

Thank you for signing in early

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



SERDP and ESTCP Webinar Series

- The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
- Options for accessing the webinar audio
 - Listen to the broadcast audio if your computer is equipped with speakers
 - Call into the conference line
 - (669) 900-6833 or (929) 205-6099
 - Required webinar ID: 910-2654-9690
 - YouTube live stream
 - <https://www.youtube.com/user/SERDPESTCP>
- For questions or technical issues, please email serdp-estcp@noblis.org or call 571-372-6565

Advances in the Detection of Submerged Unexploded Ordnance in Marine Environments

February 11, 2021



Welcome and Introductions

Rula A. Deeb, Ph.D.
Webinar Coordinator



Webinar Agenda

- **Webinar Logistics** (5 minutes)
Dr. Rula Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
Dr. David Bradley, SERDP and ESTCP
- **Understanding the Role of Munitions Mobility and Burial in Long-Term Management of Underwater UXO Sites** (55 minutes + Q&A)
Dr. Timothy Marston, Applied Physics Laboratory, University of Washington
- **Final Q&A session**

Zoom Instructions

- Download Zoom
 - <https://zoom.us/download>
- If you cannot download Zoom, you can view the slides using an internet browser
 - Create a free Zoom account (<https://zoom.us/signup>)
 - Use a compatible browser (Firefox, IE or Edge)
 - View the webinar at <https://success.zoom.us/wc/91026549690/join>
- If the material is not showing on your screen or if screen freezes
 - Key in Ctrl + F5 to do a hard refresh of your browser

Zoom Instructions (Cont'd)

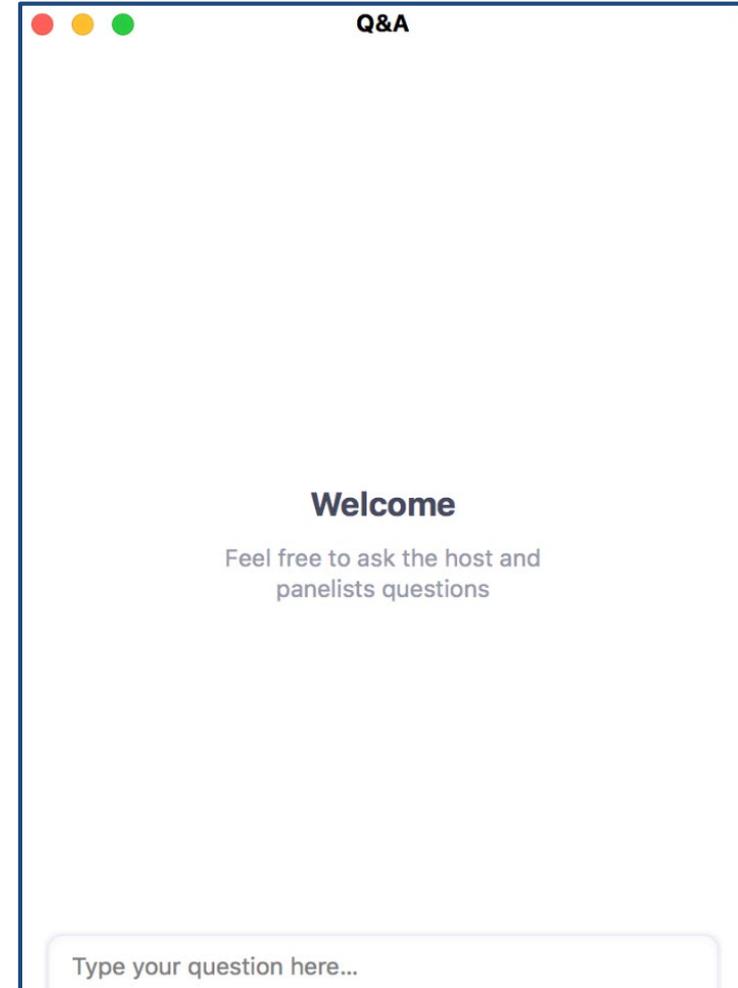
- If you are connecting to computer audio
 - Click the arrow next to the “Join Audio” button
 - Select test “Speaker and Microphone”
 - Follow prompts
- If you experience difficulties with the audio, call into the conference line
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In Case of Continued Technical Difficulties

