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Results from an Informal Demonstration of a Buried-UXO Detection, Classification, Geo-Location System

(Presentation)

Kevin Williams
Timothy Marston
Dana Woodruff
Shelley M. Cazares

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INSTITUTE FOR DEFENSE ANALYSES
4850 Mark Center Drive
Alexandria, Virginia 22311-1882

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About This Publication

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For More Information

Shelley M. Cazares, Project Leader
scazares@ida.org, 703-845-6792

Leonard J. Buckley, Director, Science and Technology Division
lbuckley@ida.org, 703-578-2800

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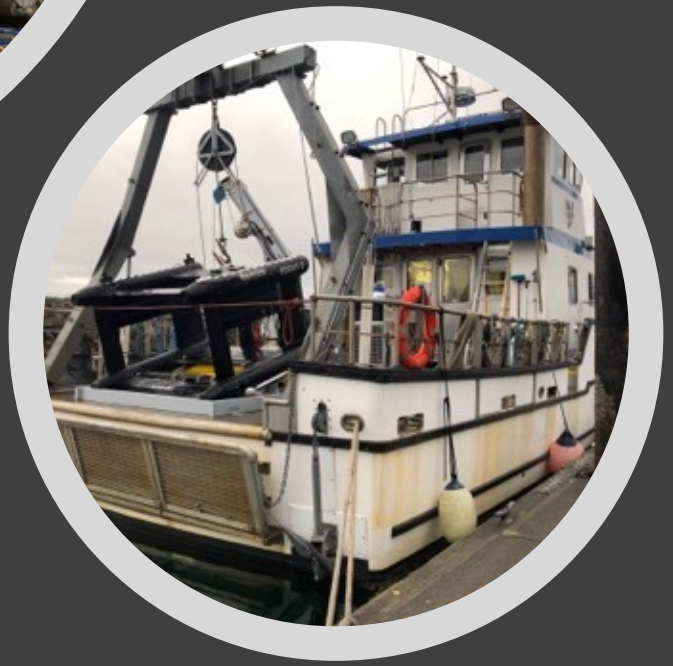
Executive Summary

The Applied Physics Laboratory of the University of Washington (APL-UW) has built a Multi-Sensor Towbody (MuST) based on a MacArtney FOCUS3 towbody. The first sensors to be integrated on to the towbody are two EdgeTech sonars: a high resolution sidescan sonar and a novel sub-bottom synthetic aperture sonar that generates high-resolution 3D imagery and has been designed to detect and classify buried objects. An informal demonstration of MuST was carried out in Sequim Bay, WA in September of 2020. An UXO testbed was put in place by the Pacific Northwest National Laboratory (PNNL) Marine and Coastal Research Laboratory (MCRL). The testbed, located in the north end of the bay, contained an assortment of inert UXO of various sizes and shapes. The distributed UXO ranged in size from 81 millimeter mortar shells to 155 millimeter Howitzer shells. The UXO were positioned by divers in various orientations and burial states ranging from proud to fully buried. Non-UXO items consisting of crab pots, SCUBA tanks, cement blocks, etc. were distributed in the survey region to act as additional clutter and potential false alarms over and above the natural and manmade clutter already present at the testbed site. MuST operations were carried out over a training region where known targets were at known locations and in a blind survey area where further examples of the same targets (UXO and clutter) were deployed in locations unknown to the MuST team. Classification results were generated via a combination of expert user and convolutional neural network strategies. In carrying out the classification effort both acoustic frequency/angle data and acoustic image data for each target at a variety of approach angles and ranges were used. Detection, geolocation, and classification results obtained were subsequently compared to ground-truth by the Institute for Defense Analyses (IDA). Seven of the nine UXO were correctly detected and classified with two false alarms and a geolocation accuracy of about 2.5 meters. [Work supported by SERDP and ESTCP].



Results from an informal demonstration of a buried-UXO detection, classification, geo-location system

- Kevin Williams, Tim Marston
  Applied Physics Laboratory,
  University of Washington

- Dana Woodruff
  Pacific Northwest National Laboratory,
  Marine and Coastal Research
  Laboratory

- Shelley Cazares
  Institute for Defense Analyses

Outline

We summarize the effort in four parts:

- The Sensing System – the Multi-Sensor Towbody (MuST)
- The Targets – the munitions and clutter items used
- The Demonstration – where, when, and how
- Data products used in classification study
- Results for detection, classification and geolocation

Multi-Sensor Towbody (MuST) Major Mechanical Components

MuST is deployed from a 50-foot ship via A-frame or crane

In-Water MuST Systems:

- Towbody
- Acoustic Sensors
- Guest Sensor Ports

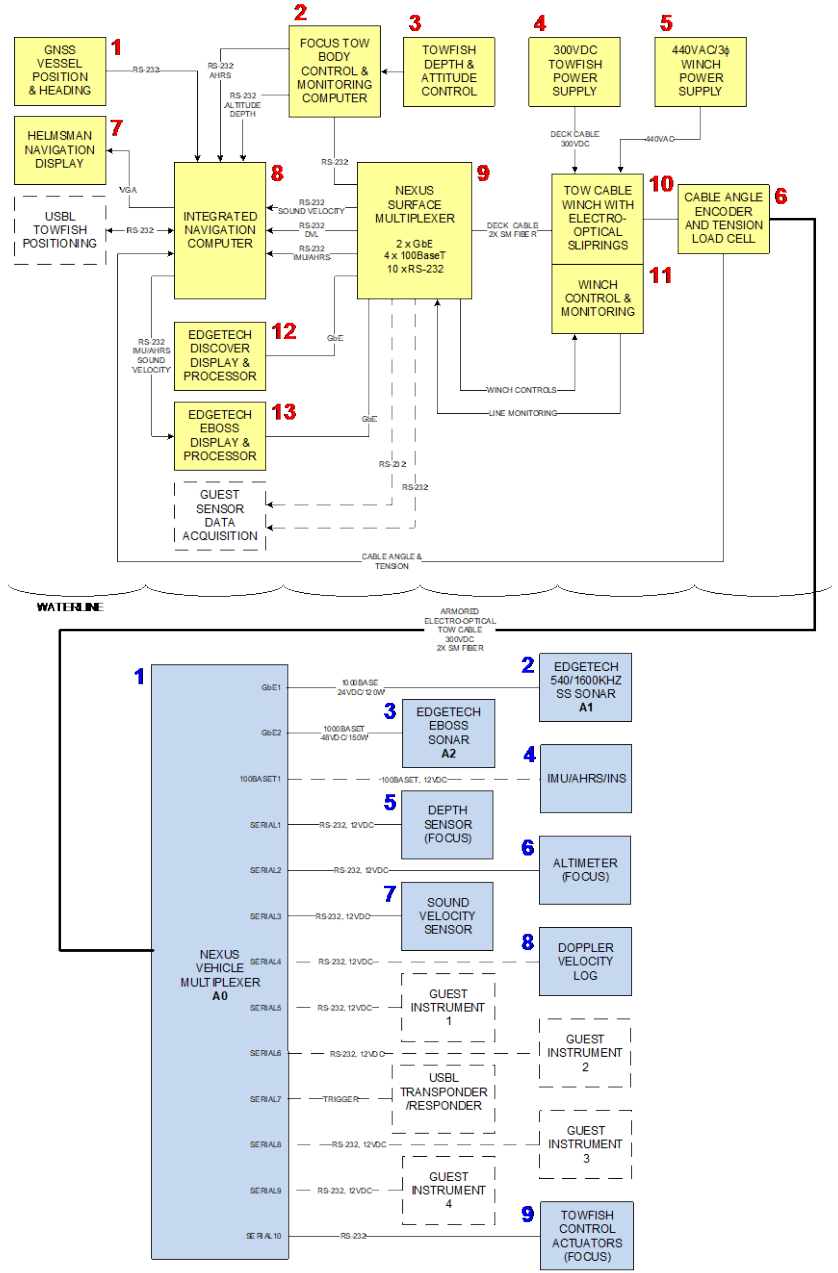
Shipboard MuST Systems:

