Thank you for signing in early

The webinar will begin promptly at
12:00 pm ET, 9:00 am PT

SERDP DOD • EPA • DOE | ESTCP

SERDP and ESTCP Webinar Series

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT

- You have two options for accessing the webinar
  1. Listen to the broadcast audio if your computer is equipped with speakers
  2. Call into the conference line

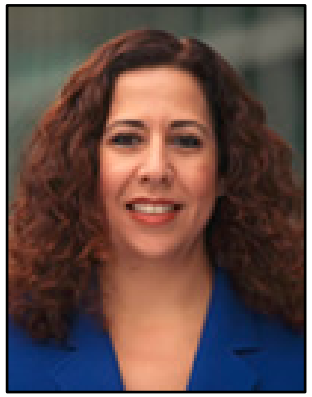
     U.S./Canada: 1-877-665-8320
     International: 303-248-0285
     Required conference ID: 48268668
- For any question or issues, please email serdp-estcp@noblis.org or call 571-372-6565

"Recent Advances in the Classification of Underwater Munitions near a Water-Sediment Boundary"

February 25, 2016

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions



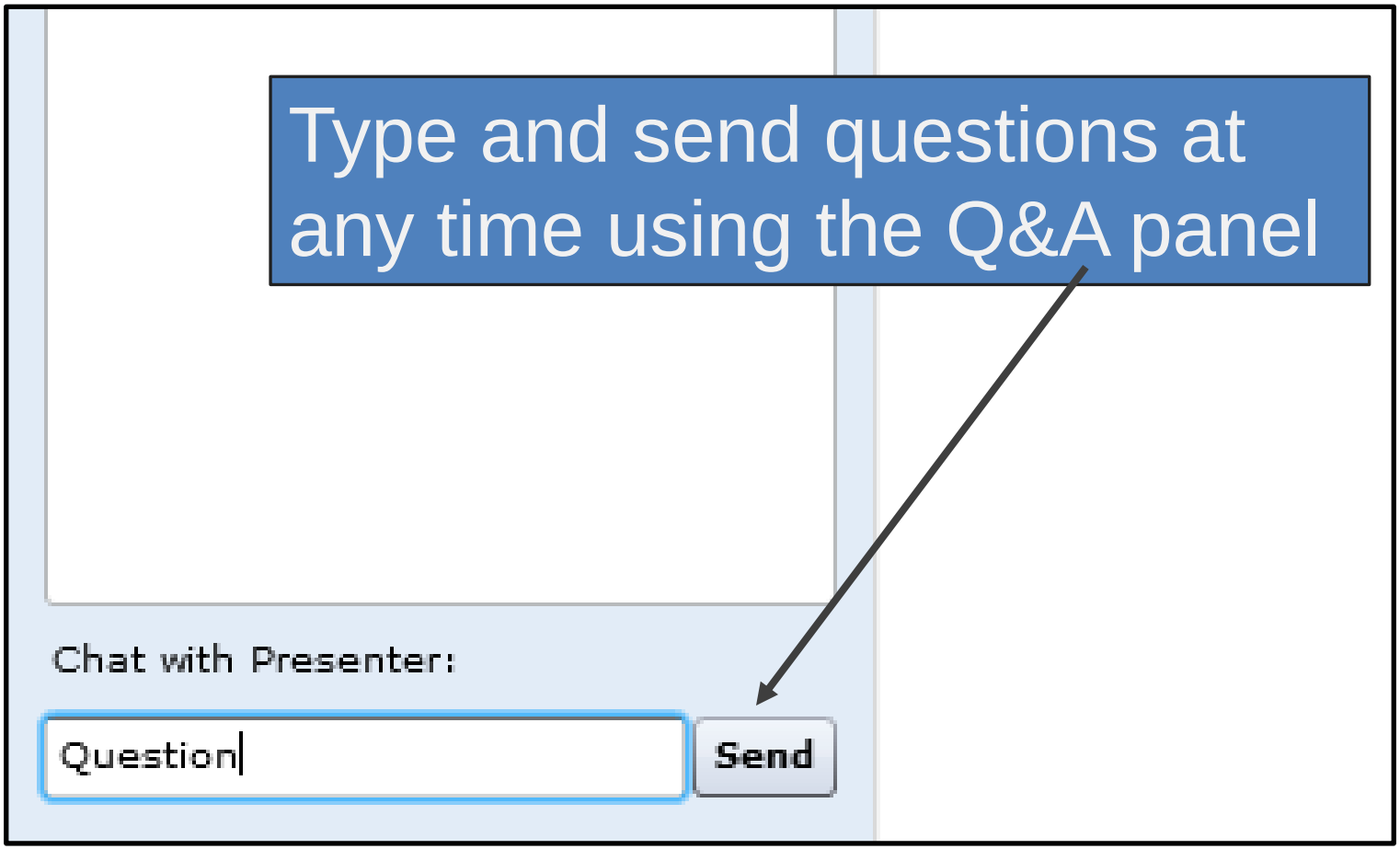
Rula A. Deeb, Ph.D.
Webinar Coordinator

SERDP DOD • EPA • DOE | ESTCP

Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Herb Nelson, SERDP and ESTCP
- **Recent Advances in the Classification of Underwater Munitions near a Water-Sediment Boundary** (50 minutes)
  Dr. Aubrey España, Applied Physics Laboratory, University of Washington
  Dr. Tim Marston, Applied Physics Laboratory, University of Washington
- **Final Q&A session**

How to Ask Questions



In Case of Technical Difficulties

- Delays in the broadcast audio
  - Click the mute/connect button
  - Wait 3-5 seconds
  - Click the mute/connect button again
  - If delays continue, call into the conference line
    - U.S./Canada: 1-877-665-8320
    - International: 303-248-0285
    - Required conference ID: 48268668
- Submit a question using the chat box

SERDP and ESTCP Overview

Herb Nelson, Ph.D.
Munitions Response Program Manager

SERDP

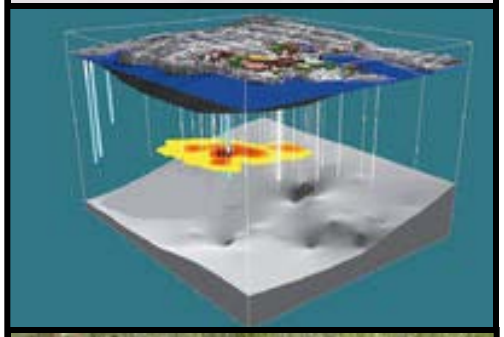
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

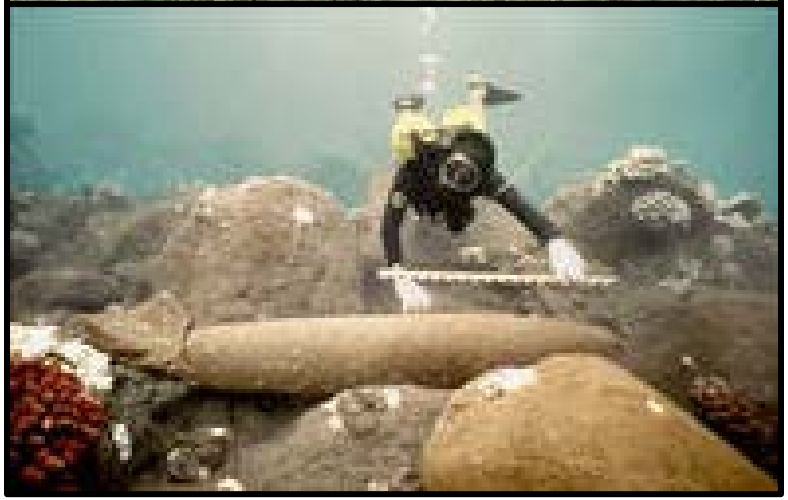
Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms



Munition Response

- Munitions on land
  - Classification
- Munitions underwater
  - Wide area and detailed surveys
  - Cost-effective recovery and disposal
  - Characteristics of munitions underwater, their environment and mobility



SERDP and ESTCP Webinar Series

DATE	Topics
March 24, 2016	Cadmium and Chromate Elimination Efforts: Implementation Plans and Strategic Roadmaps for Three DoD Depots
April 7, 2016	Resource Conservation and Climate Change
April 21, 2016	Long Term Monitoring Issues at Chlorinated Solvent Sites

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

SERDP DOD • EPA • DOE | ESTCP

"Recent Advances in the Classification of Underwater Munitions near a Water-Sediment Boundary"

Aubrey España, Ph.D.
Applied Physics Laboratory
University of Washington

SERDP DOD • EPA • DOE | ESTCP

Agenda

- Project team
- Technical problem and challenges faced
- Technical approach
  - 5-year integrated plan
- Project objectives
- Outline for webinar
- Significance of results (a few spoilers)

Project Team

- Dr. Steven G. Kargl (PI)
  - Expertise in acoustic wave propagation and target scattering
- Dr. Aubrey L. España (Co-PI)
  - Expertise in finite-element analysis of the acoustic response of targets
- Dr. Jack McLaughlin
  - An expert in signal processing with applications to target detection and classification
- Dr. Kevin L. Williams
  - Expertise in at-sea field measurements and reduction of sonar data to acoustic templates used in classifications schemes. He is the PI for MR-2501
- Dr. Tim Marston (separately funded)
  - An expert in signal processing with applications to target detection and reduction of sonar data to relevant data products

Technical Problem Definition

- Discarded WWII-era munitions pose a hazard to environment and public safety
- Need for assessing/predicting locations of munitions relative to the sea floor in the presence of clutter

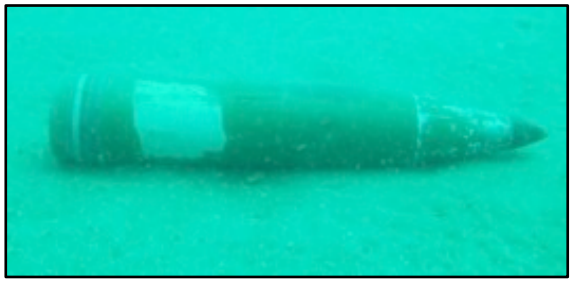
Challenges

- Acoustic response is affected by many factors

<u>Operational choices</u>
Vehicle altitude
Vehicle path

<u>Environmental Factors</u>
Target type
Burial state
Bottom topography
Bottom composition
Sea state

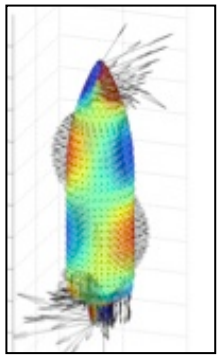
<u>Processing tools</u>
Data products
Feature sets
Training/testing methods

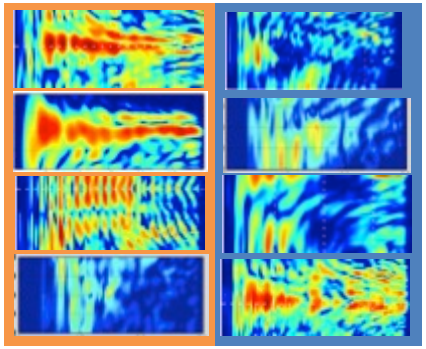


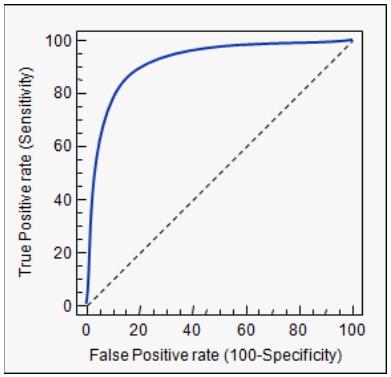
Interdisciplinary Chain

- Approach thus far has been very categorized
- Need to re-think our flow chart

Target → **Environment** → **Classification** → **Performance**





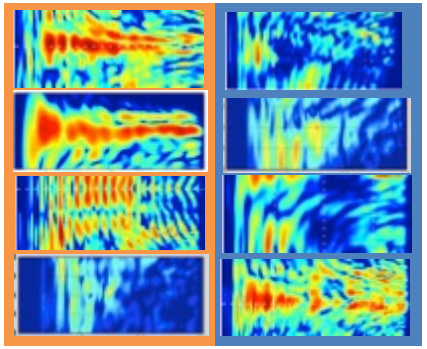


Performance Chain

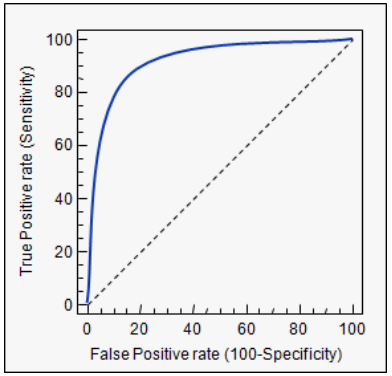
Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

Target-In-the-Environment-Response (TIER)

Classification



Performance



Problem Statement

- The ultimate goal of our work is to deliver a cost-effective, field-tested, tow body system with an operations/classification package for the detection and classification of munitions in underwater environments
- The 5-year integrated plan
  - MR-2505: Operations/Classification Package will develop and train classification algorithms leading to operational protocols to be executed with a tow body system
  - MR-2501: Tow Body Package is a design study of a platform using commercial-off-the-shelf (COTS) components

5-Year Integrated Plan

Operations/Classification Package | **Tow Body Package**

MR-2231 FY12-15
- TREX13 (sand)
- BAYEX14 (mud)
- Validated models

MR-2505 – Year 1
- Develop/train classification algorithms

MR- 2501 – Year 1
- One-year tow body design study

MR-2505 – Year 2
- Rail experiment in an acoustically hard environment

Follow-on to MR-2501 Year 1
- Tow body construction & dock-side testing

MR-2505 – Year 3
- Test trained classifiers on tow body data

Follow-on to MR-2501 Year 2
- Engineering test (Puget Sound)

Follow-on to MR-2501 Year 3
- Full field test of tow body system with operational classifiers and protocol/logistics

