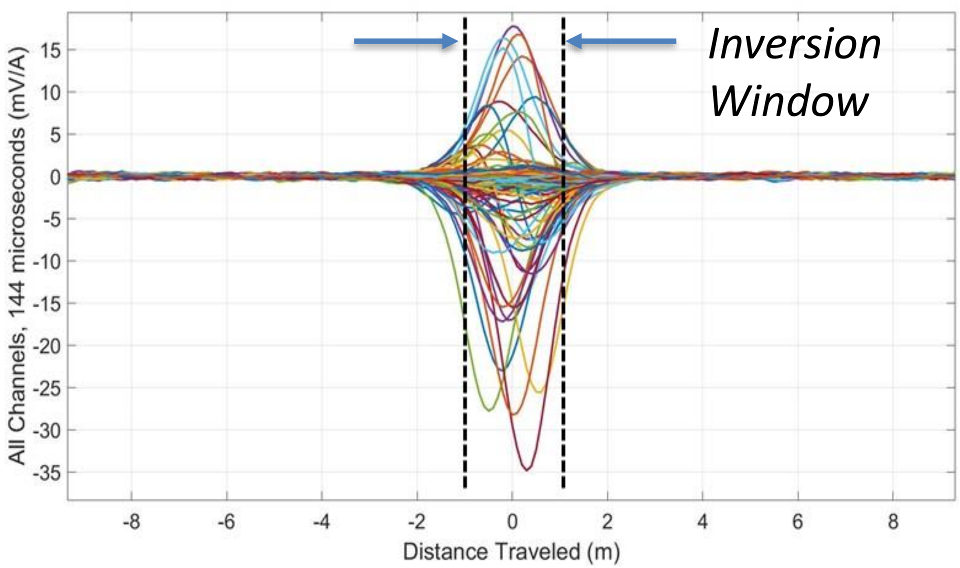
- Optimized for uniform field distribution at ranges >1 meter

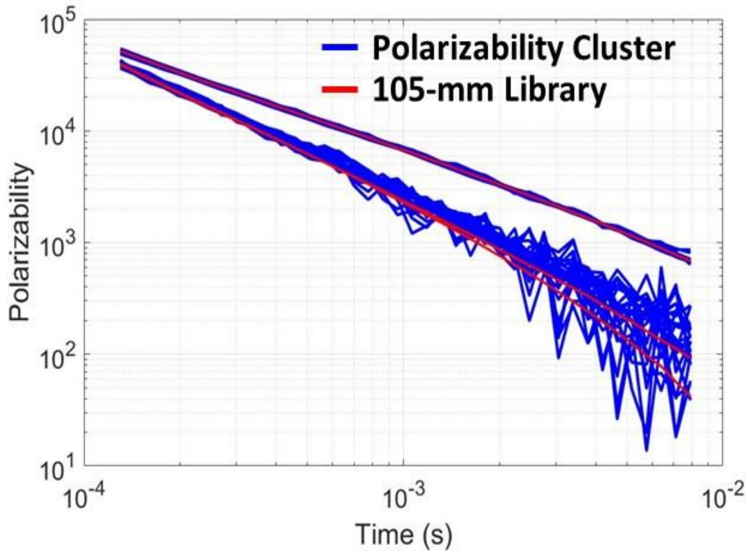
Electromagnetic Simulation: Dynamic Encounters



250 Dynamic Simulations:

- 20m lines (+/-10m from target)
- Across track offsets +/-1.6m
- Standoff ranges 1m – 2.4m
- TOI included 81mm – 155mm
- Dynamic noise added from OPTEMA survey data