- Ship Navigation
- Towbody Geo-location
- Towbody Handling
- Towbody Command and Control
- Data Processing

MuST Functional Block Diagram

Shipboard Equipment

In-Water Equipment



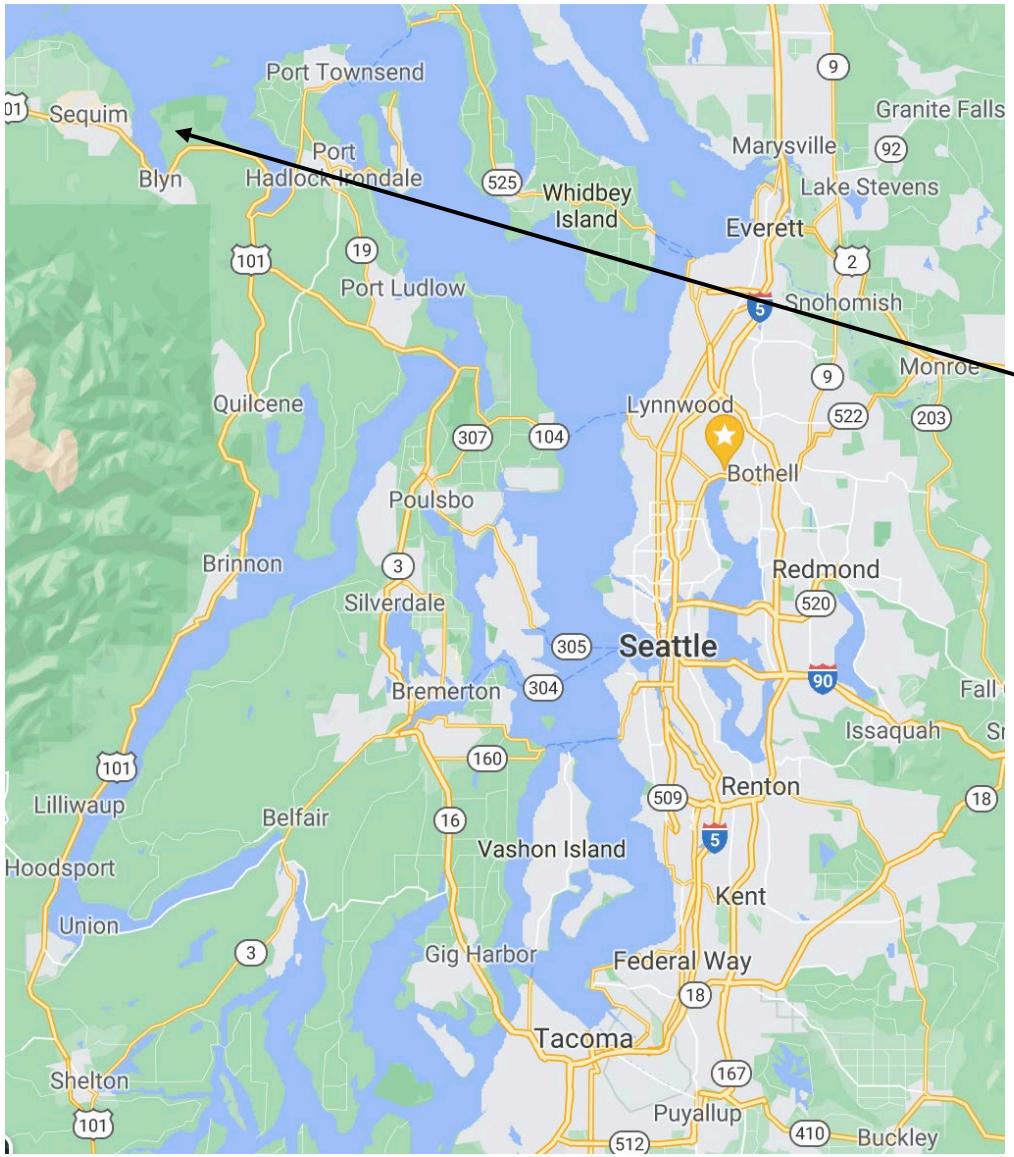
Target types placed in Sequim Bay, WA - 2020