Technical Objectives

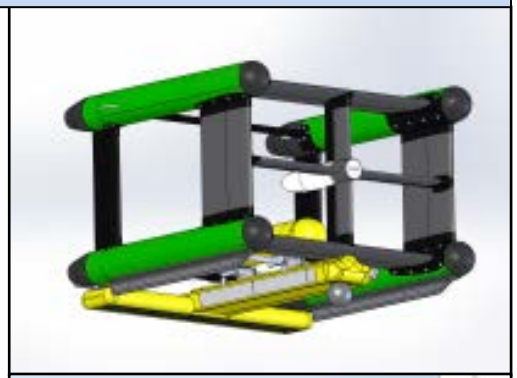
Operations/Classification Package

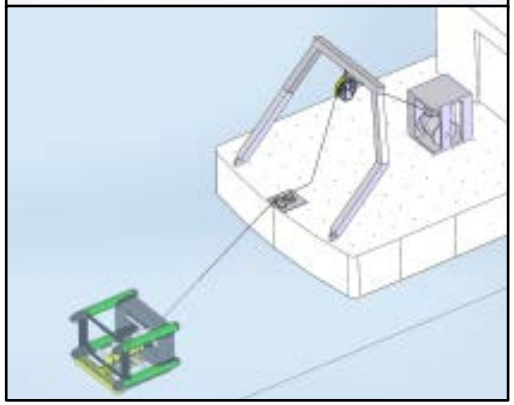
MR-2231 FY12-15
- TREX13 (sand)
- BAYEX14 (mud)
- Validated models

MR-2505 – Year 1
- Develop/train classification algorithms

Tow Body Package

MR- 2501 – Year 1
- One-year tow body design study





- Use available experimental data to develop, train and test classifiers
- Use our models to generate sets of data to augment the experimental data
- Use models to dissect physics and improve performance

Webinar Outline

Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

Target-In-The-Environment

- Raw data – processing tools – data products
- Results from field experiments
- Models and their significance

Target Classification

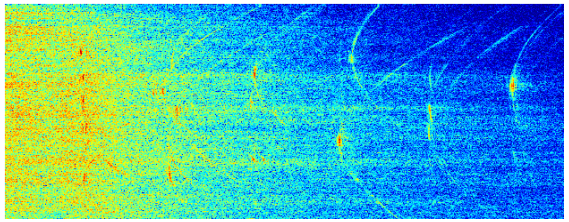
- Training a classifier
- Testing a classifier
- Simple example

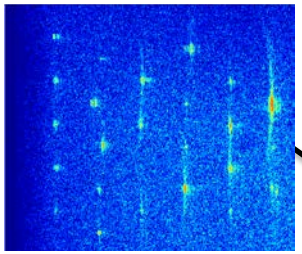
Performance

- Classification study on real data
- Performance estimation ***How good did we do?***
- Performance optimization ***Can we do better?***

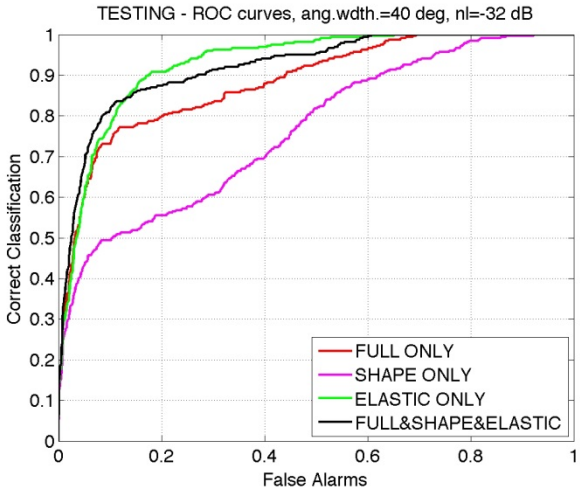
Significance (Spoilers!)

SAS processing – targets still visible in noisy environments!



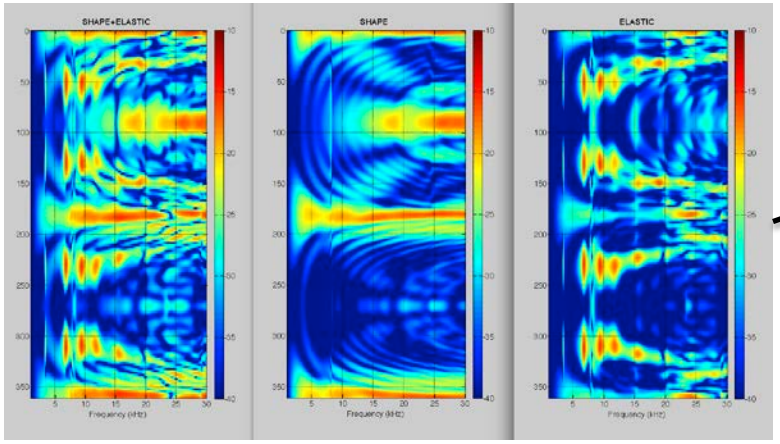


Classification is improved via insight gained from models



Models – We can dissect the physics!

FULL **SHAPE** **ELASTIC**



“Part 1: Target-In-The-Environment”

Tim Marston, Ph.D.
Applied Physics Laboratory
University of Washington

Agenda

Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

Target-In-The-Environment

- Raw data – processing tools – data products
- Results from field experiments
- Models and their significance

sification

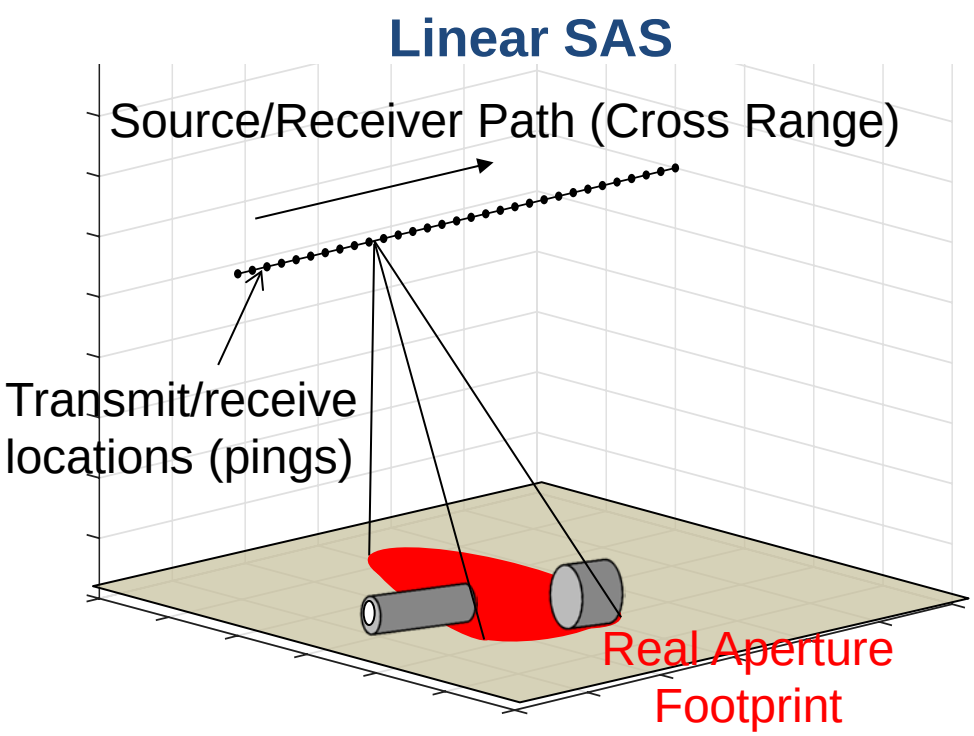
lassifier
assifier
mple

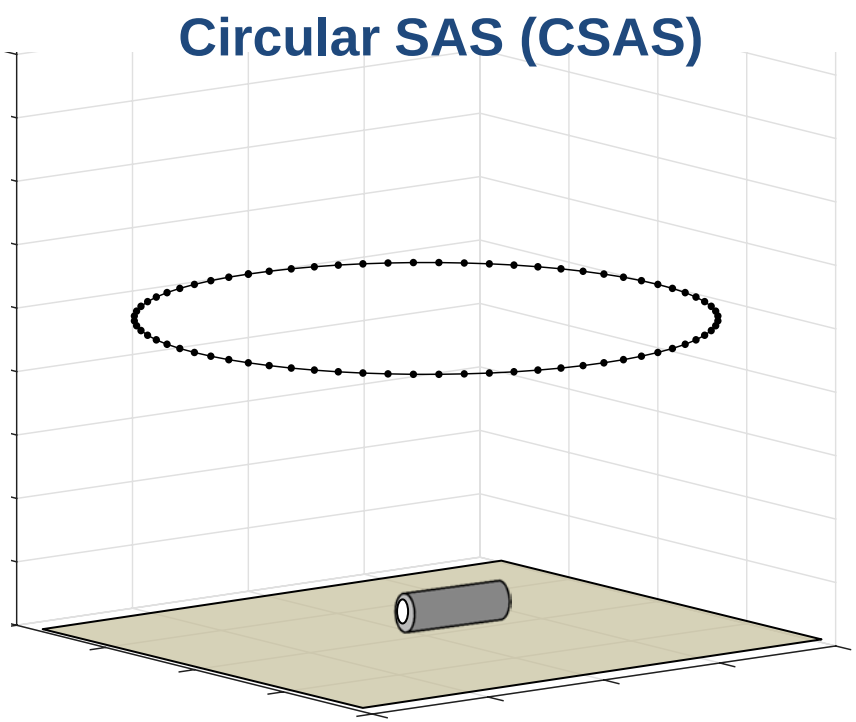
Performance

- Classification study on real data
- Performance Estimation
  How good did we do?
- Performance Optimization
  Can we do better?

Synthetic Aperture Sonar (SAS)

- Move the sonar while illuminating the same spot on the sea floor with several pings
- Higher resolution in the cross range dimension