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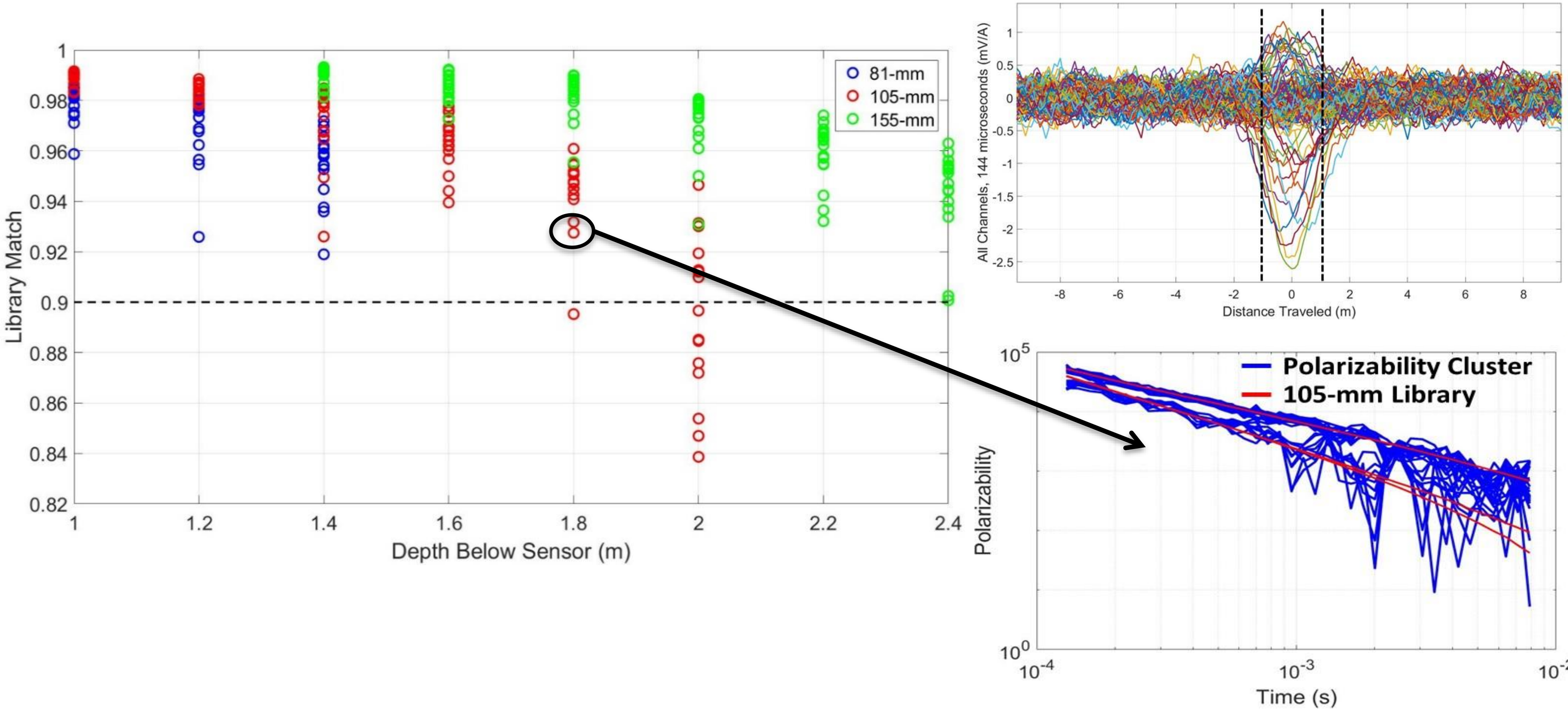
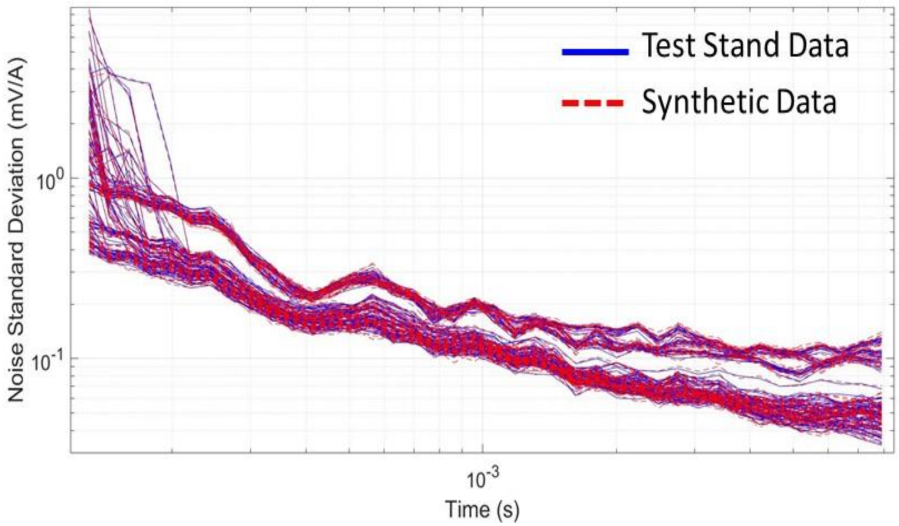
Electromagnetic Simulation: Dynamic Encounters



- Library match value of 0.9 used for classification quality threshold
- 81mm – 1.4m; 105mm – 1.8m; 155mm – 2.4m reliable classification depths
- Transmitter effective power = 200 A-turns