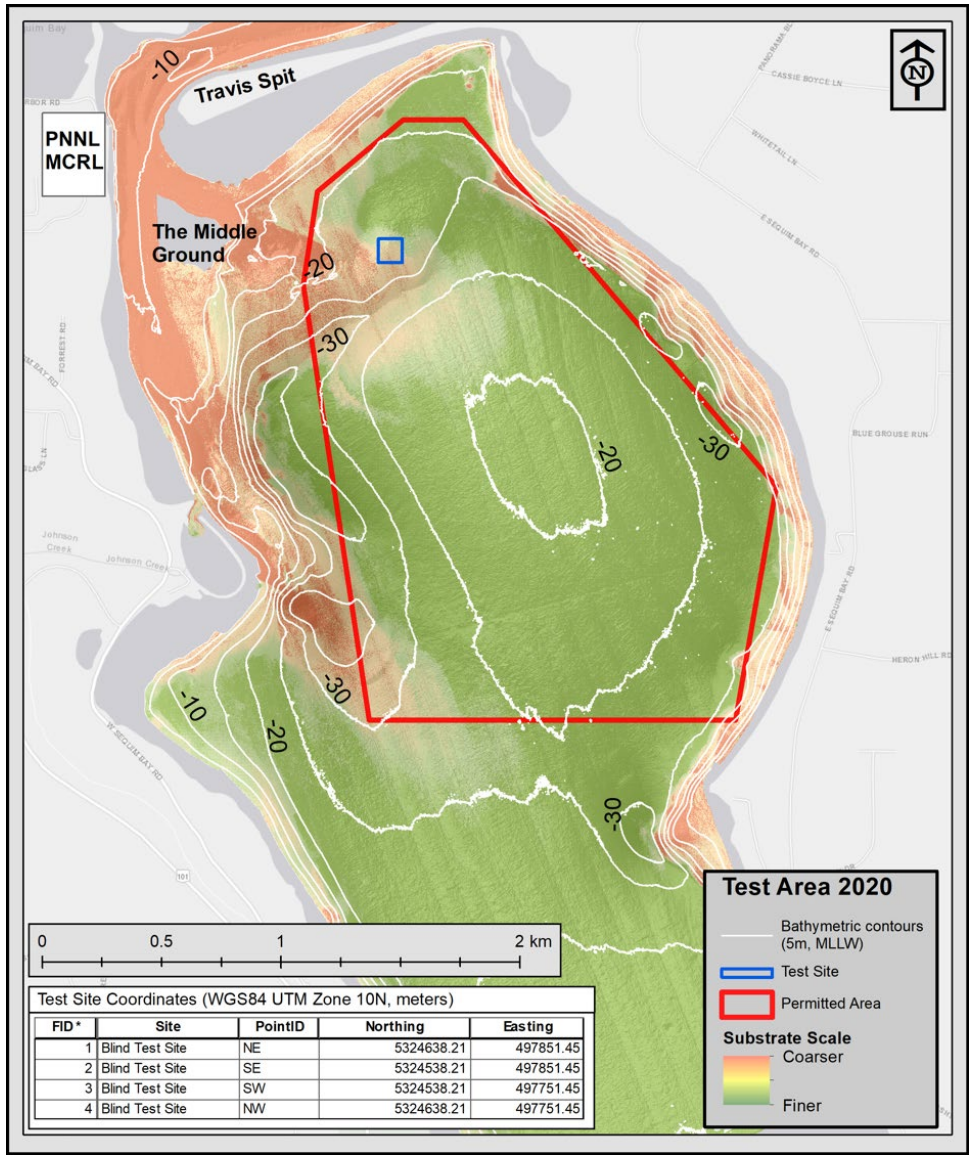
- **Science Targets: (left to right)**
  - Solid aluminum cylinder
  - Hollow aluminum cylinder

- **Inert UXO and Replicas: (left to right)**
  - 81 mm mortar (M889A1)
  - 105 mm projectile (M60)
  - 105 mm projectile (HEAT)
  - 155 mm Howitzer projectile (M107)
  - 155 mm Howitzer replica

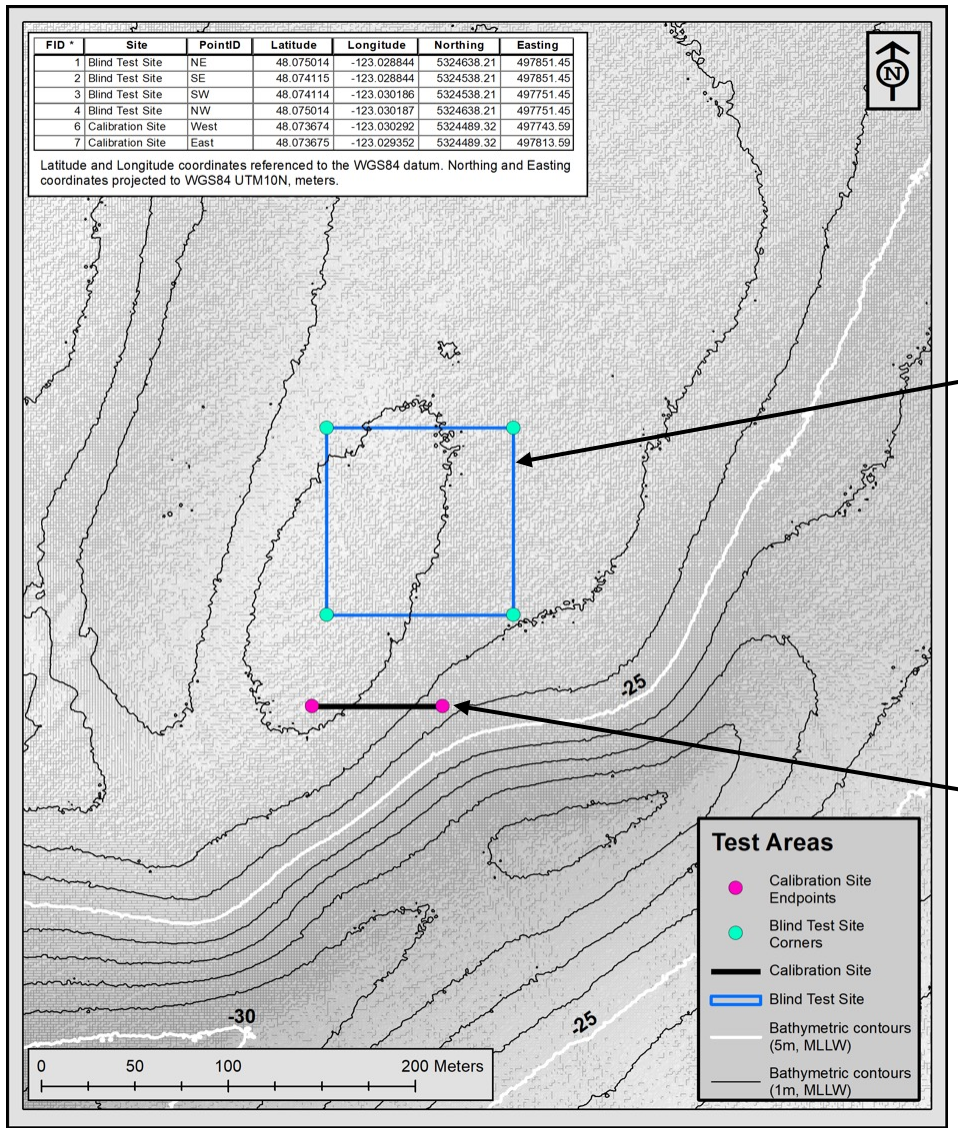
- **Clutter Objects: (left to right)**
  - Anchor
  - Cement block
  - Scuba tank
  - Crab trap