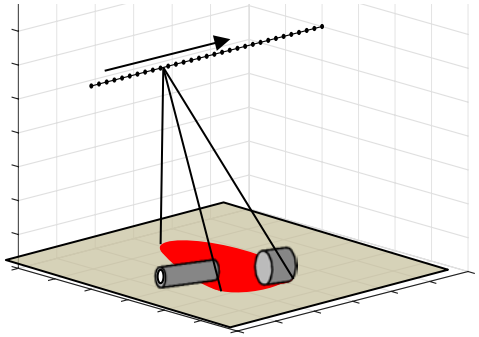


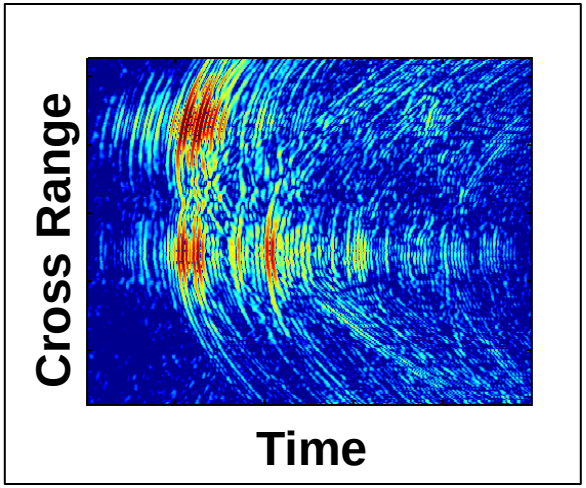


Raw Data

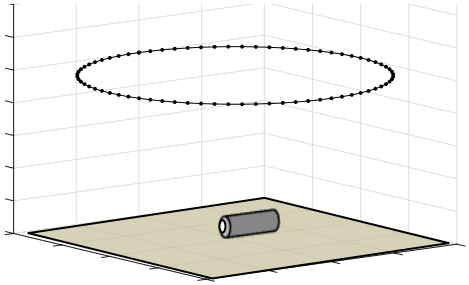
Pulse Compressed Time Data

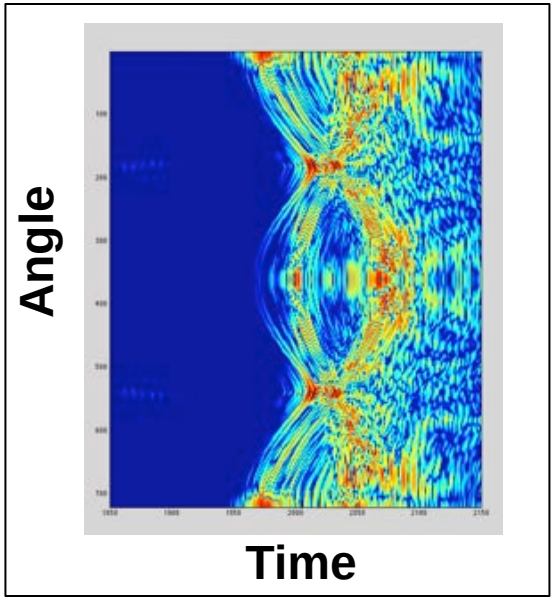
Linear Vehicle Path





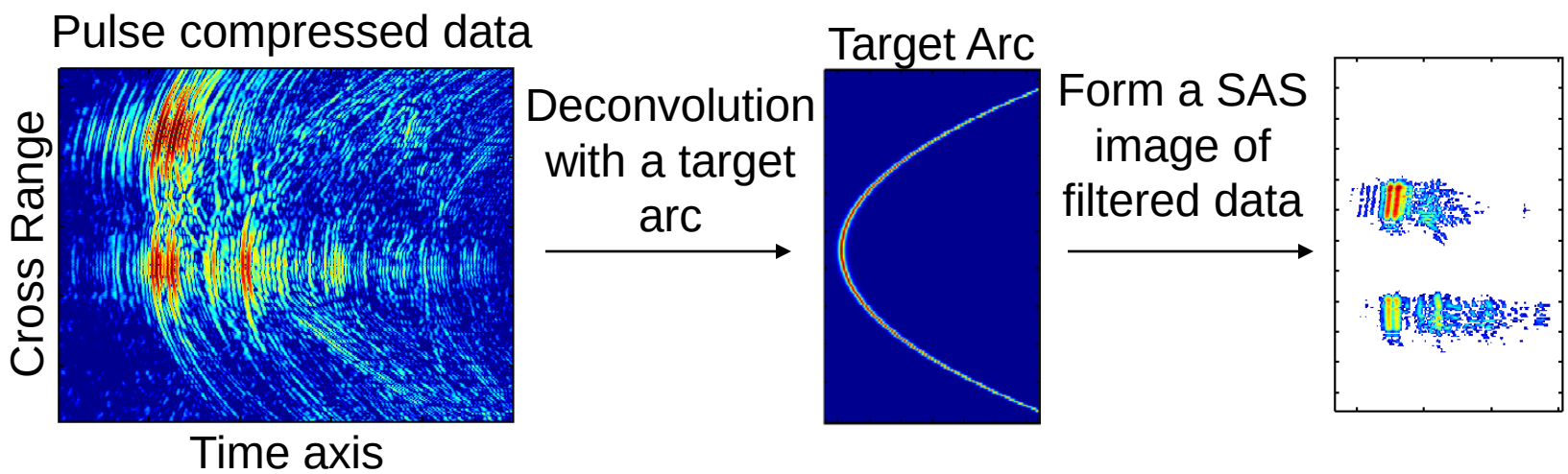
Circular Vehicle Path





Raw Data to Data Product

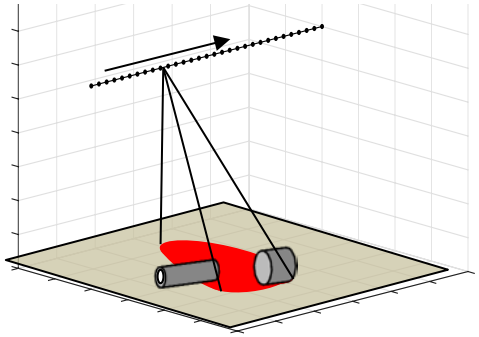
SAS Image



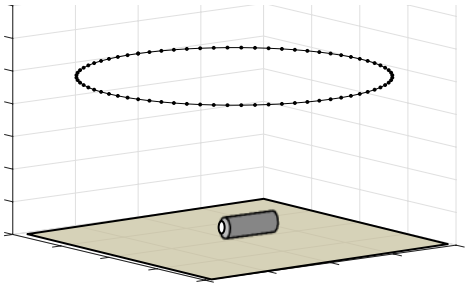
Data Products

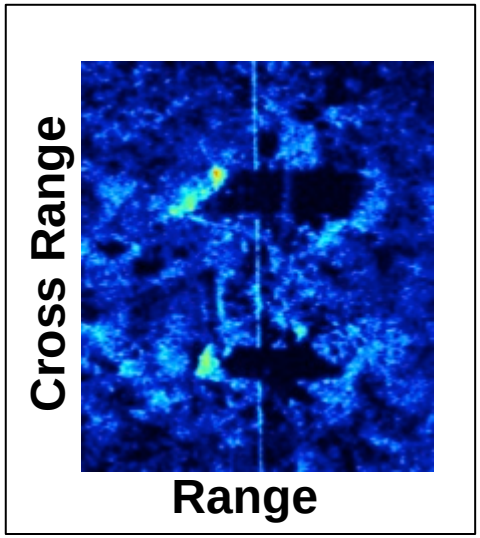
High Frequency SAS Images

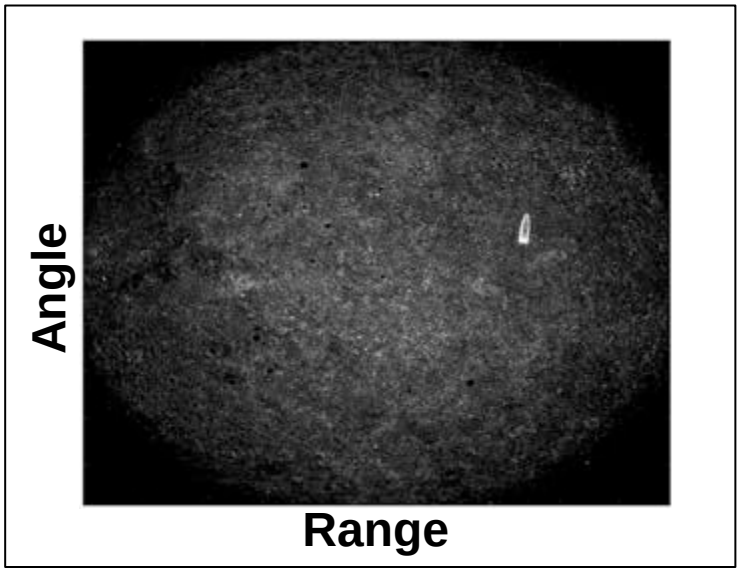
Linear Vehicle Path



Circular Vehicle Path



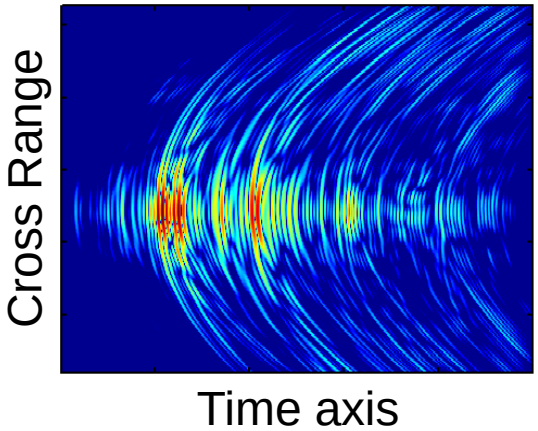




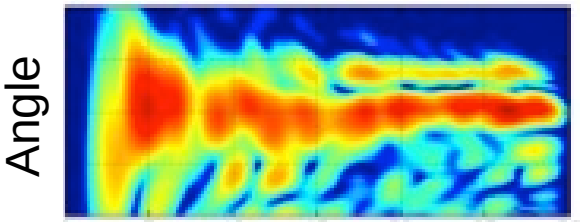
Raw Data to Data Product
Acoustic Color

- Target Strength (TS) as a function of frequency and target orientation with respect to the incoming sound

Filtered pulse compressed data



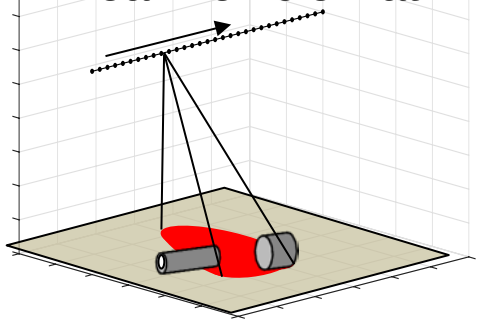
Fast Fourier Transform (FFT) →



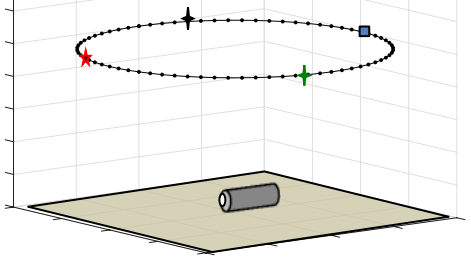
Data Products

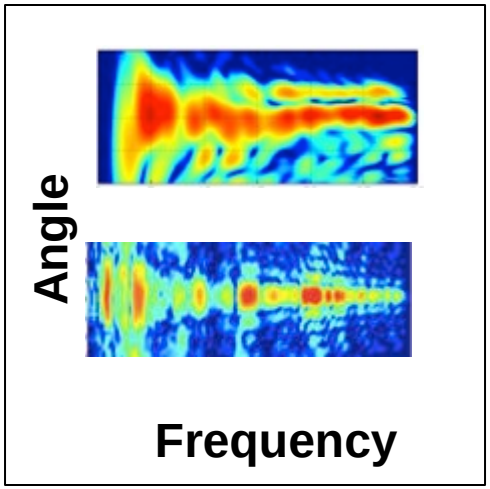
Low Frequency Acoustic Color

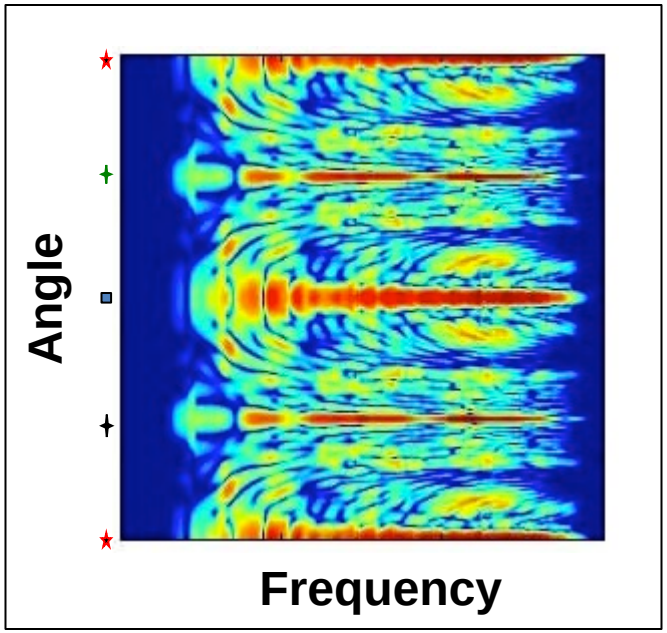
Linear Vehicle Path



Circular Vehicle Path







Field Experiments

- Three experiments were conducted from 2010 – 2014
- Environments span a range of conditions
- Targets included several inert UXO, scientific targets, and a few clutter items

PONDEX10

- Fresh water
- Water depth of ~17 m
- Sand sediment
- 6 targets
- Low frequency sonar signal

TREX13

- Sea water
- Water depth of ~17 m
- Sand sediment
- 11 to 27 targets
- Low frequency sonar signal
- Good visibility

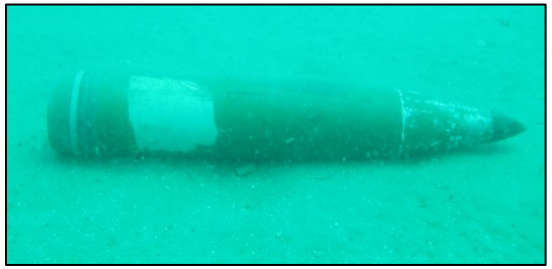
BAYEX14

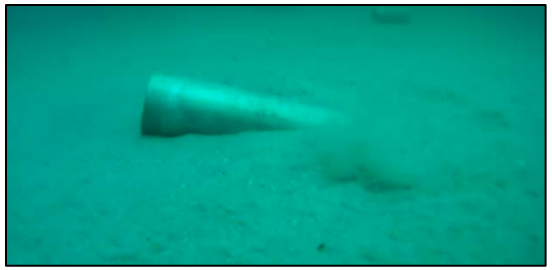
- Brackish water
- Water depth of ~8 m
- Mud layer over sand
- 11 to 27 targets
- Low and high frequency sonar signals
- Poor visibility