- Download a PDF of the slides at <https://serdp-estcp.org/Tools-and-Training/Webinar-Series/02-11-2021> and call into the conference line
 - (669) 900-6833 or (929) 205-6099
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- We will also be live streaming the webinar on the SERDP and ESTCP YouTube channel
 - <https://www.youtube.com/user/SERDPESTCP>

How to Ask Questions

- Find the Q&A button on your control bar and type in your question(s)
- Make sure to add your organization name at the end of your question so that we can identify you during the Q&A sessions



SERDP and ESTCP Overview

David L. Bradley, Ph.D.
SERDP and ESTCP



SERDP

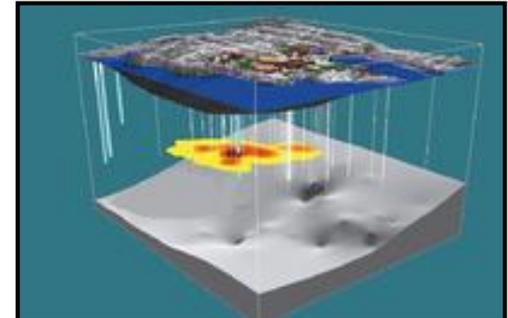
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
 - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
 - Advanced 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

- Environmental Restoration
- Installation Energy and Water
- Munitions Response
- Resource Conservation and Resiliency
- Weapons Systems and Platforms



Munitions 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	Topic
February 25, 2021	Managing Chlorinated Solvents in Groundwater Using Biological Treatment
March 11, 2021	New Resource Conservation Paradigms on DoD Lands
March 25, 2021	Safer Alternatives for Surface Engineering and Structural Materials in Weapons Systems and Platforms: A Fred Lafferman Tribute Webinar
April 8, 2021	Advances in Understanding PFAS Ecological Risks
April 22, 2021	Innovative Approaches to Monitor and Survey At-Risk Species on DoD Lands
May 6, 2021	Fate, Transport and Treatment of Munitions Constituents in Soil and Groundwater

For upcoming webinars, please visit

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



Sequim Bay Blind UXO Testbed Survey Results with the Multi-Sensor Towbody eBOSS Volumetric SAS

Timothy Marston, Ph.D.
University of Washington



Webinar Overview

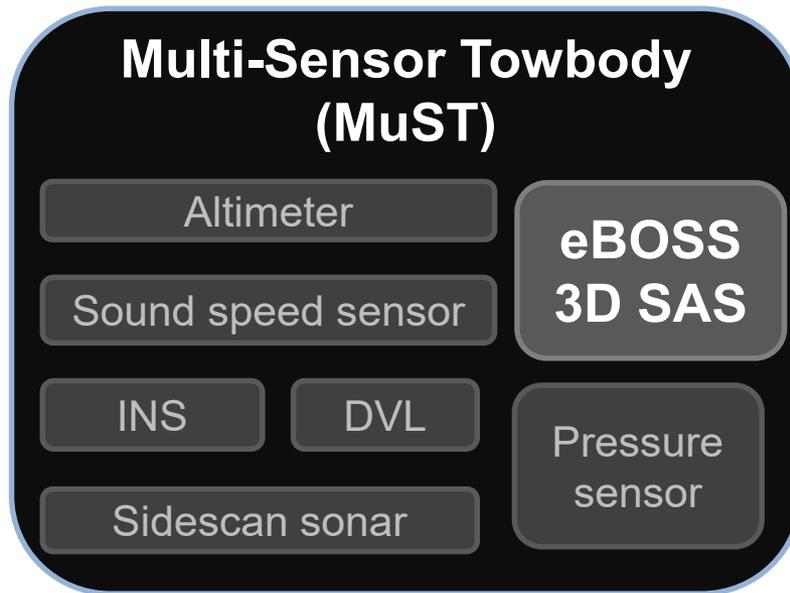
- Multi-Sensor Towbody (MuST)
- Sequim Bay testbed survey
- Volumetric SAS and the eBOSS
- MuSTLive: Realtime data visualization
- MuST eBOSS toolkit
- UXO classification exercise
- Benefit to DoD

Multi-Sensor Towbody (MuST)