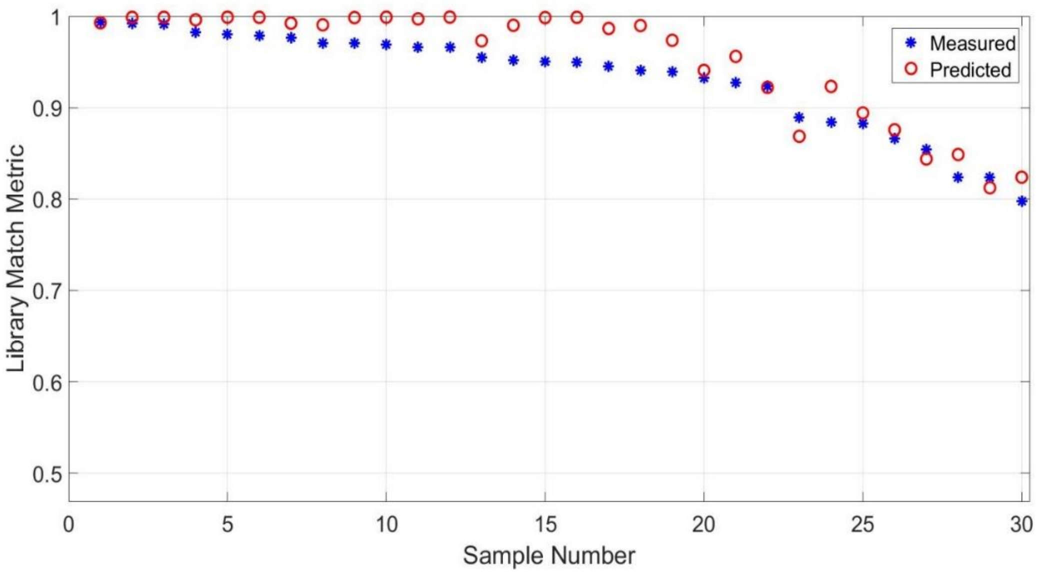
Experimental Setup: Grid Measurements

Noise Standard Deviation for 90 Data Channels



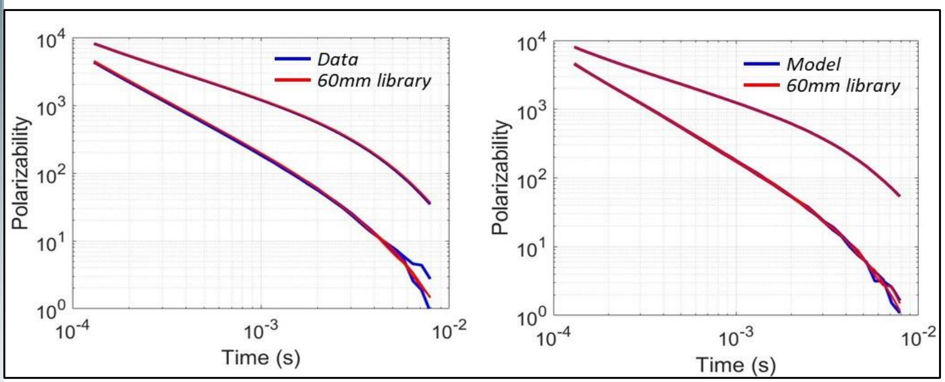
- 2/3-scale mockup replicates full-scale concept Tx spacing
- Static grid measurements collected to compare model predictions with actual inversion results
- Sensor noise captured and added to simulation to produce synthetic data

Electromagnetic Experiment: Model Verification

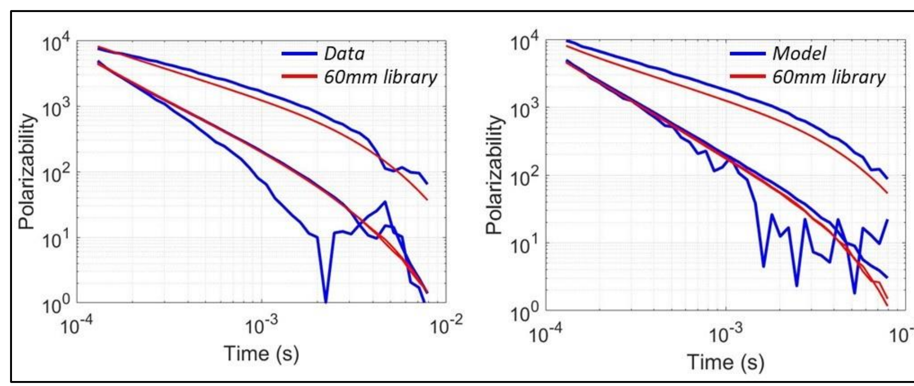


- 30 grid measurements
- Includes well constrained and poorly constrained grid locations
- Predicted match within 5% of observed match