Field Experiments: In-Situ Photos

PONDEX10

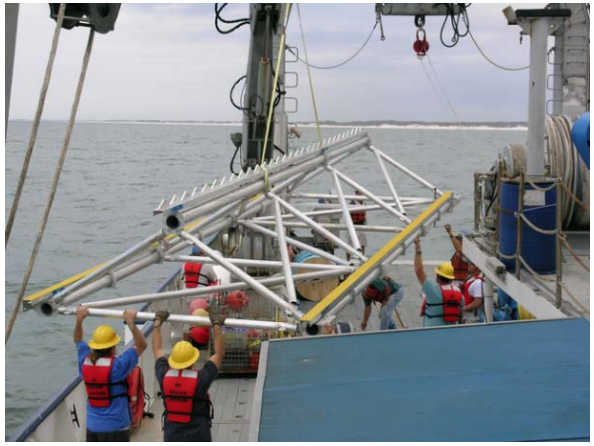
TREX13

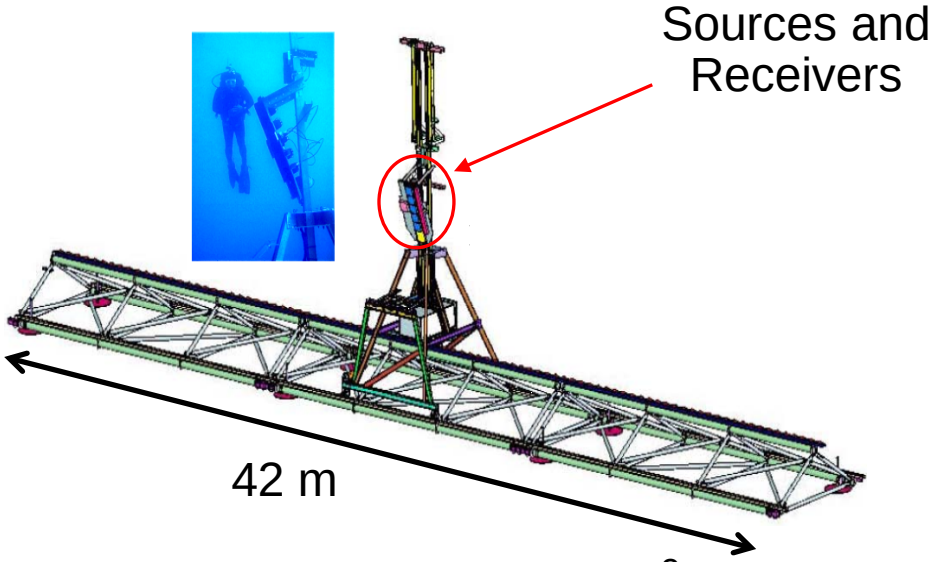


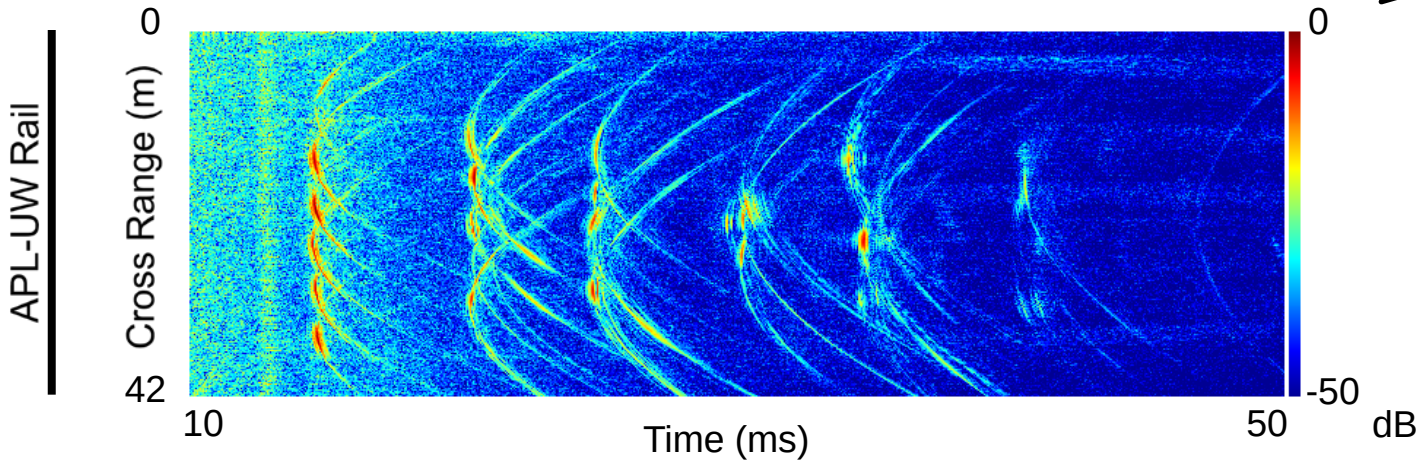


BAYEX14

APL-UW Tower-Rail System

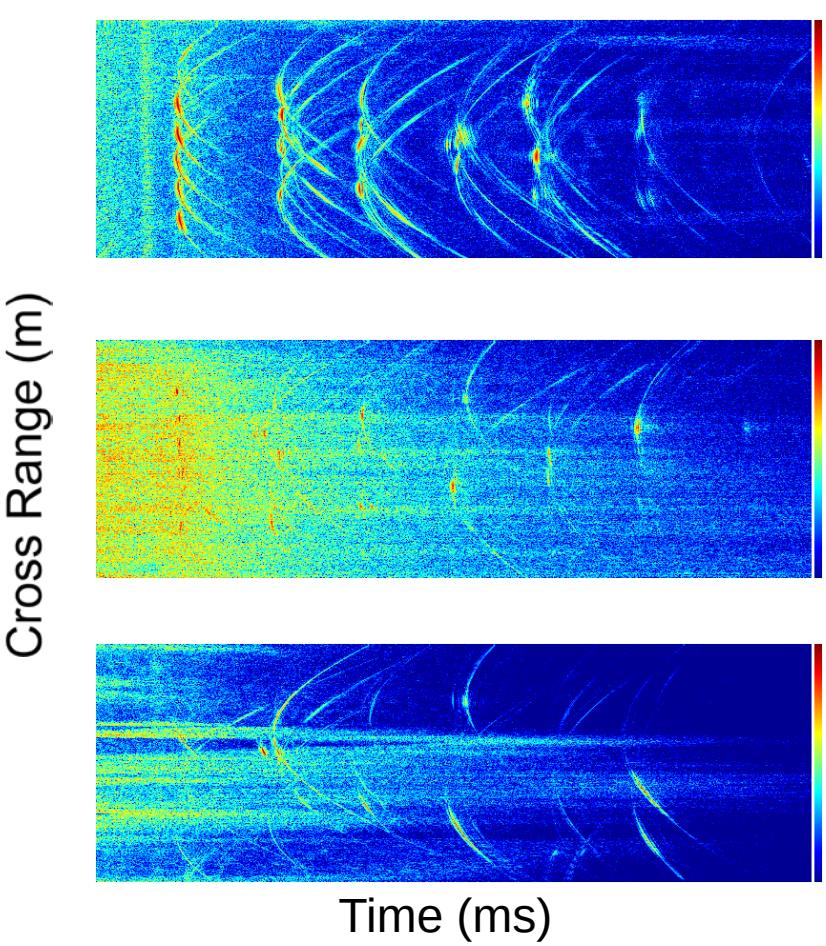


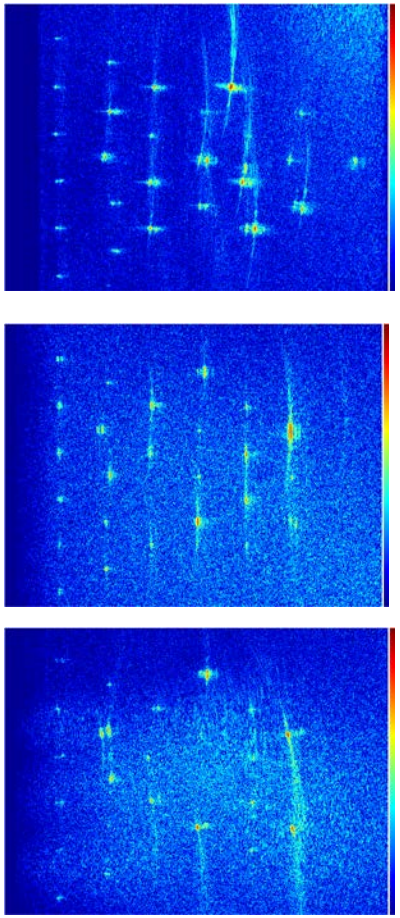




Benefits of SAS Processing

Can still form SAS images of objects even in noisy environments





Data sequence: 34
Date: 4/25/2013

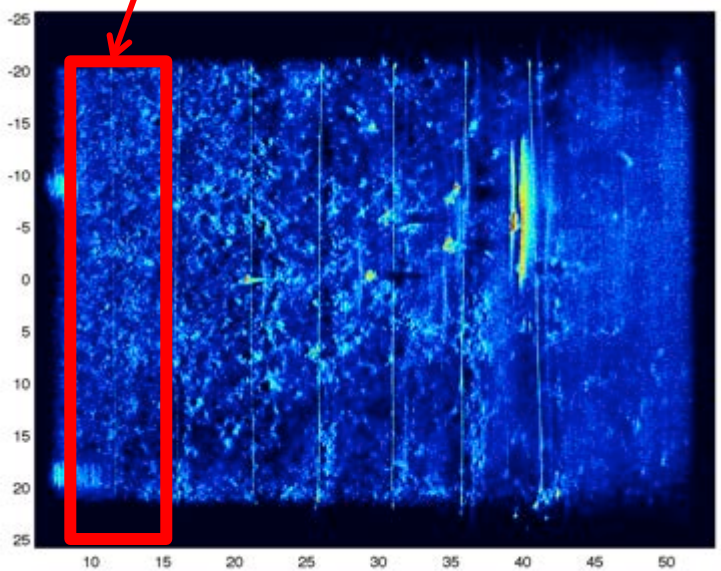
Data sequence: 82
Date: 4/30/2013

Data sequence: 92
Date: 5/1/2013

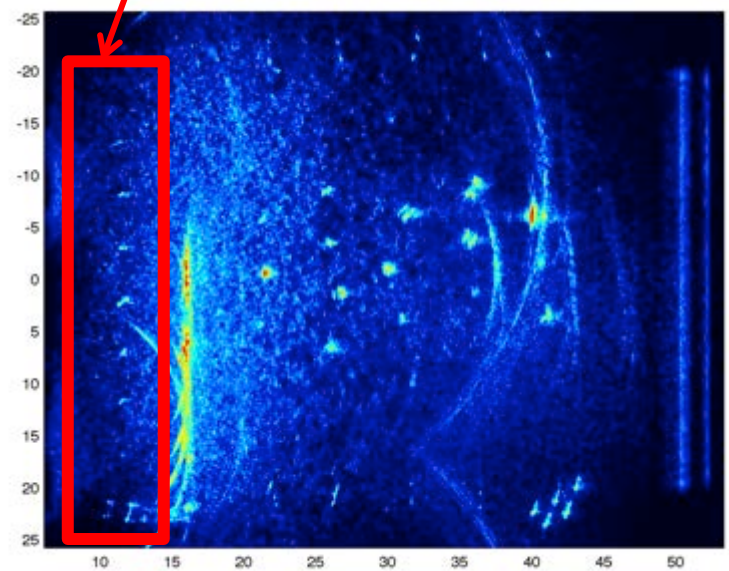
Benefits of Using Low Frequency (LF)

Allows for the detection of buried objects

High frequency SAS image
Appears that there is nothing here …..



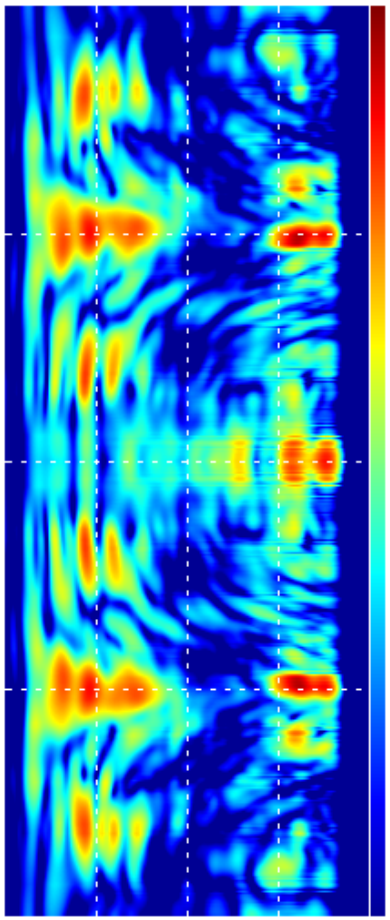
Low frequency SAS image
When in fact, there is!



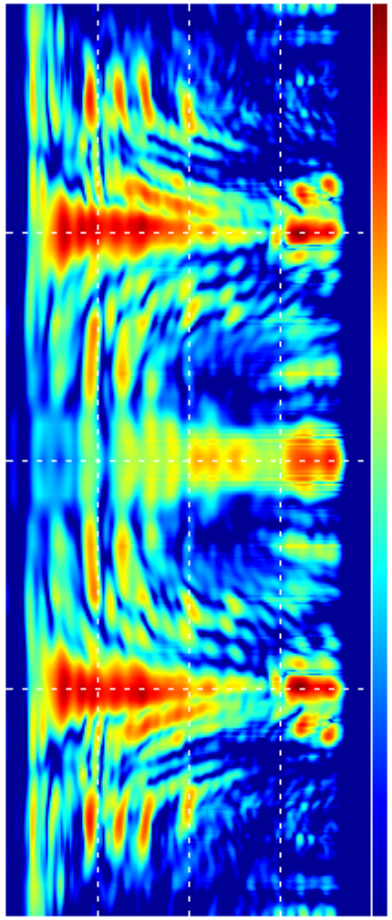
Benefits of LF Acoustic Color

Reveals things about the material, internal structure, etc.

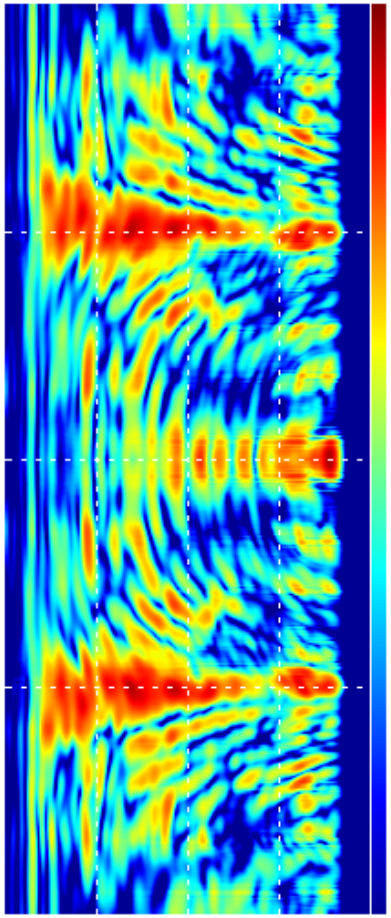
Aluminum Replica



Steel Replica



Steel Artillery Shell



Hybrid Modeling Approach

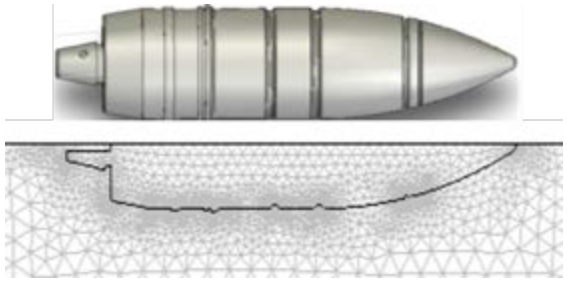
Finite Element (FE)

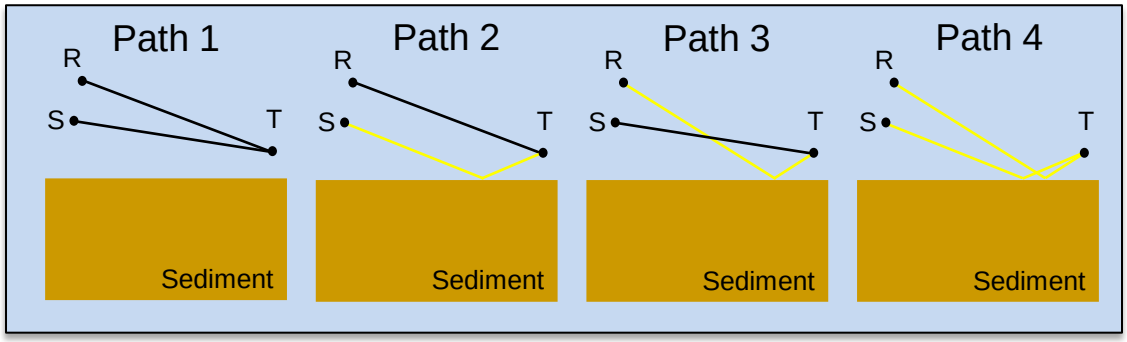
- Handles target interaction with environment

Fast Ray Model

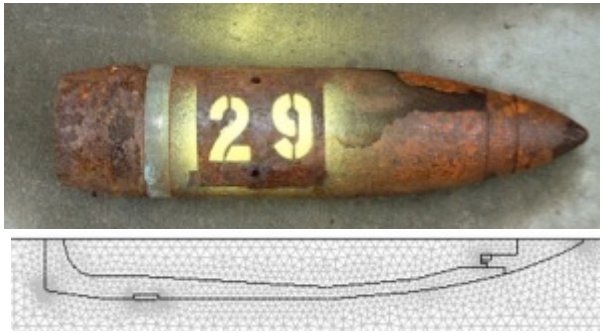
- Handles propagation of sound to and from the target

FE Model for Aluminum Replica





FE Model for 105-mm Bullet



References

1) A.L. España, et al., *JASA,* **136**, 109-121, 2014
2) S. Kargl, et al., *IEEE J Ocean Eng,* vol. 40, 632--642, 2015
3) M. Zampolli, et al., *JCA*., **20**, p. 1240007 (14 pp.), 2012