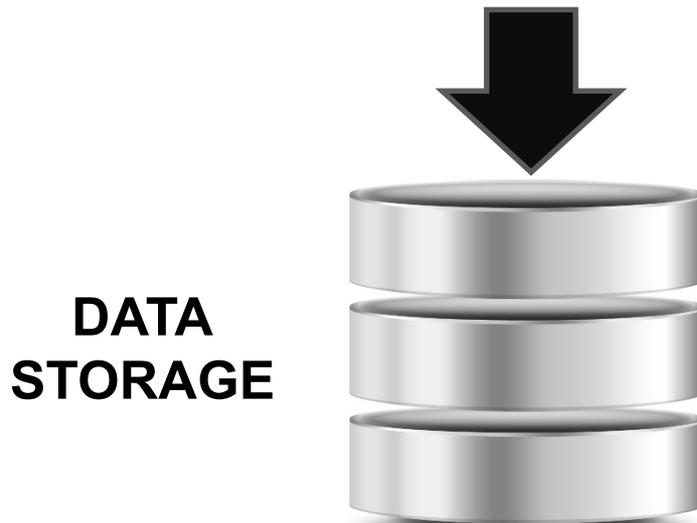
- An APL designed platform for proud and buried UXO detection and identification
- Designed around a MacCartney Focus-3 Towfish
- Current sensors
 - EdgeTech 2205 dual frequency sidescan sonar
 - EdgeTech Buried Object Scanning Sonar (eBOSS)



SYSTEM & SENSORS



LIVE ANALYSIS



POST PROCESSING



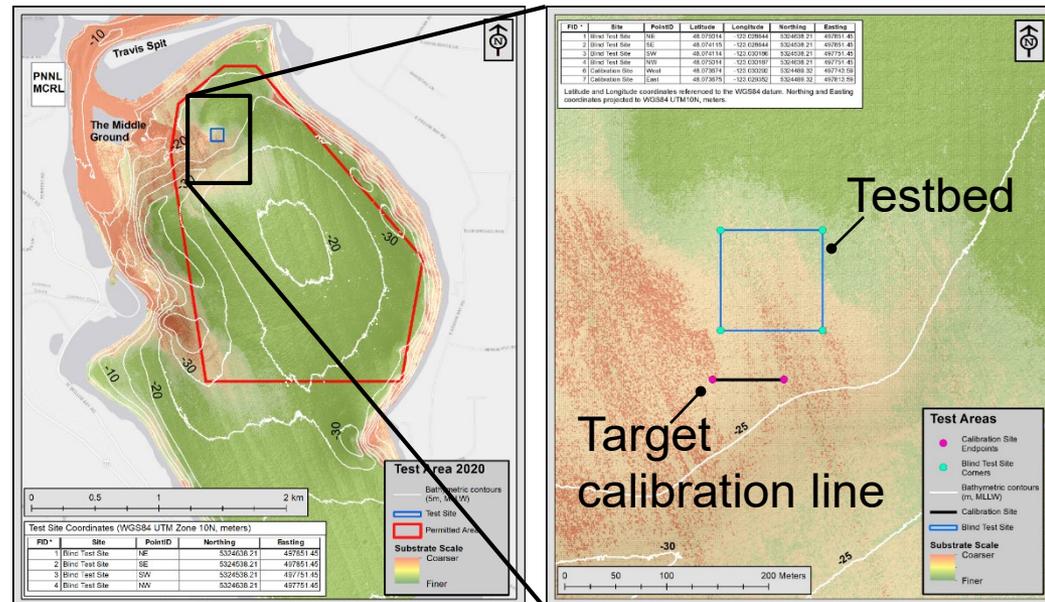
Sequim Bay Blind Testbed Survey

- 16 targets placed in 100x100m box by PNNL
- Target list known, placement and burial states were not known



Map from: <https://www.experiencewa.com>

Maps from pre-site multi-beam survey results



Sequim Bay Blind Testbed Survey

Targets



- 16 targets (2 science, 10 UXO, 4 clutter) placed in unknown locations in a 100x100m box by PNNL
- Target list was known; placement and burial states were not