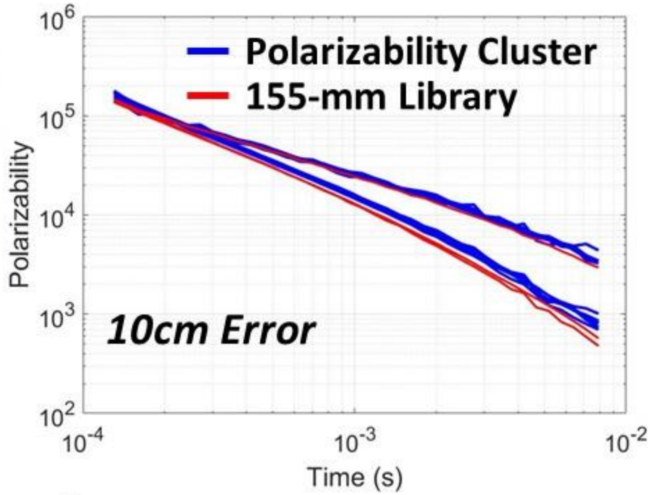
Constrained

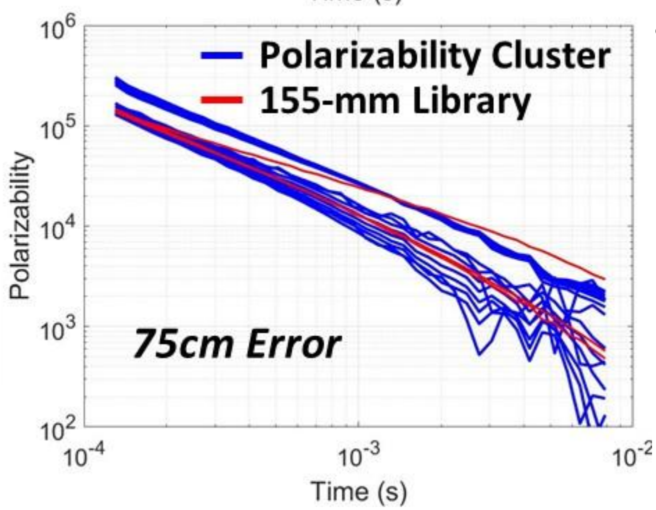


Poorly Constrained



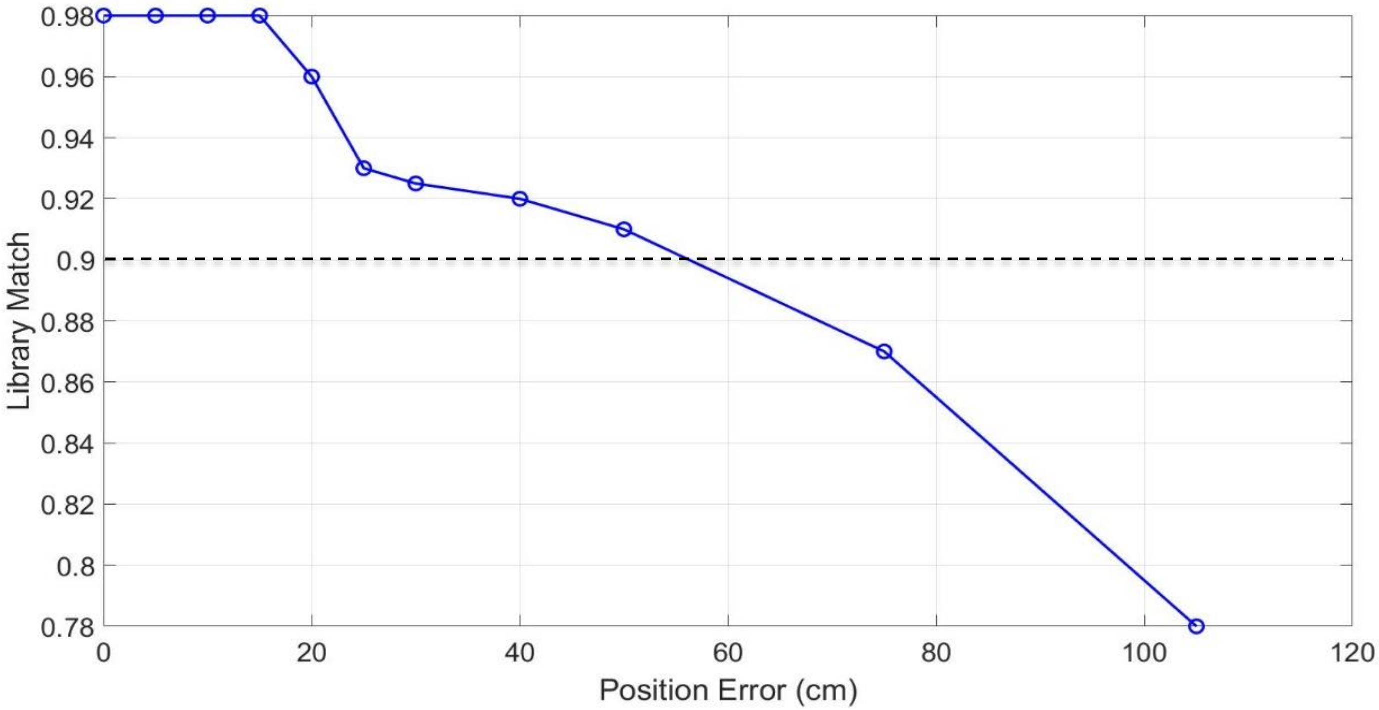
Electromagnetic Experiment: Error Simulation