Location of Demonstration: Sequim Bay, WA





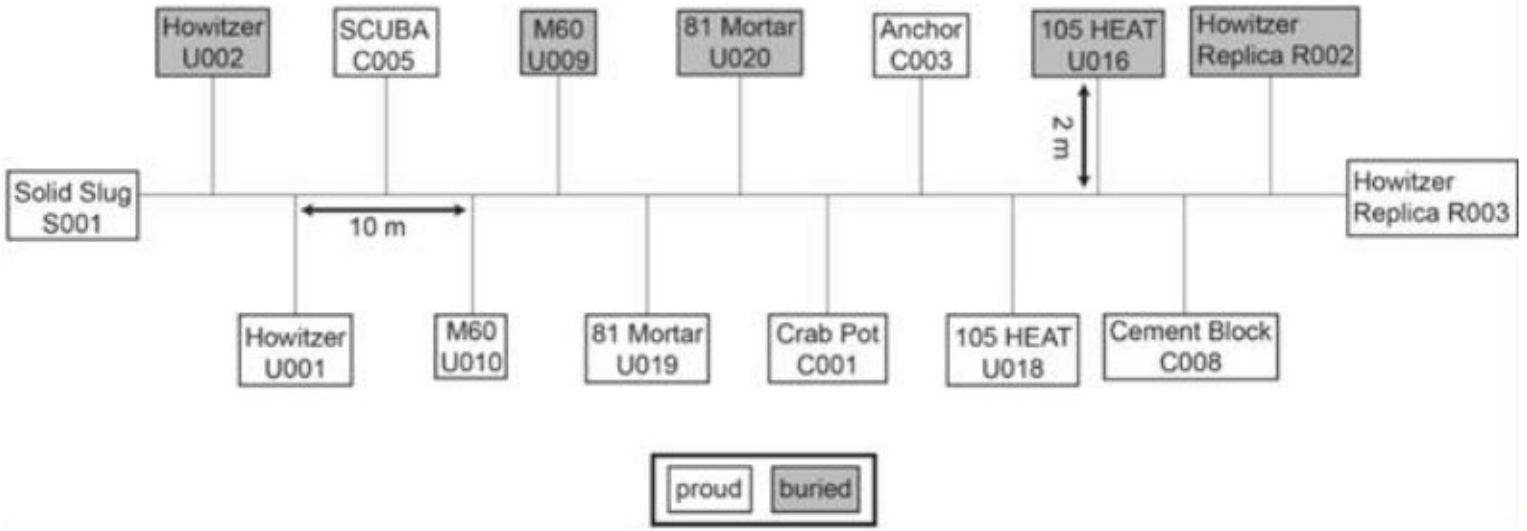
Test Area Geometry



Blind Test Area

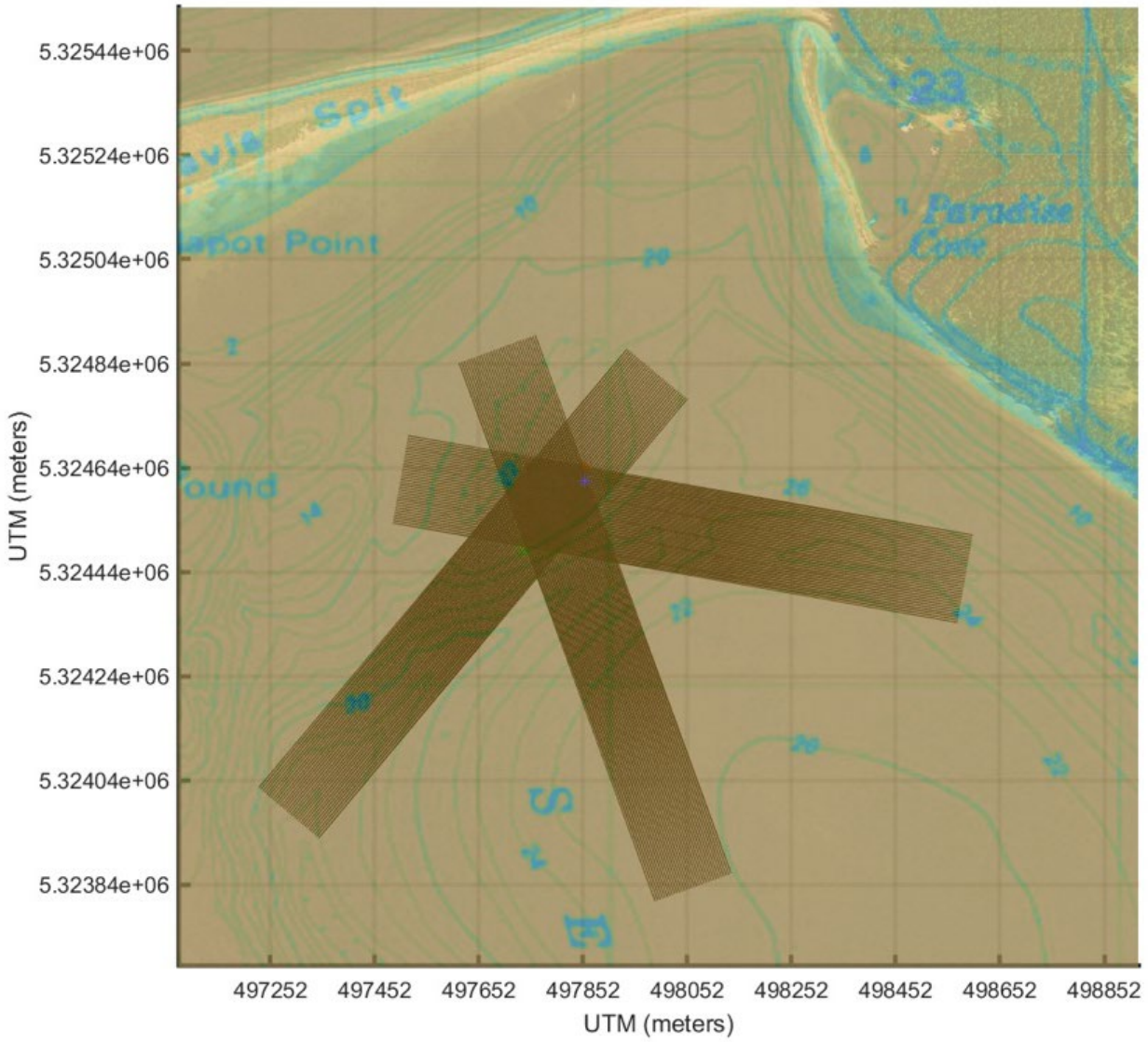
Calibration Line

Calibration Line Target Locations



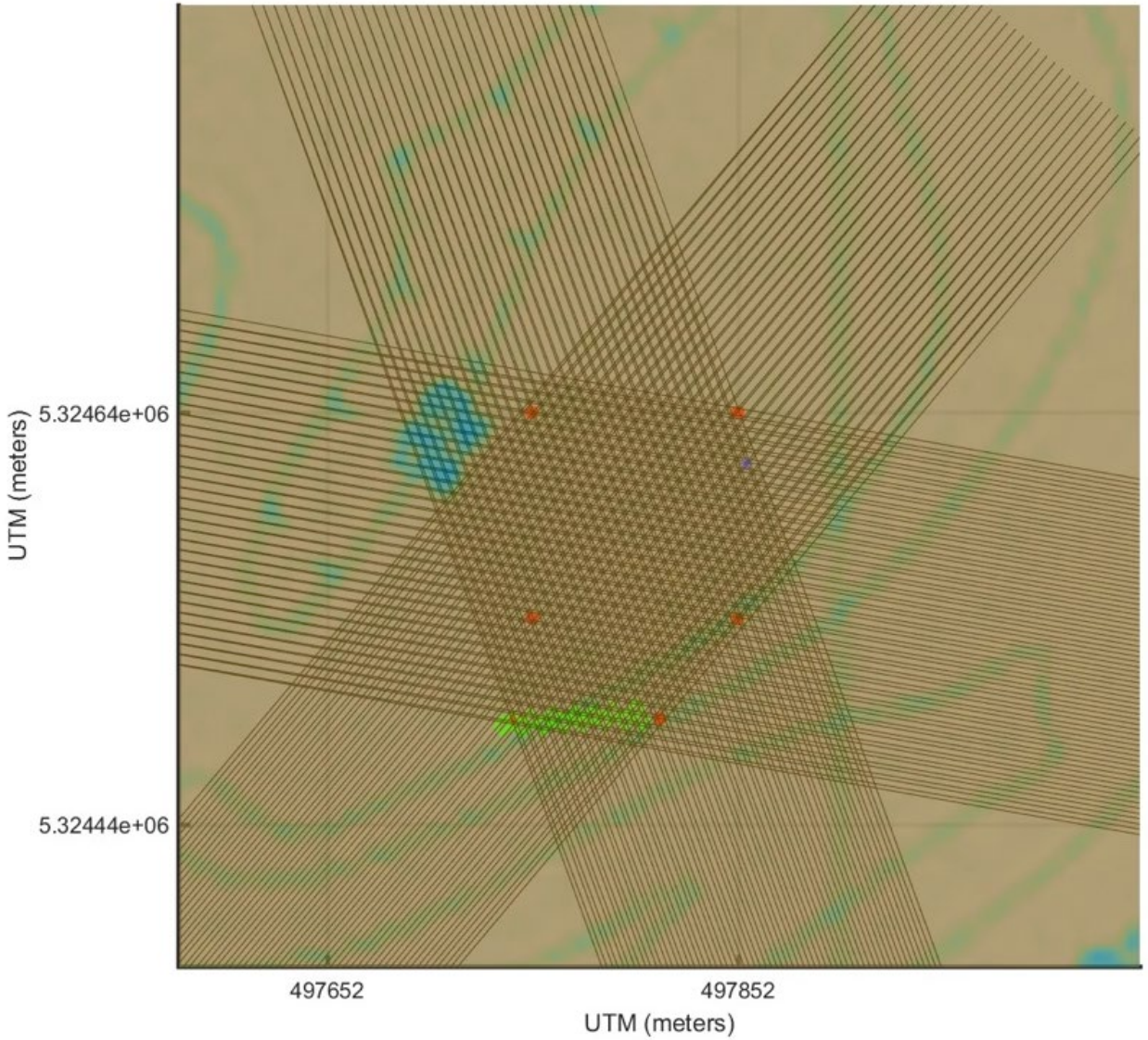
S001 – 330 deg. (slug)
R002 – 310 (Howitzer rep)
U016 – East (105 HEAT)
U001 – 070 (Howitzer)
U010 – 060 (M60)
U020 – East (81 mortar)
U019 – 060 (81 mortar)
U009 – 080 (M60)
U018 – 090 (105 HEAT)
U002 – 080 (Howitzer)
R003 – 000 (Howitzer rep)

Operations



- Main test over 4 days
- Survey lines shown – 3 approach angles into blind and calibration areas
- Lead into areas generally from the south
- Long lead-ins to get towbody GPS position and stable flying altitude
- GPS fix also at end of each run