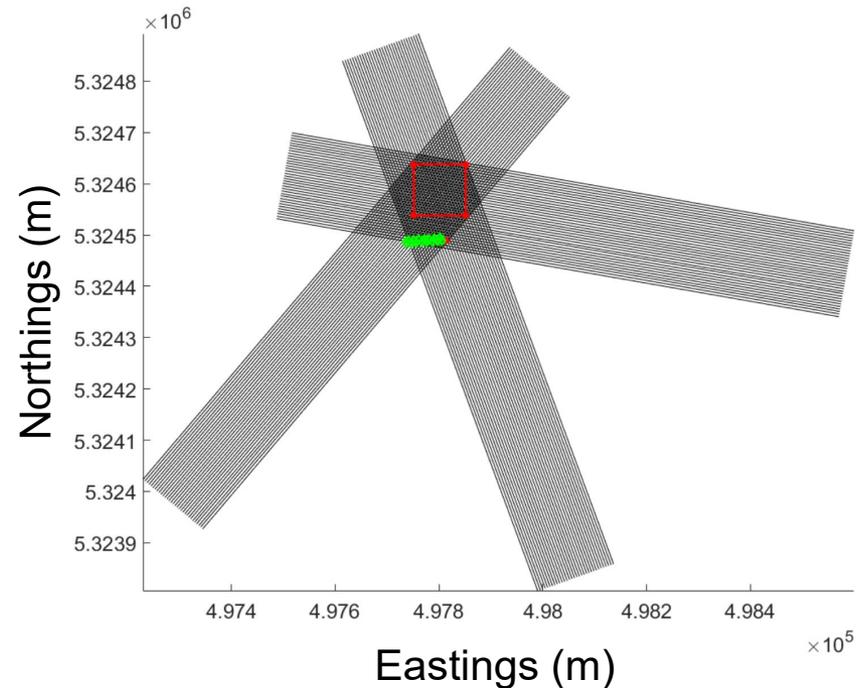
Target Name	Class
60x30 cm solid aluminum cylinder	Science
60x30 cm hollow cylinder	Science
81 mm mortar	UXO (x2)
105 mm (M80)	UXO (x2)
105 mm (HEAT)	UXO (x2)
155 mm (M107)	UXO (x2)
155 mm replica	UXO replica (x2)
Anchor	Clutter
Cement block	Clutter
Scuba tank	Clutter
Crab trap	Clutter

UXO = unexploded ordnance

Sequim Bay Blind Testbed Survey

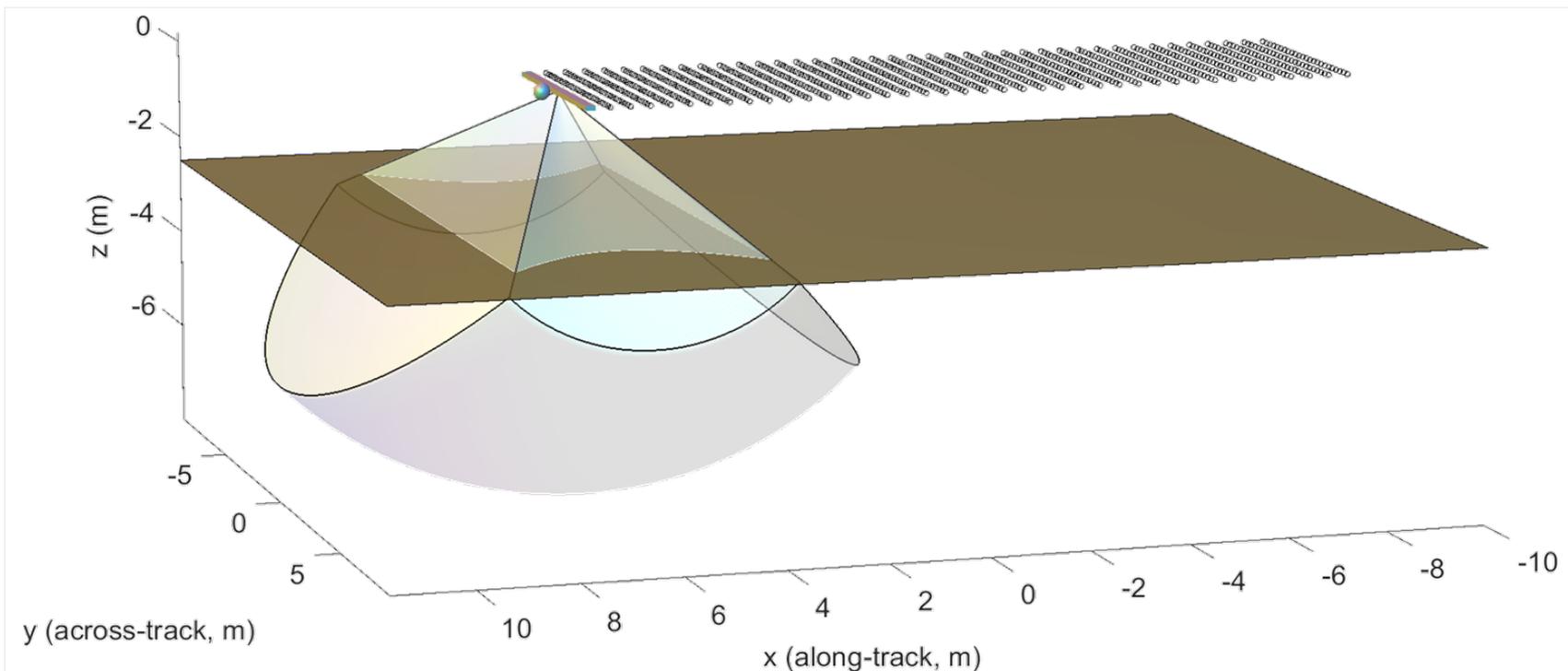
- Survey track line sets
 - 60 degree spacing for aspect angle diversity
 - 5-meter track spacing for grazing angle diversity