- Acquired dynamic data over 155mm using constant tow speed
- Added sample-to-sample position error in post-processing
- Evaluated single shot tolerance to relative position error between samples

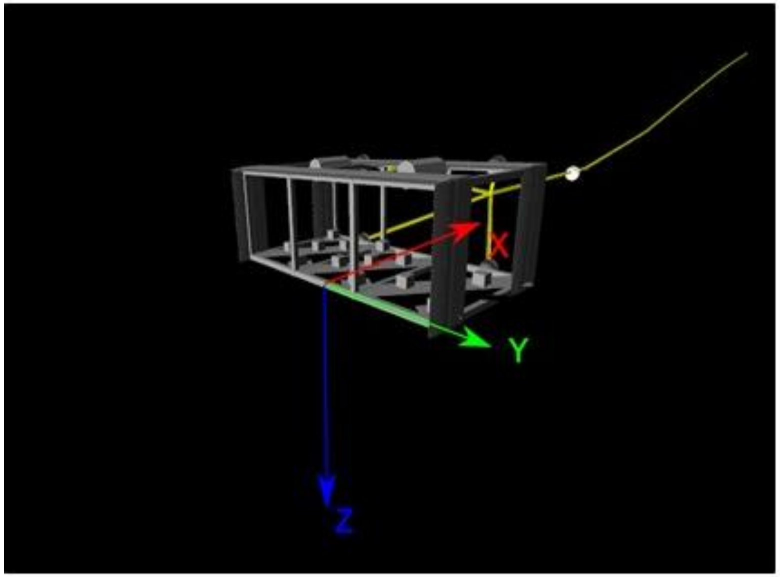
Electromagnetic Experiment: Error Simulation



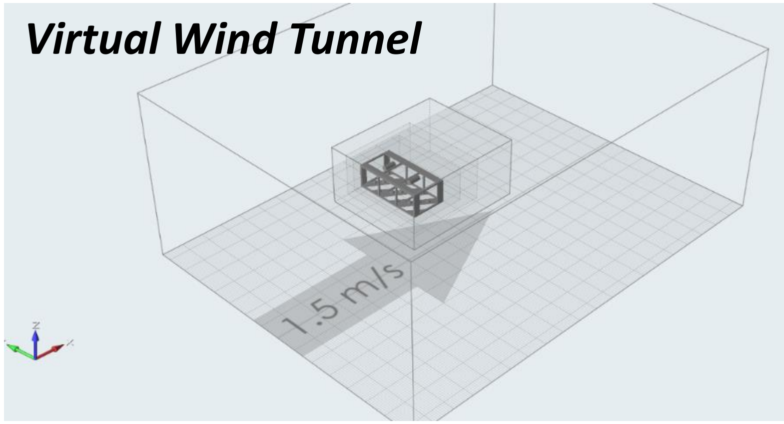
- No change in classification quality for up to 15cm sample-to-sample position error
- Quality match value (0.9 or higher) maintained to 50cm error