Operations

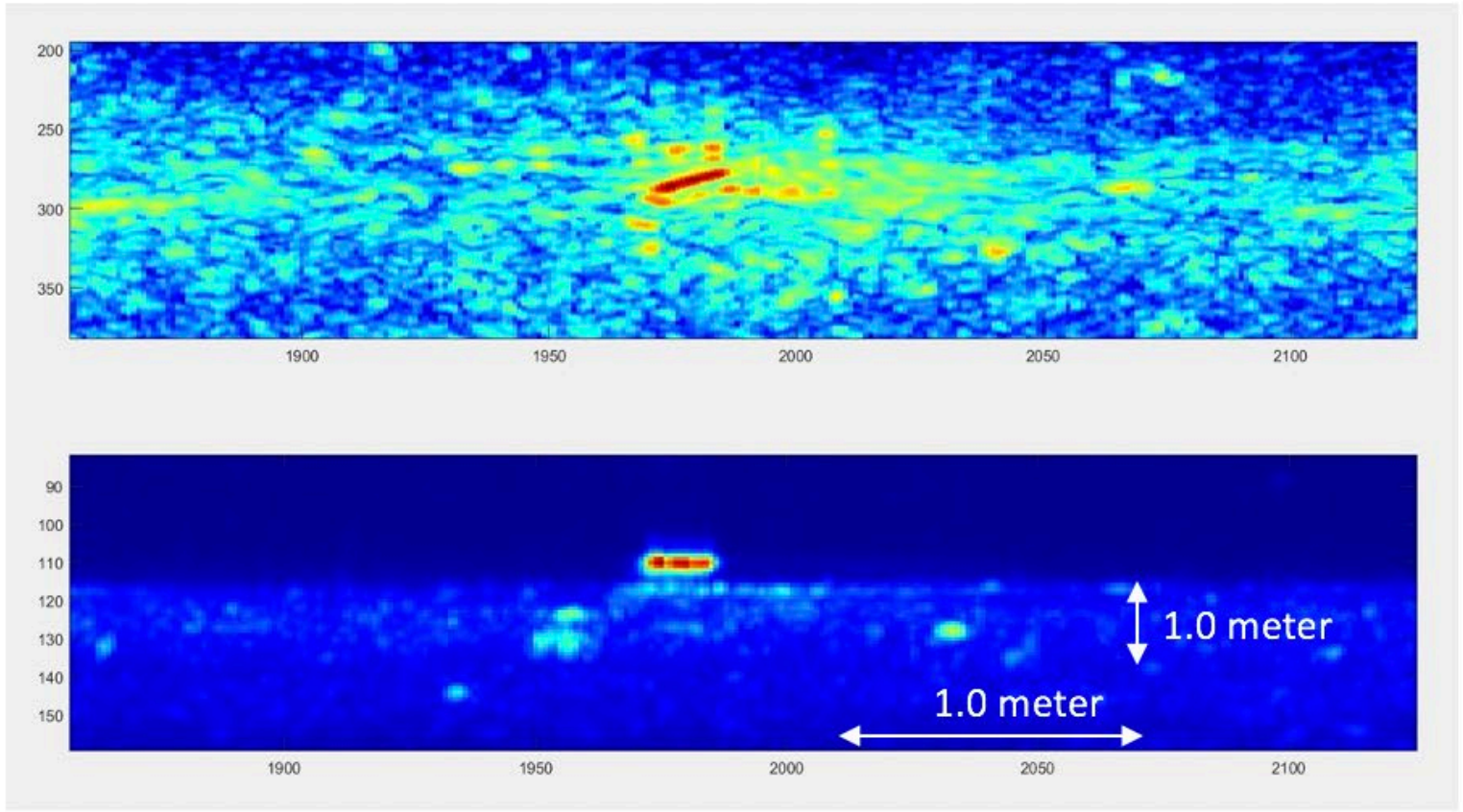


- Close up of areas showing survey lines
- Green diamonds show ground truth GPS locations of targets in calibration line, independently measured by PNNL testbed management team
- Red dots show end points of calibration lines and corners of blind test area

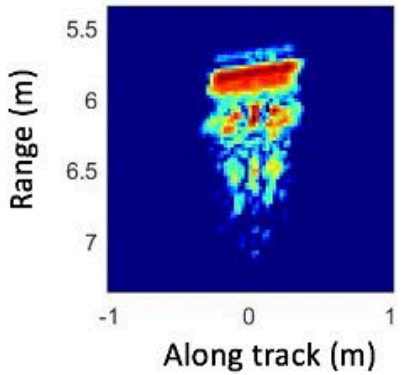
Initial Detection/Geolocation Effort

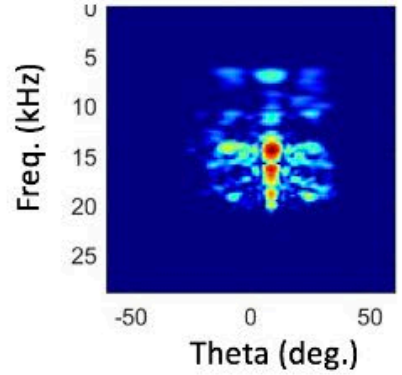
- Maximum Intensity Projections (MIPs)
- Proud target image and acoustic color indicate it is the hollow Aluminum cylinder

Real Time – Real cross track plus SAS along track Imaging



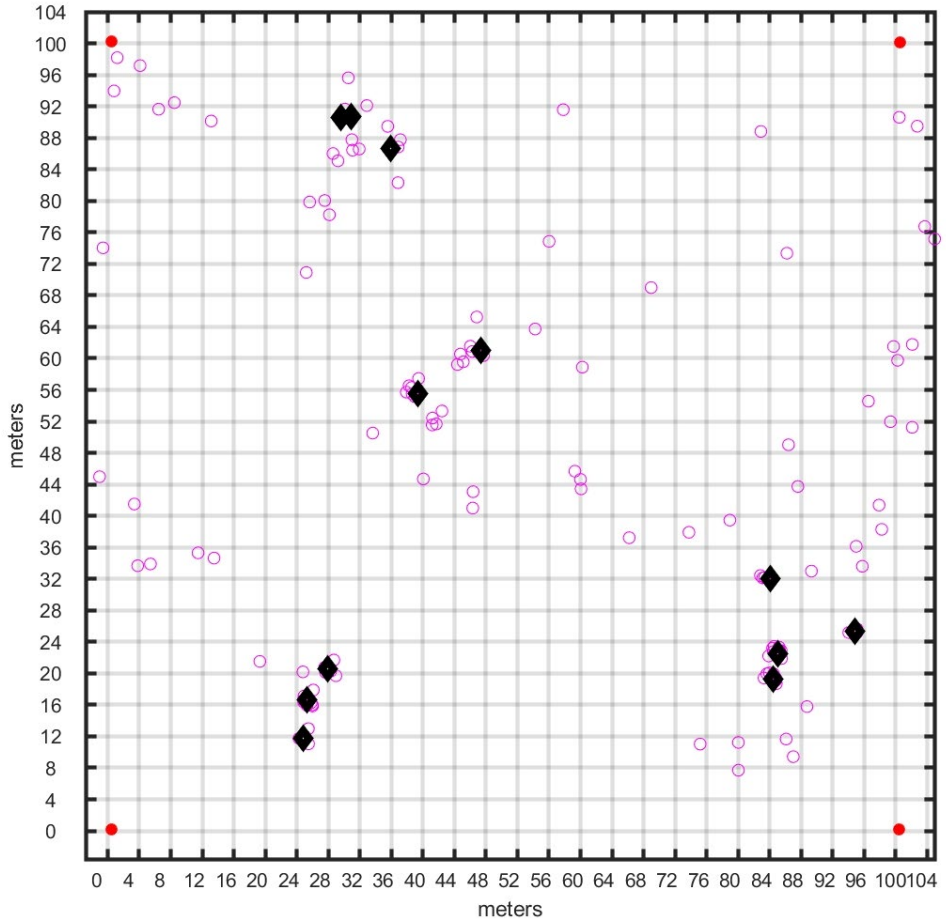
Post processed data products for hollow Al cylinder





Initial Detection/Geolocation Effort

- Red dots were corners of test area
- Magenta circles were initial calls as TOIs (Targets of Interest) from each pass
- Black diamonds were intermediate calls as TOIs after consolidating passes