Model and Data Comparison

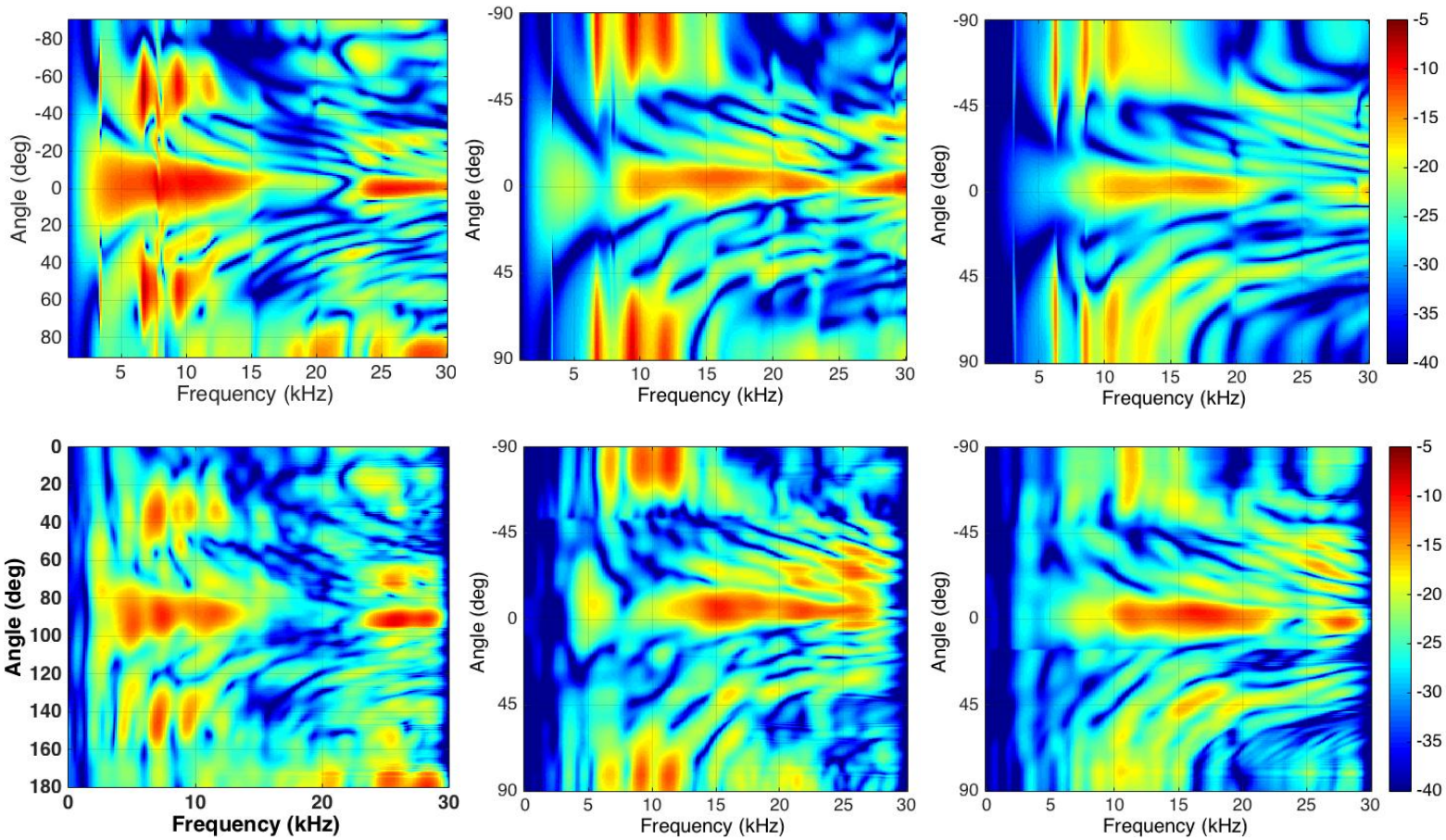
Proud
Range=10 m

Proud
Range=5 m

Buried
Range=5 m

MODEL

DATA

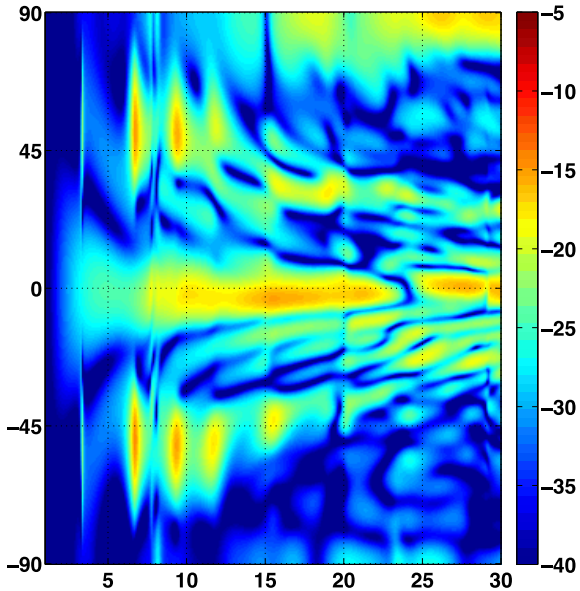


Significance of Model Results

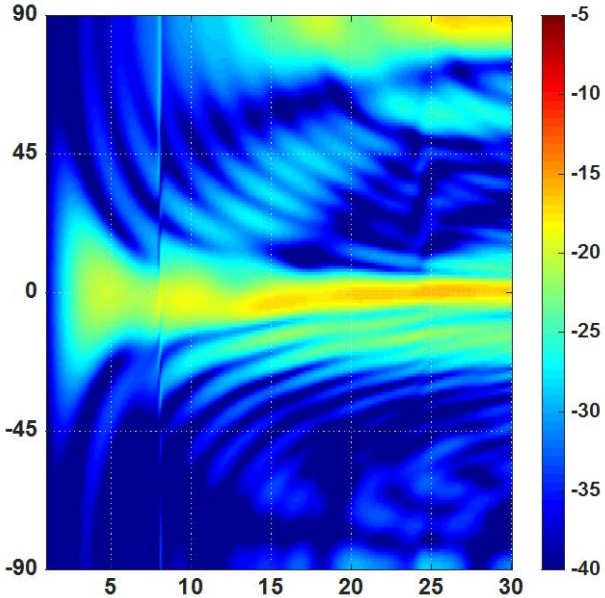
Dissecting the physics – Shape versus Elastic Response

Compute the FE model for a rigid equivalent of the UXO (increase the material sound speed and density)

Full Response



Shape (Rigid) Response



Significance of Model Results

Rigid response is very similar for similar sized objects

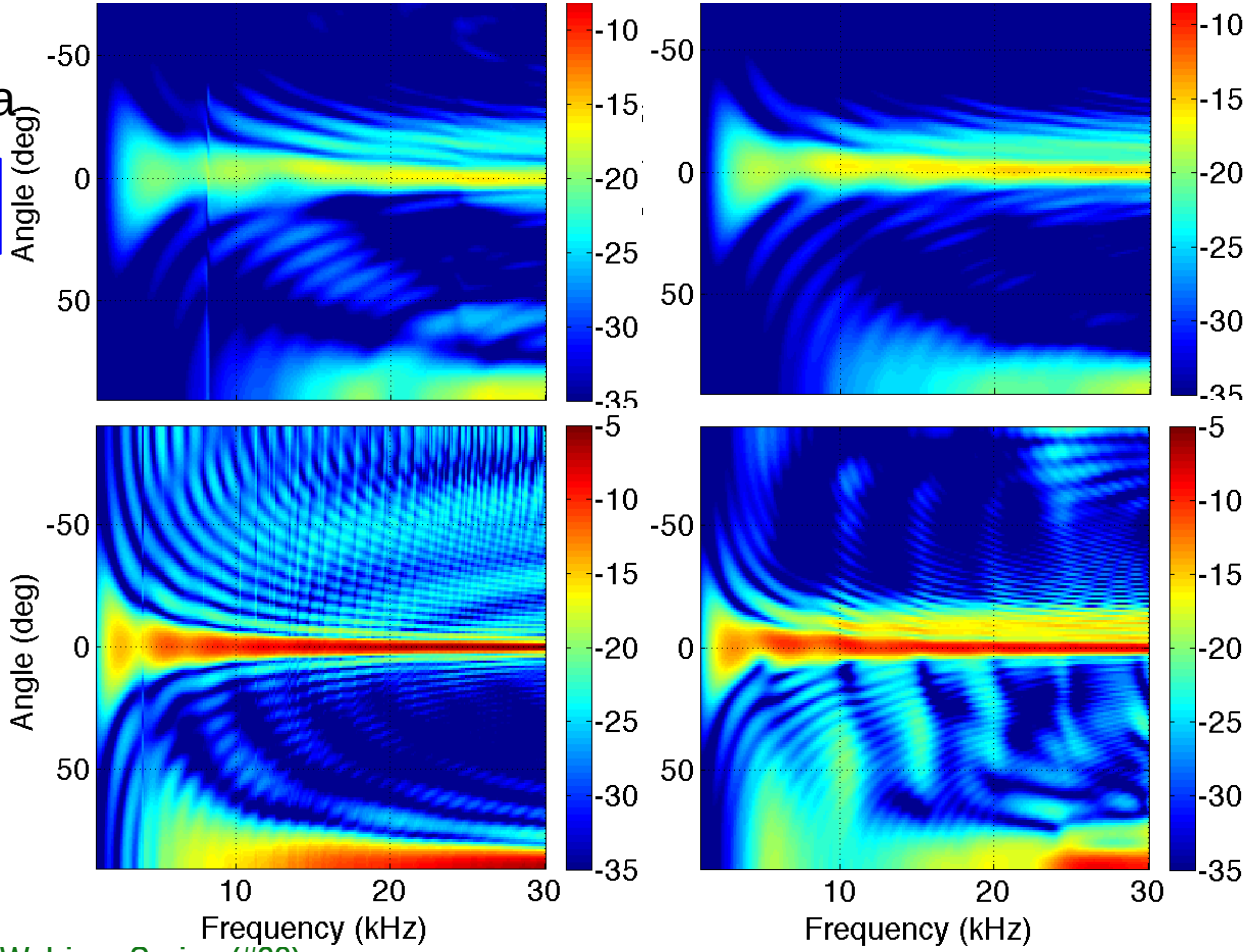
Difficult to distinguish objects of similar size and shape

UXO Replica

105 Bullet

Scuba Tank

Howitzer with Endcap



Conclusions for Part 1

- SAS processing can resolve targets in noisy environments
- Low frequency advantageous for buried target detection
- Low frequency acoustic color highlights material and internal structure
- Models allow separation of shape and elastic response
- Models offer insight into better data products for improved classification and performance

Q&A Session 1

SERDP DOD • EPA • DOE | ESTCP

“Part 2: Classification and Performance”

Aubrey España, Ph.D.
Applied Physics Laboratory
University of Washington

Agenda for Part 2

Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

Target-In-The-Environment

- Raw data – processing tools – data products
- Results from field experiments
- Models and their significance

Target Classification

- Training a classifier
- Testing a classifier
- Simple example

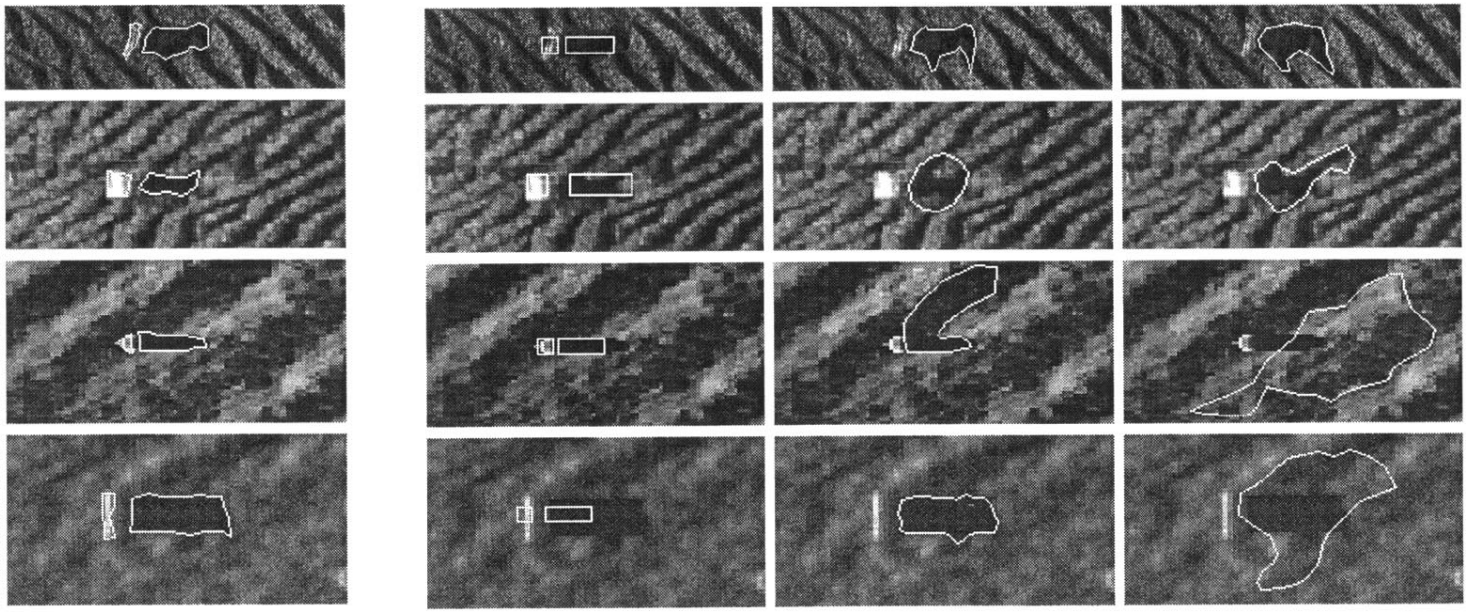
Performance

- Classification study on real data
- Performance Estimation
  How good did we do?
- Performance Optimization
  Can we do better?