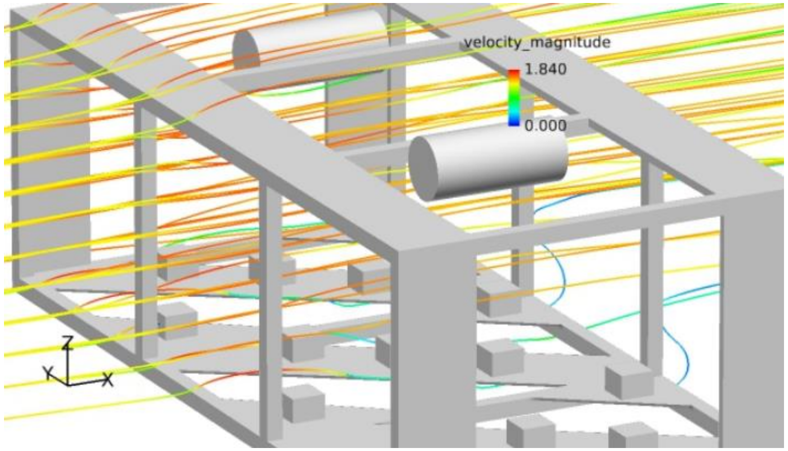
Hydrodynamic Modeling and Simulation

ProteusDS



Virtual Wind Tunnel

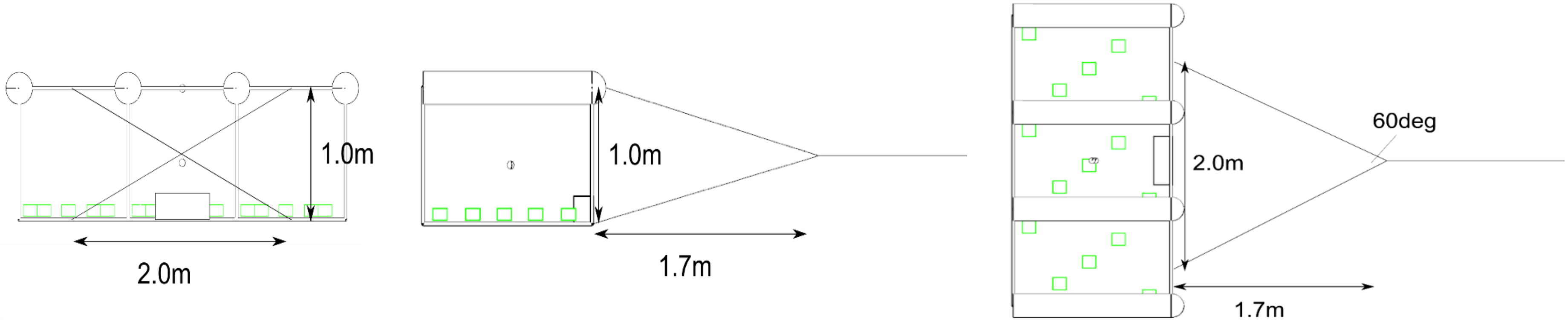


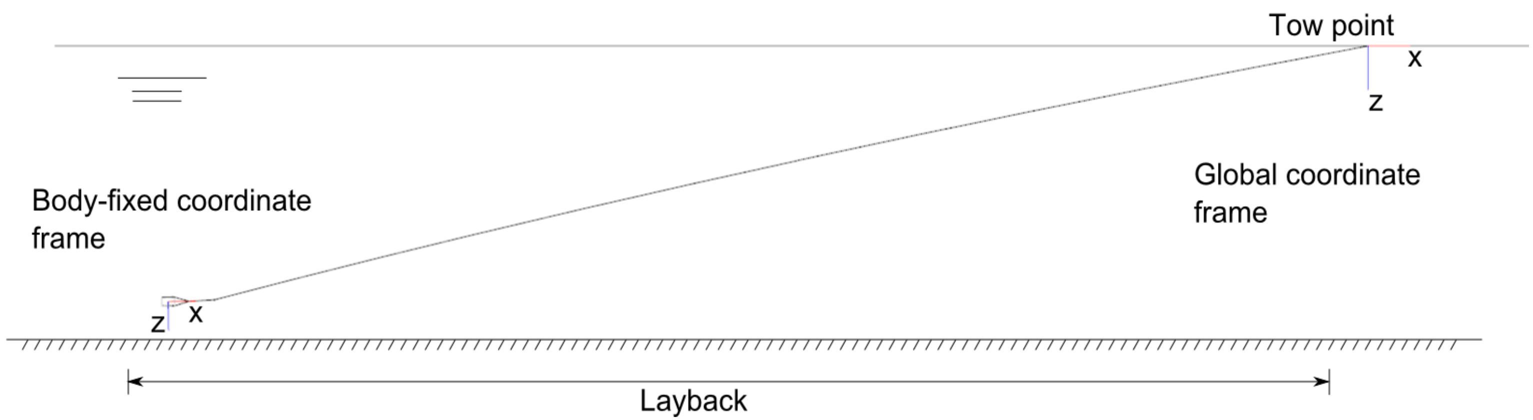


DSA ProteusDS Simulation Environment:

- Identifies forces acting on towed body
- Finite element model determines towed body response to load cases
- Accounts for mass distribution and buoyancy (volume of components)
- Drag analysis accounts for hydrodynamic shielding through Virtual Wind Tunnel (VWT) simulations

Hydrodynamic Model: Design





- Four point tow bridle designed for yaw and pitch stability
- 6 DOF rigid body model that calculates loads and buoyancy force
- Towline angle determined by drag and clump weight
- Depth determined by towline angle and layback