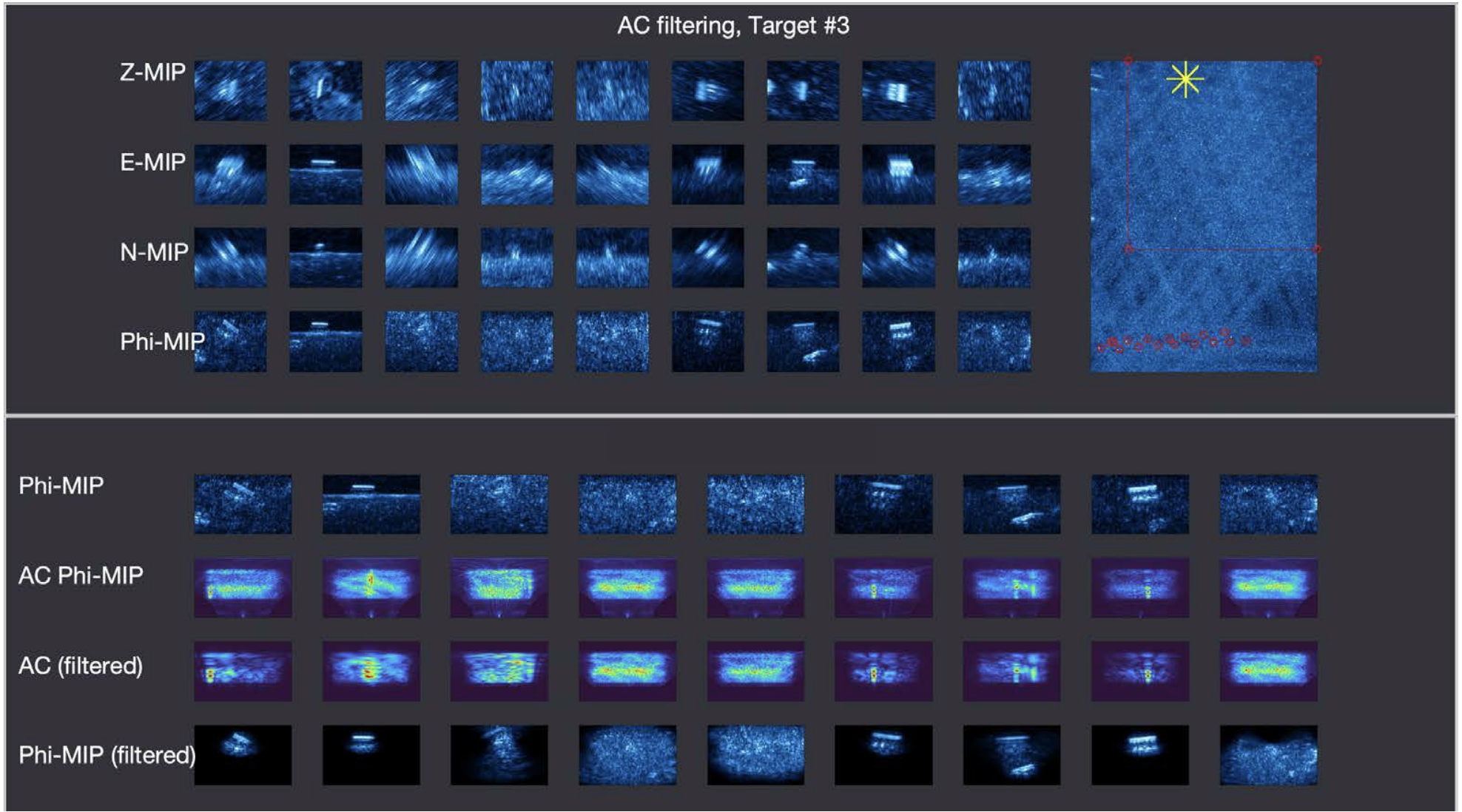


UTM estimates:

497775.79	5324549.78
497776.32	5324554.61
497778.87	5324558.53
497835.44	5324557.32
497836.07	5324560.54
497845.84	5324563.36
497835.12	5324569.99
497790.33	5324593.53
497798.40	5324598.96
497786.94	5324624.70
497781.95	5324628.72
497780.57	5324628.62

Post-Processing Code (by Tim Marston)

- Mosaic of all data, all directions – click on potential target, shows all survey files with data at that location found and the location imaged



9 survey files found that have data at location indicated by yellow asterisk

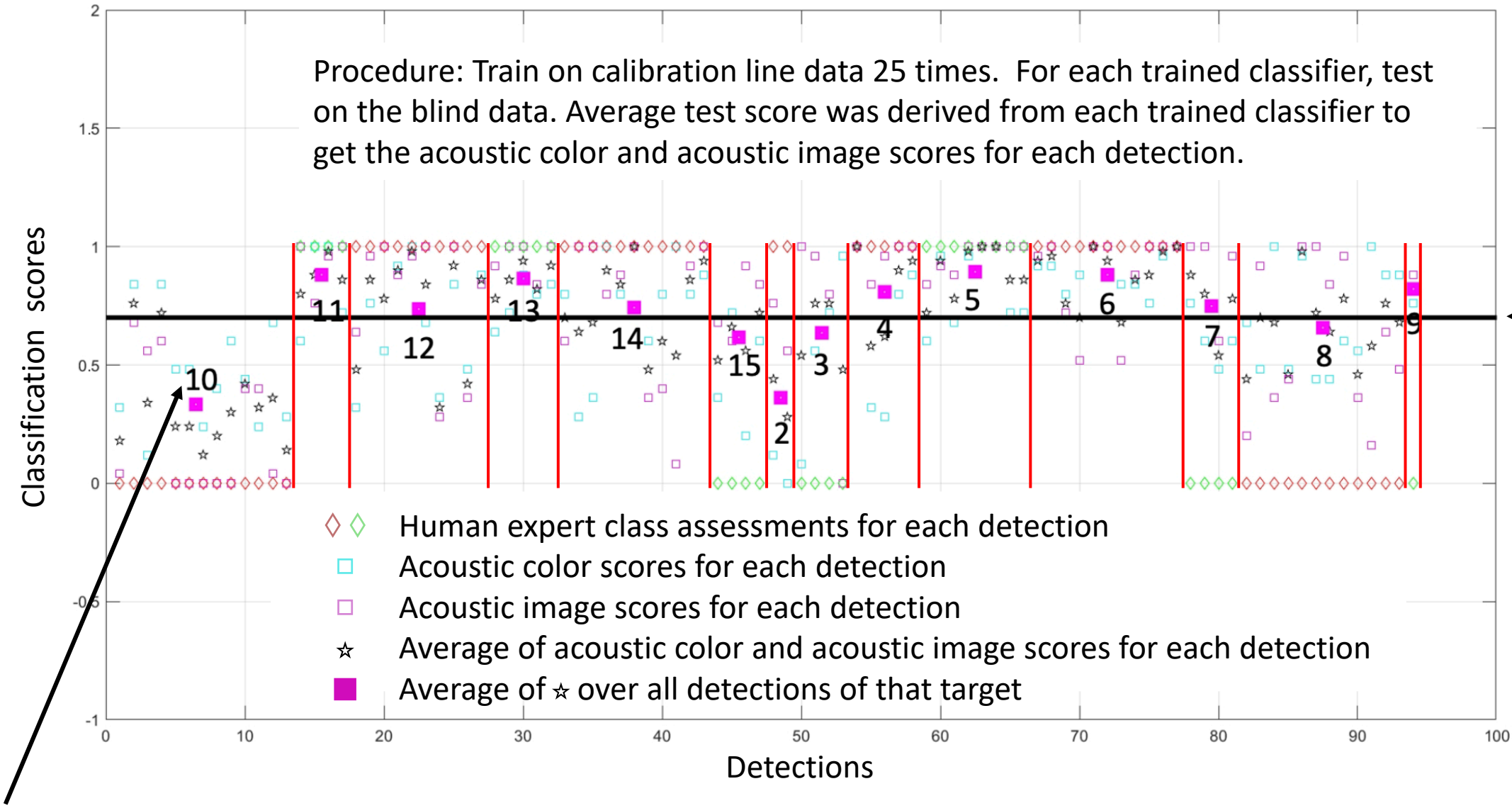
Maximum Intensity Projections (MIPs) calculated