Feature Extraction

- Derived from measurable, descriptive target characteristics
- Provides a clear separation between target and clutter
- High frequency SAS Images: Geometric characteristics – mean highlight, mean shadow

Difficulty → They must be extracted automatically

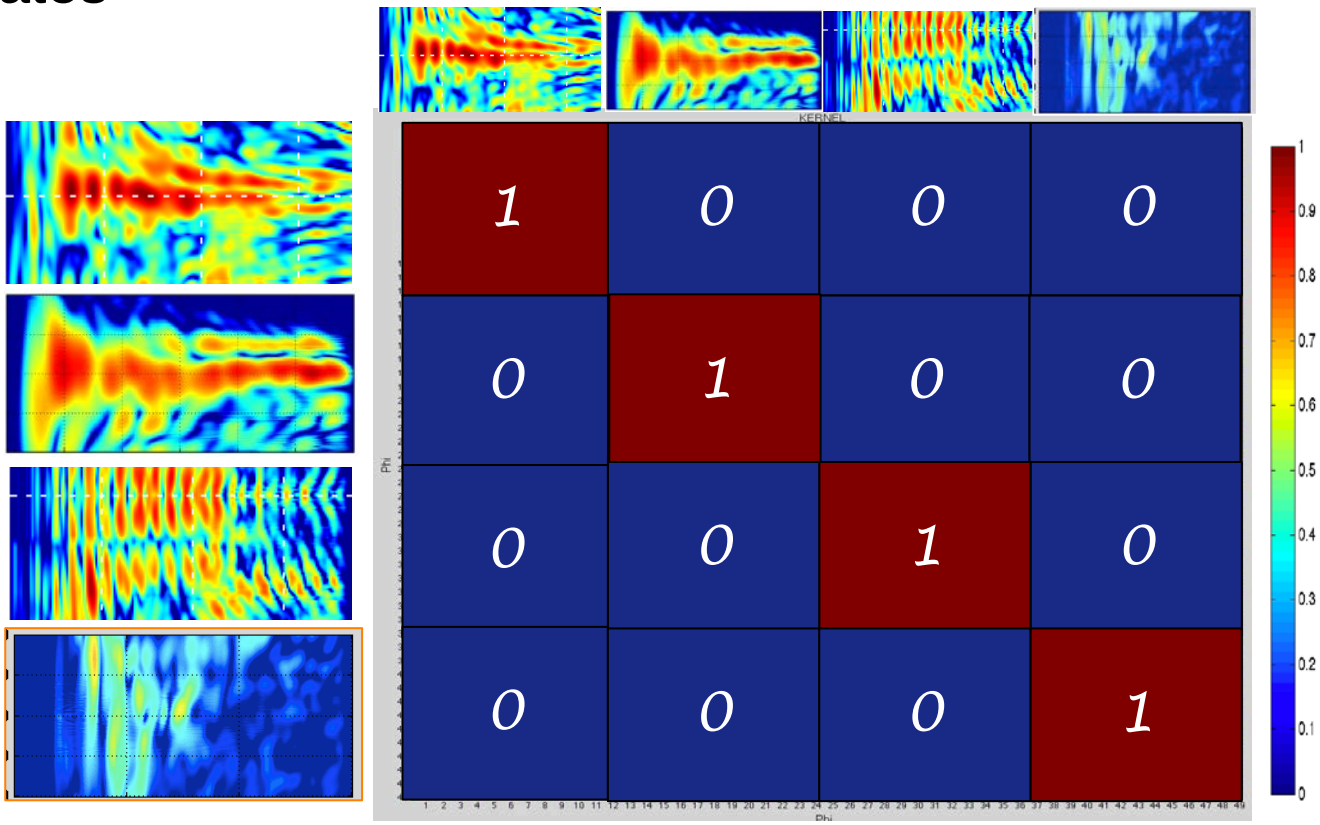


Reed, S.; Petillot, Y. & Bell, J., An automatic approach to the detection and extraction of mine features in sidescan sonar, IEEE J. Oceanic Eng., 2003, 28, 90-105

Feature Extraction

Design Matrix – Ideal Case

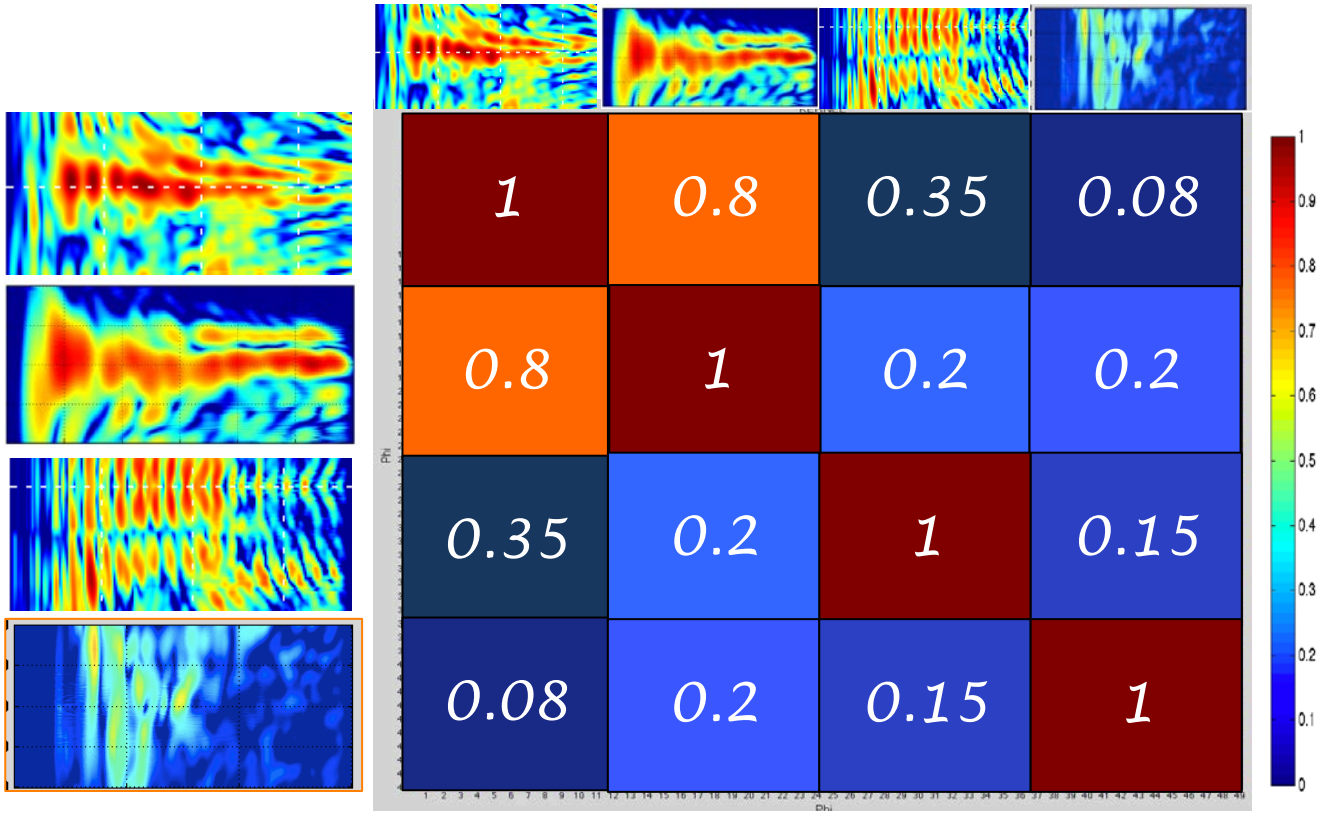
- Low frequency: Template matching – pattern recognition
- Measure of the similarity between the acoustic color templates



Feature Extraction

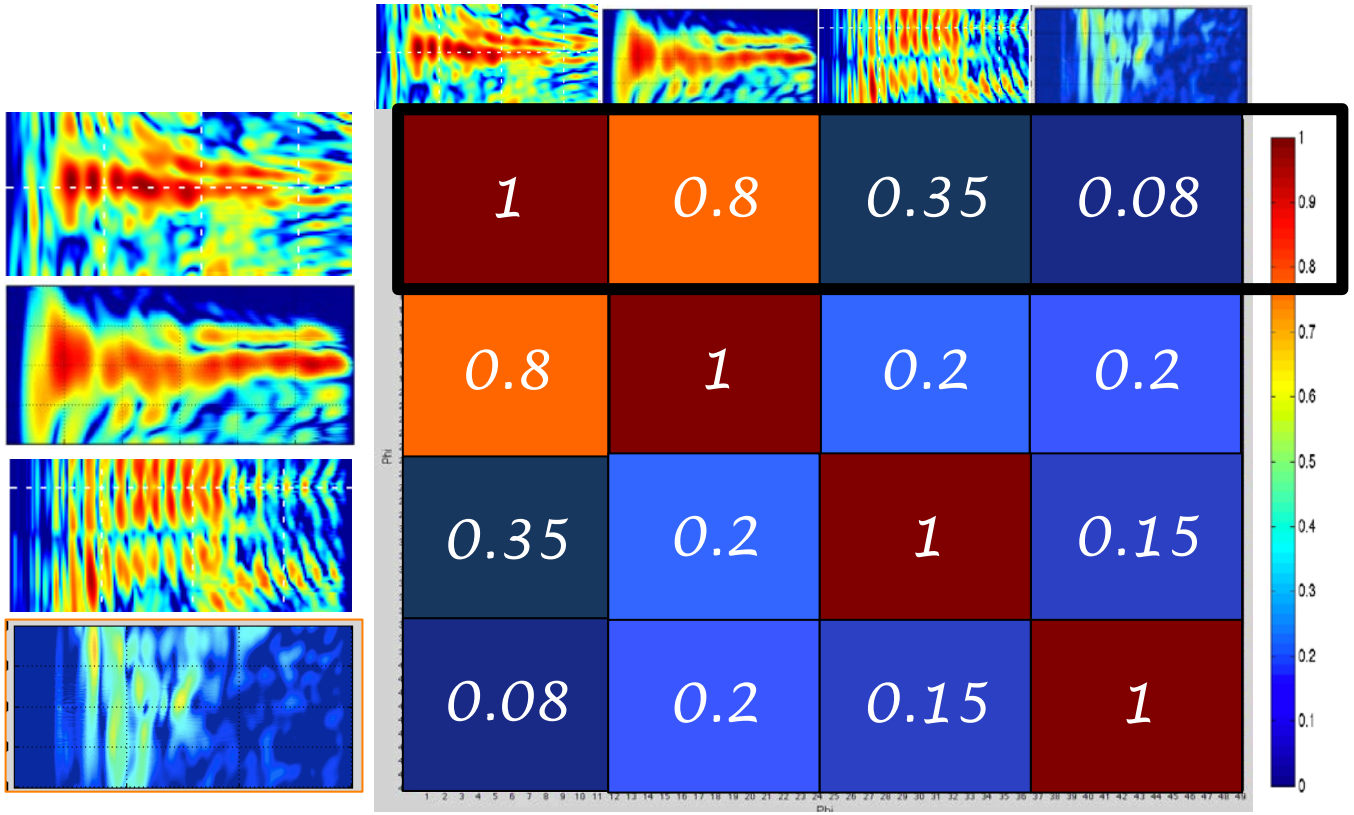
Design Matrix – Reality

- Use non-linear kernel to increase the separation between targets and non-targets



Training the Classifier

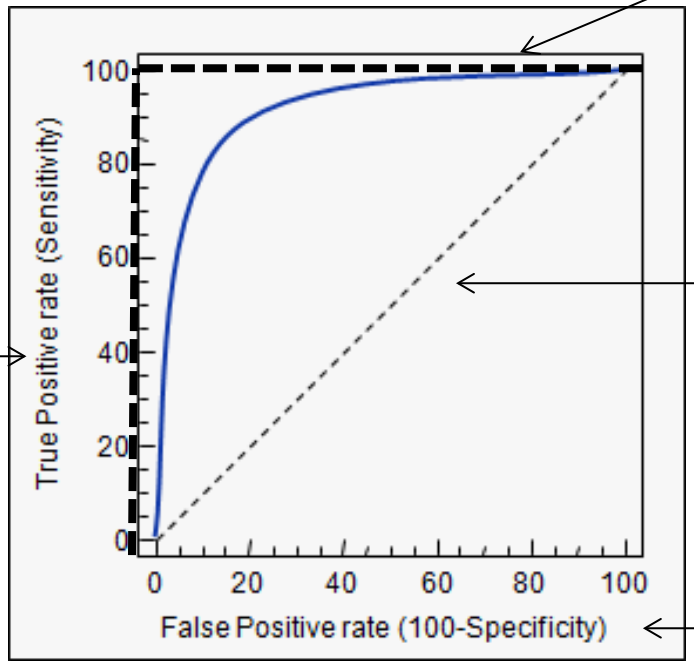
- Example – Relevance Vector Machine (RVM)
- Picks out the most “relevant” feature vectors, i.e., those that are most “discriminatory” between targets and non-targets



Testing the Classifier
Performance Estimation

- Receiver-Operator Characteristic (ROC) curve
- Measure of how often you correctly classify a target versus how often you're wrong
- Useful for cost/risk analysis