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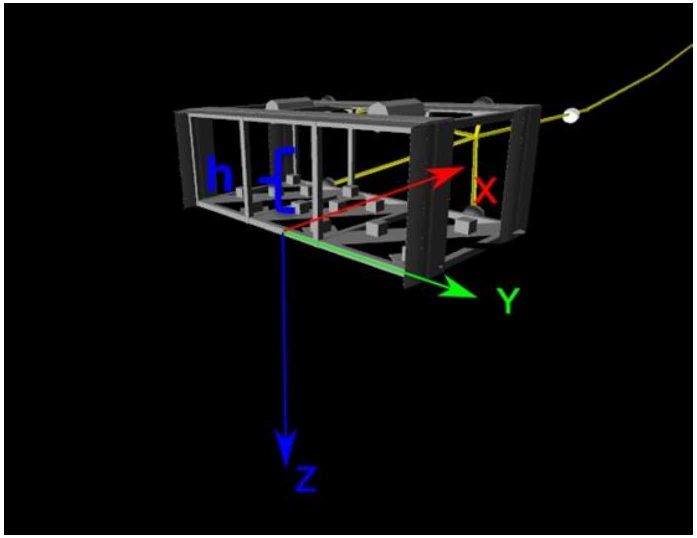
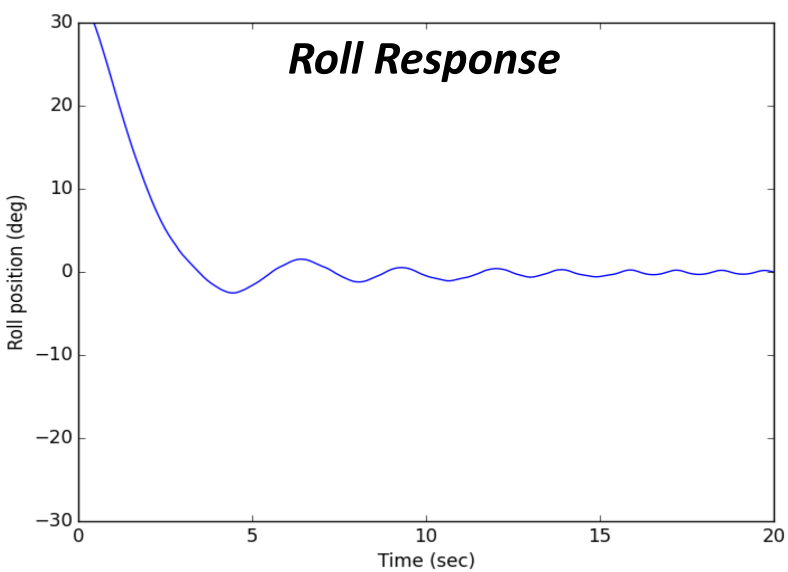
Hydrodynamic Simulation: 25 Load Cases

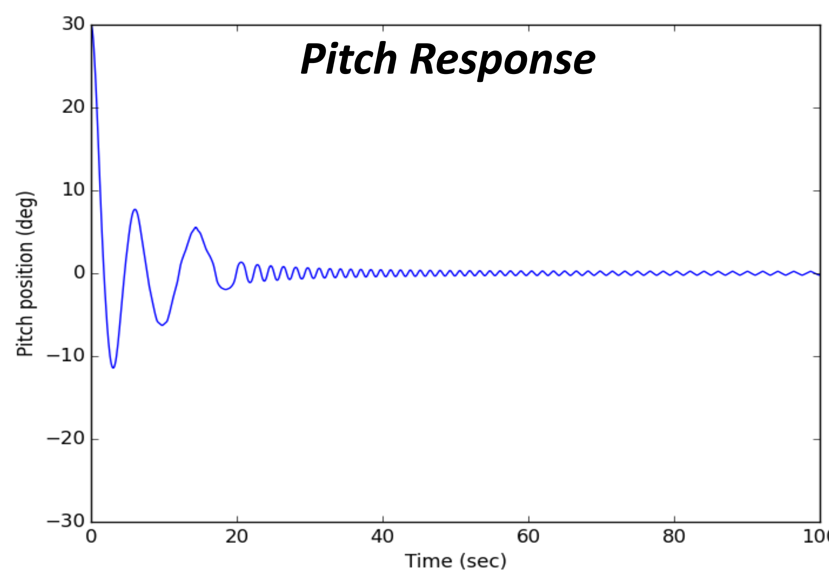
Category	Sub-Category	test	Test Number	Comments
Stability Load Cases				
	Towed EMI sensor righting moment			Array only, no towline. Initial roll/pitch offset.
		Roll	S-01	
		Pitch	S-02	
	Transient response			Towline present, yaw/heave offset.
		Sway	S-03	
		Heave (falling)	S-04	
		Heave (rising)	S-05	
	Wave response			Wave test cases, both wave encounter frequencies.
		Sea state 3 - opposing	S-06	Height: 1.25m Period: 5.0sec
		Sea state 3 - with	S-07	Height: 1.25m Period: 5.0sec
	Cross current			Platform stability and sway position in 0.5 m/s and 1 m/s cross current
		0.5 m/s	S-08	
		1 m/s	S-09	
Control Load Cases				
	Winch response			Determine towed EMI sensor heave response to winch control
		1.0 m/s tow speed, 25kg clump weight	C-01	
		1.0 m/s tow speed, 50kg clump weight	C-02	
		1.0 m/s tow speed, 75kg clump weight	C-03	
		1.5 m/s tow speed, 25kg clump weight	C-04	
		1.5 m/s tow speed, 50kg clump weight	C-05	
		1.5 m/s tow speed, 75kg clump weight	C-06	
		2.0 m/s tow speed, 25kg clump weight	C-07	
		2.0 m/s tow speed, 50kg clump weight	C-08	
		2.0 m/s tow speed, 75kg clump weight	C-09	
Operating Load Cases				
	Operating configurations			Determine loads and layback on the system during normal towing operations
		Tow speed 1 knot	O-1	
		Tow speed 2 knot	O-2	
		Tow speed 3 knot	O-3	
		Tow speed 4 knot	O-4	
	Turning			Determine array stability when turning
		Turning - 1	O-5	
	Start/stop			Determine towed EMI sensor reaction on start up or sudden stop
		Sudden stop	O-6	
		Start up	O-7	