Filtered Phi MIPS (bottom two lines) are the data products used in classification

AC = acoustic color

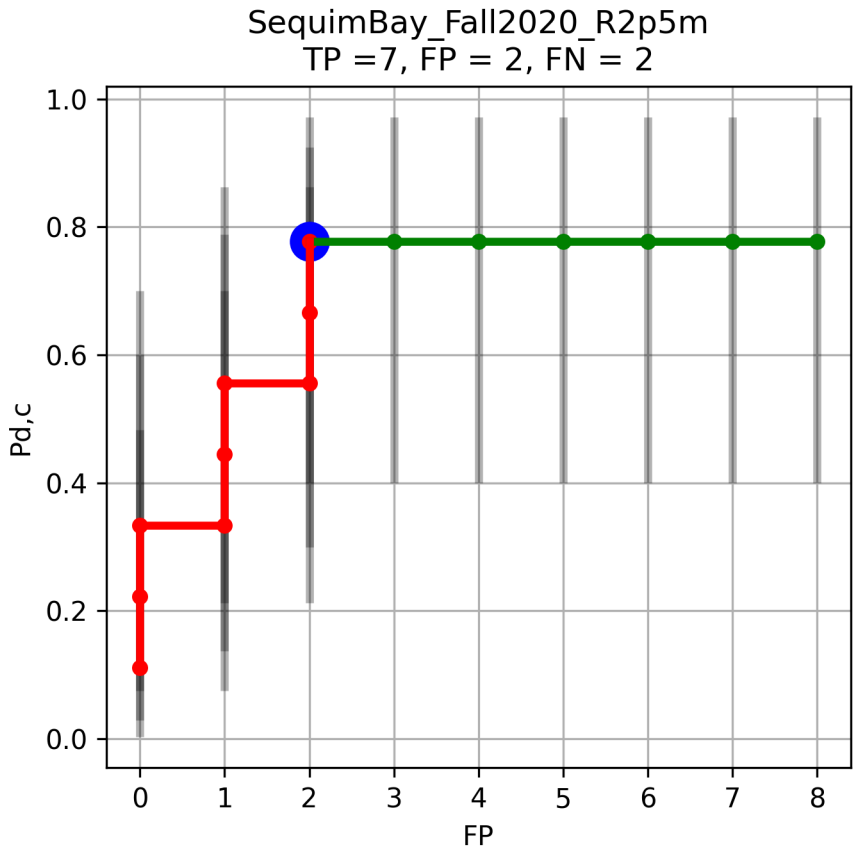
Classification for Targets in Blind Test Area

Vertical red lines separate targets – horizontal separation of lines indicative of the number of times a target was detected



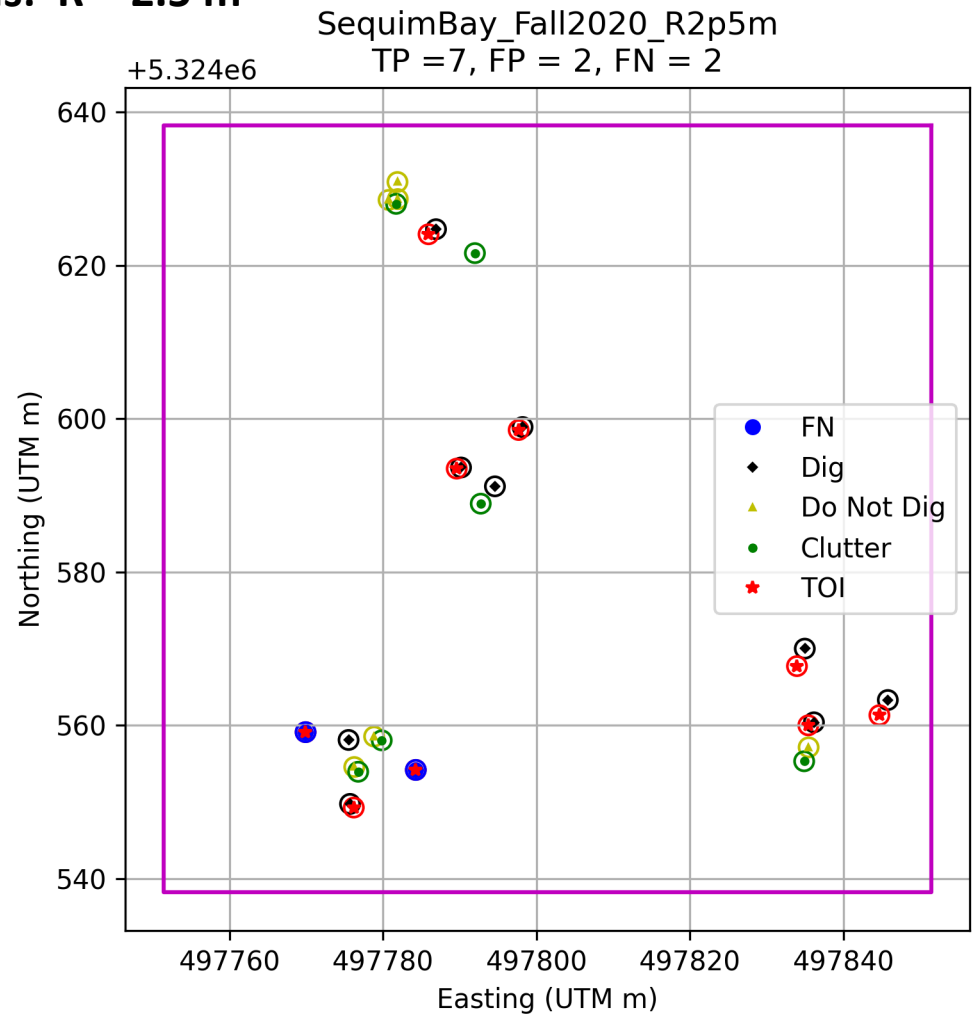
Detection/Classification/Geolocation Results vs. Ground Truth

Detection Halo Radius: R = 2.5 m



2 False Negatives (FNs) i.e., missed UXOs:

- U015 (81mm)
- U017 (81mm)



(Circles in plot have a radius of HALF the detection halo radius R → so two markers are <=R if their circles touch or intersect)

Summary

- Research level operation successfully demonstrated
- Better Inertial Navigation System has been integrated into MuST
- On-going Development :
  - Better detection algorithms
  - Automated classification algorithms
- Sequim Bay 2021 test in September
  - More targets
  - Greater variety of targets

Initial tests in Lake Washington can be seen here:

https://www.youtube.com/watch?v=4UKmavb1TPY

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14. ABSTRACT
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