Best you can possibly do



50-50
No better than a coin toss

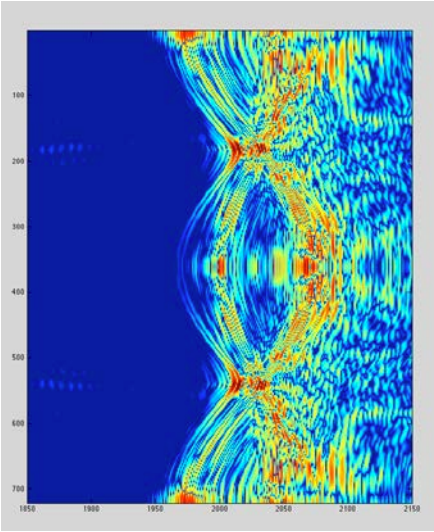
<u>True positive</u>
Target is a target

<u>False positive</u>
Identified a non-target as target

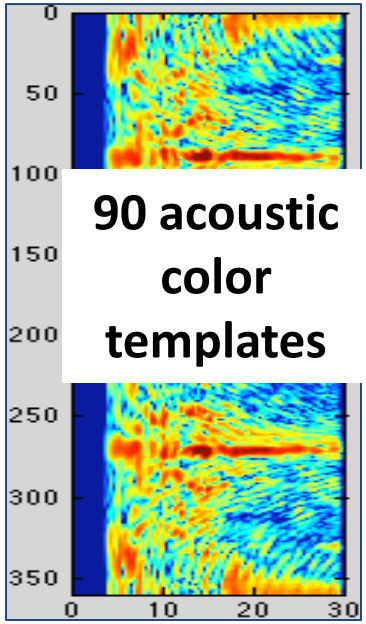
Classification Study Using TREX13 Data

Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

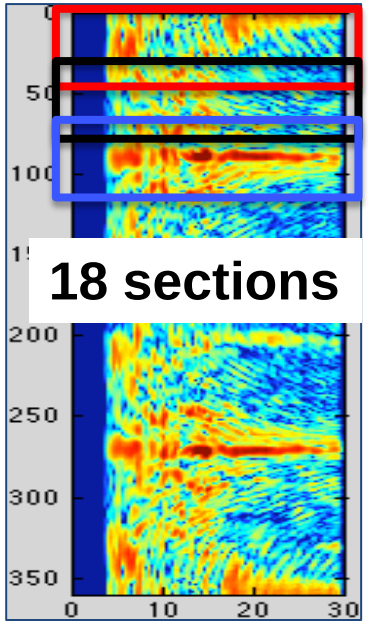
Raw Time Signals



Full Acoustic Color



Sections of Acoustic Color

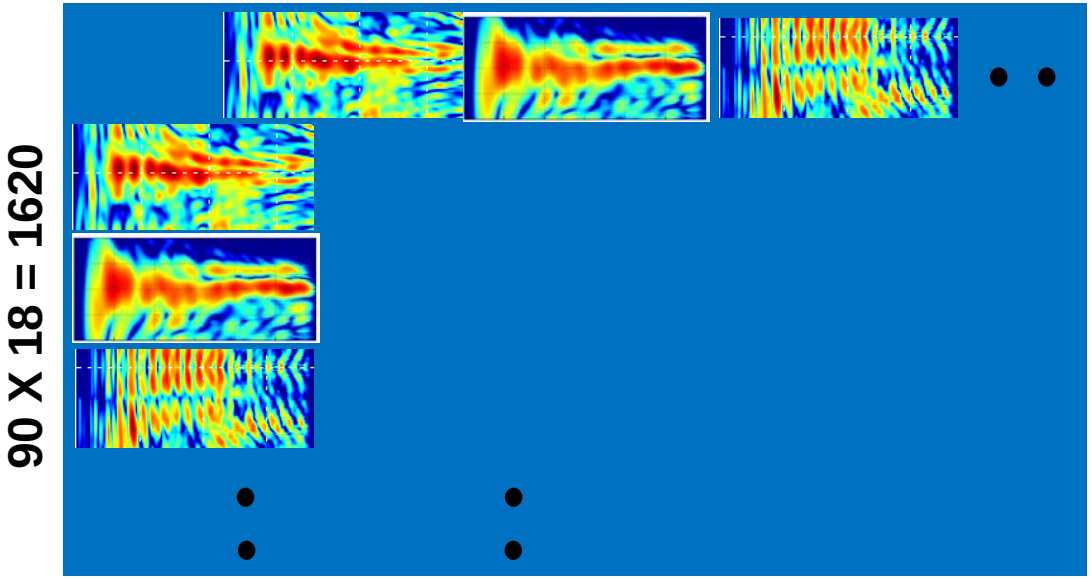


Training the Classifier

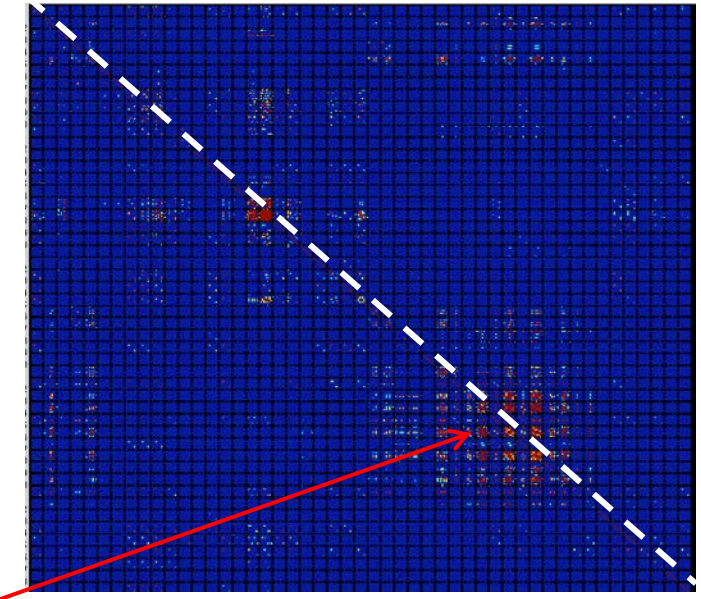
RVM chooses 162 relevant vectors

Training Set

90 X 18 = 1620



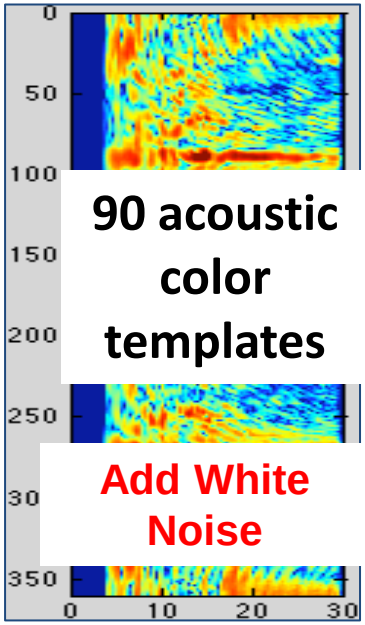
Design Matrix



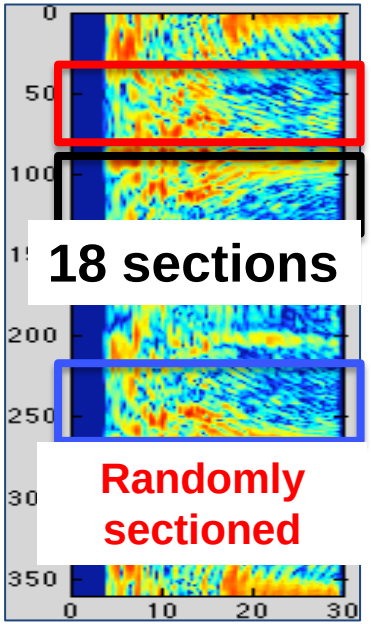
Non-zero, off-diagonal components cause problems

Testing the Classifier

Full Acoustic Color

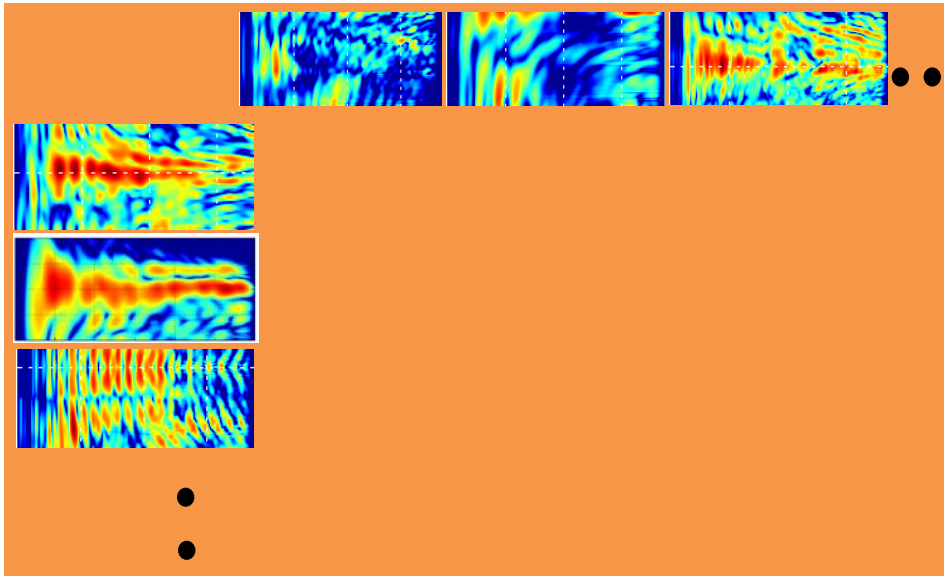


Sections of Acoustic Color



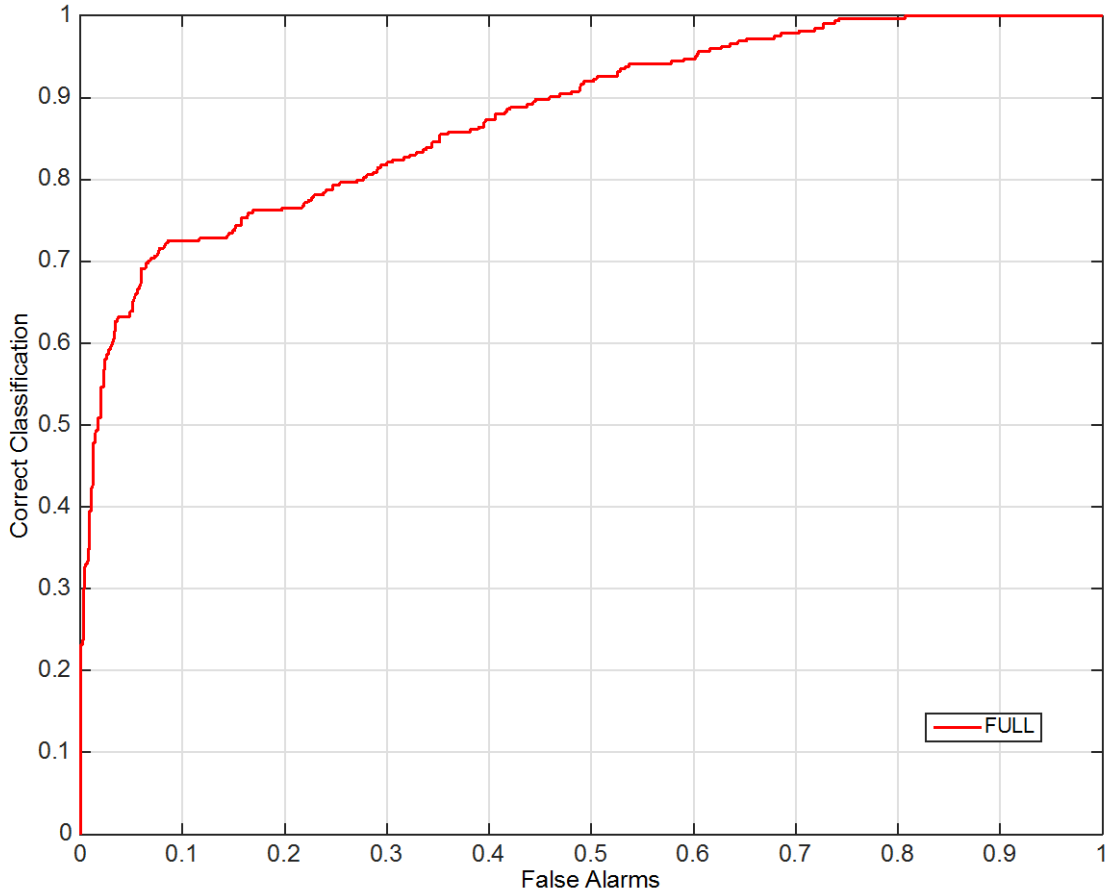
Testing Data Products (1620)

Training Data Products



Performance Estimation

Not stellar – Why? Can we do better?