Hydrodynamic Simulation: Stability

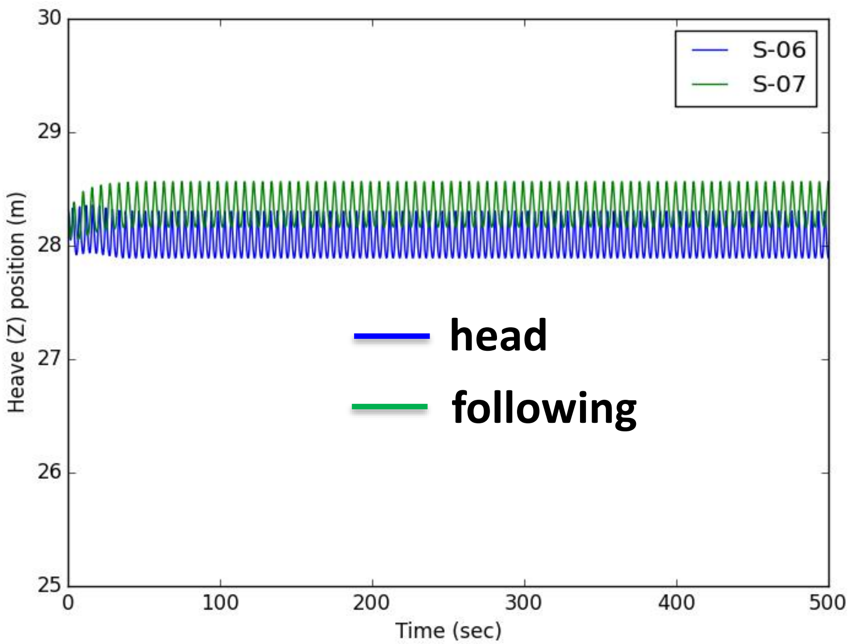


- Stability aided by increased metacentric height (h) for 3D configuration
- Increases righting moment and improves roll and pitch stability
- Roll and pitch stability tested for 30 degree perturbation; settles to within 5 degrees of neutral within 3 seconds (roll) and 20 seconds (pitch)





Hydrodynamic Simulation: Heave Response



- Sensor heave response evaluated for tow point heave and surge encountered in Sea State 3 conditions (head and following seas)
- Maximum heave variability is +/- 15cm for 1.25m wave height
- Indicates stability for maintaining seafloor standoff

Towline Tension

Load case:	Mean tension - Bottom (kN):	Max tension – Bottom (kN):	Mean tension - Top (kN):	Max tension - Top (kN):
S-06	2.32	4.98	2.44	5.20
S-07	2.26	4.09	2.37	4.28

Summary

- Methods that limit number of underwater reacquisitions will have significant cost benefit for marine UXO remediation
- Dynamic classification has the potential to reduce reacquisition by eliminating cued survey and reducing diver reacquisition for false alarms
- 3D sensor design may provide position error tolerance that is beneficial for towed deployment
- Modification of land-based sensor configuration may improve ability to operate at increased standoff
- Initial hydrodynamic analysis indicates that there are no significant operational barriers to implementing a 3D configuration for towed deployment

Acknowledgments

1. Underwater Sensor Design Feasibility – ESTCP MR-201614;
2. Dynamic Classification Live Site Demonstration – ESTCP MR-201225

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