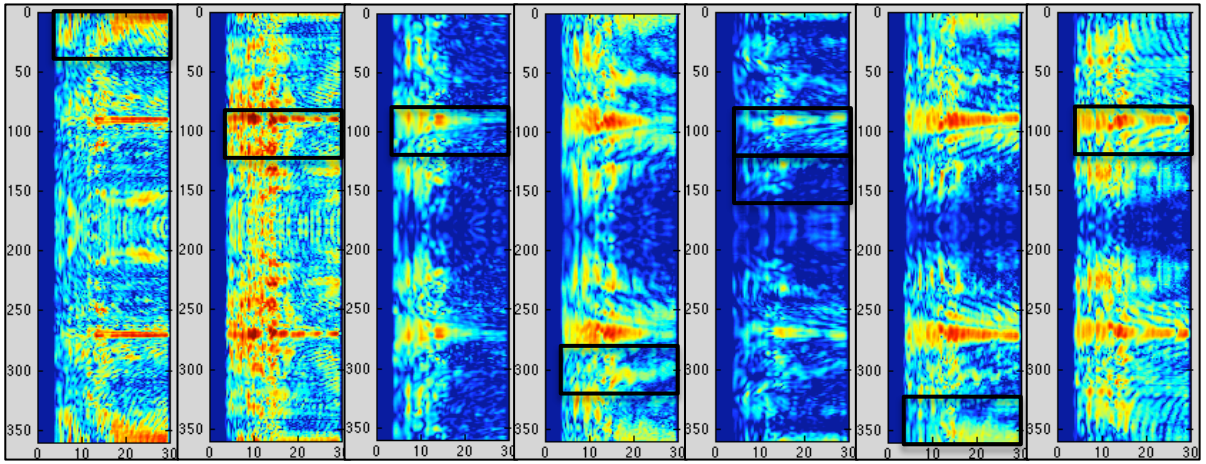


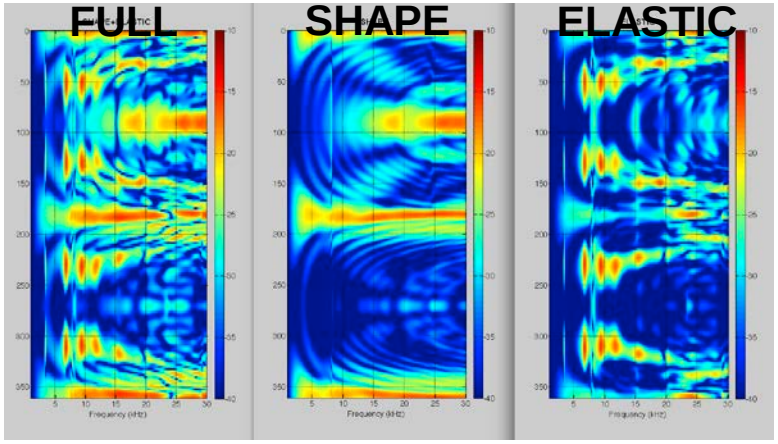
Performance Estimation

Significance

Difficulty distinguishing objects of similar size and shape

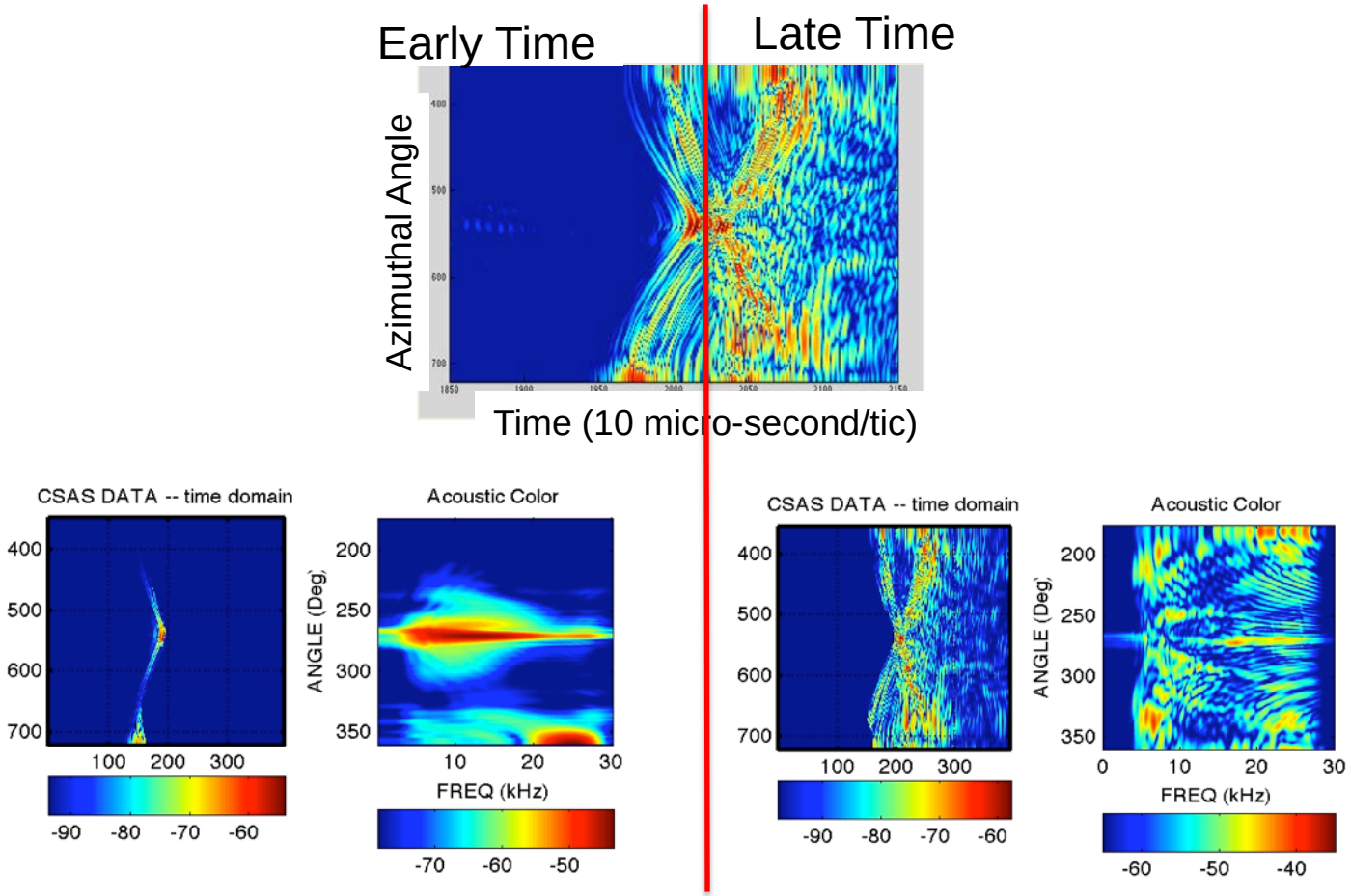
- Majority of relevant vectors are derived from broadside and end-on responses
- Recall that shape response dominates broadside and end-on responses





Performance Optimization

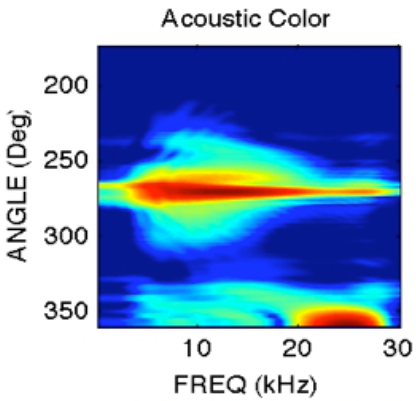
Early-time/late-time approximates shape/elastic separation

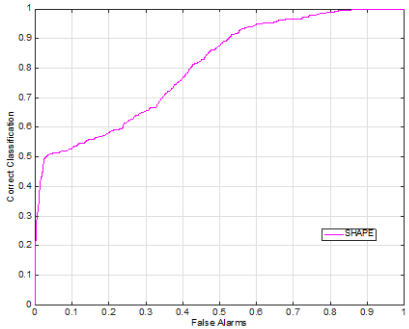


Performance Optimization

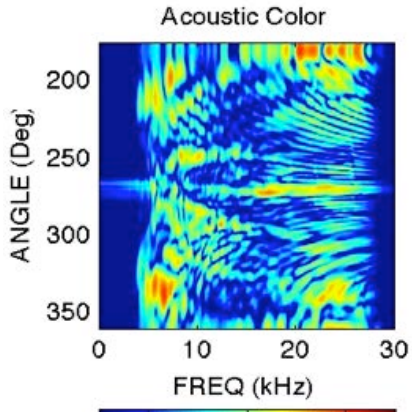
Raw data → Data products → Feature extraction → Non-linear Kernel → Classifier → Performance

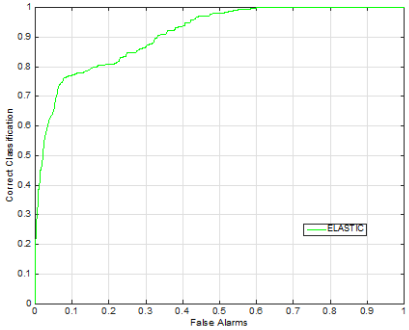
Repeat process on “Shape Only” Data Products (Early Time)





Repeat process on “Elastic Only” Data Products (Late Time)

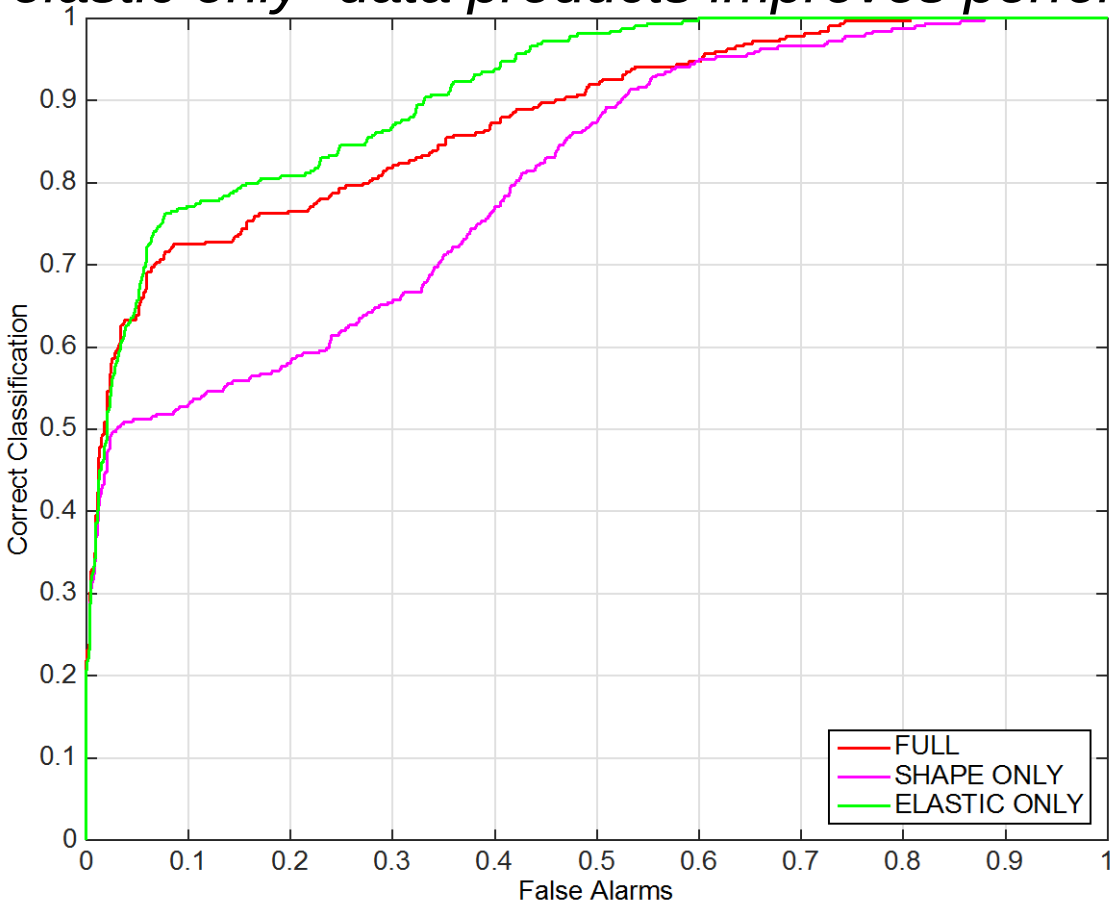




Performance Optimization

Significance

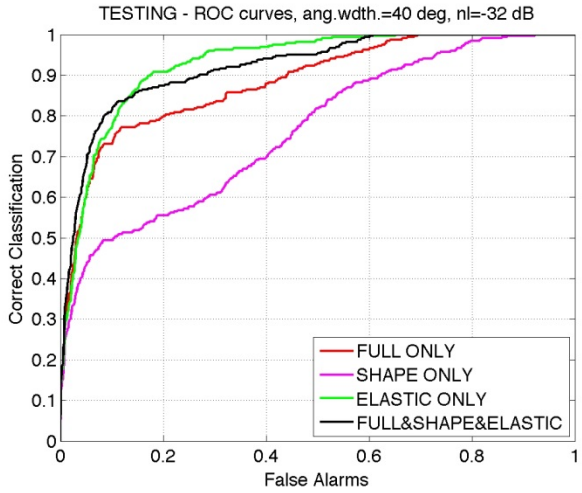
Using "elastic only" data products improves performance

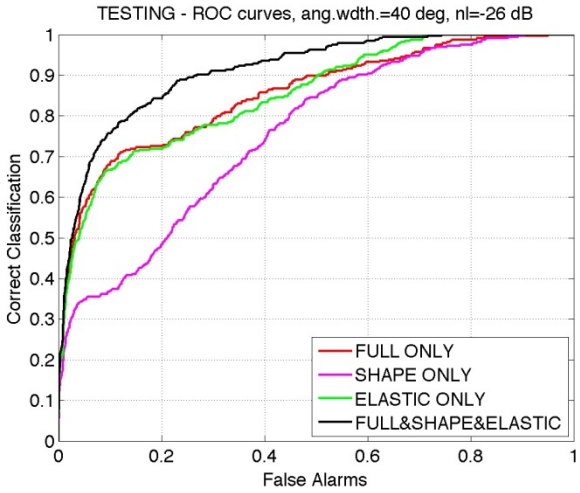


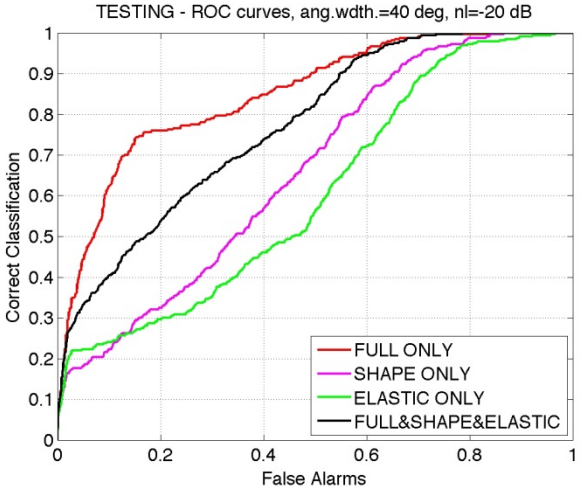
Performance Optimization

Recent Results

- Combine full/shape/elastic RVM results via average (black curve)
- ELASTIC ONLY best at low noise levels
- FULL ONLY best at high noise levels
- Full & Shape & Elastic (FSE) best at low to intermediate noise levels







Conclusions for Part 2

- Performance estimation study on TREX13 data reveals difficulty distinguishing similarly sized objects
- Early-late time separation in data approximates shape-elastic separation in models
- Current results indicate elastic information best for classification at low noise levels
- Full & Shape & Elastic (FSE) best at low to intermediate noise levels
- Full only best at high noise level

Combination of field experiments and models is resulting in improvements to current DoD detection and classification capabilities

5-Year Integrated Plan

Operations/Classification Package | **Tow Body Package**

MR-2231 FY12-15
- TREX13 (sand)
- BAYEX14 (mud)
- Validated models

MR-2505 – Year 1
- Develop/train classification algorithms

MR- 2501 – Year 1
- One-year tow body design study

MR-2505 – Year 2
- Rail experiment in an acoustically hard environment

Follow-on to MR-2501 Year 1
- Tow body construction & dock-side testing

MR-2505 – Year 3
- Test trained classifiers on tow body data

Follow-on to MR-2501 Year 2
- Engineering test (Puget Sound)

Follow-on to MR-2501 Year 3
- Full field test of tow body system with operational classifiers and protocol/logistics

For additional information, please visit
https://www.serdp-estcp.org/Program-Areas/Munitions-Response/Underwater-Environments/MR-2505

Speaker Contact Information

aespana@apl.washington.edu; 206-685-2311
marston@apl.washington.edu; 206-221-5267

SERDP DOD • EPA • DOE | ESTCP

Q&A Session 2

SERDP DOD • EPA • DOE | ESTCP

The next webinar is on March 24, 2016

"Cadmium and Chromate Elimination Efforts: Implementation Plans and Strategic Roadmaps for Three DoD Depots"

Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

SERDP DOD • EPA • DOE | ESTCP