Target field, calibration line and survey lines



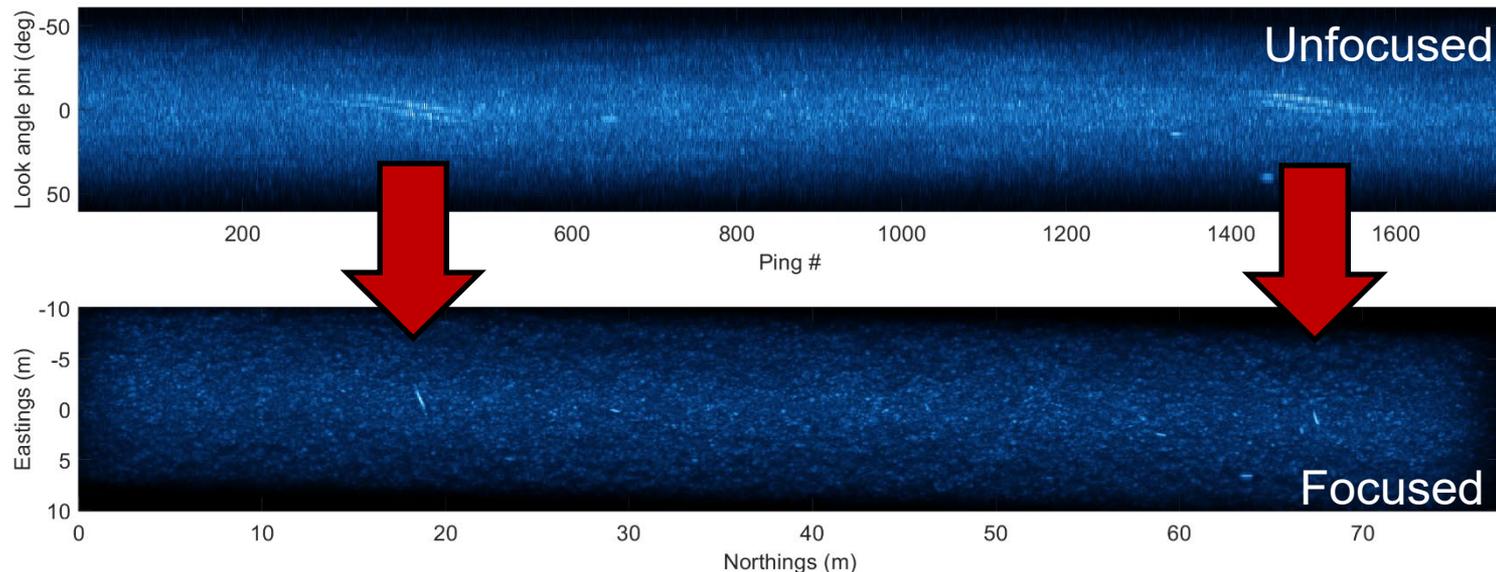
Survey Technology: Volume SAS

- SAS: Synthetic Aperture Sonar
- Most SAS systems are side-looking and can't effectively image into the sediment
- The eBOSS is down-looking and creates a planar array



Survey Technology: Volume SAS

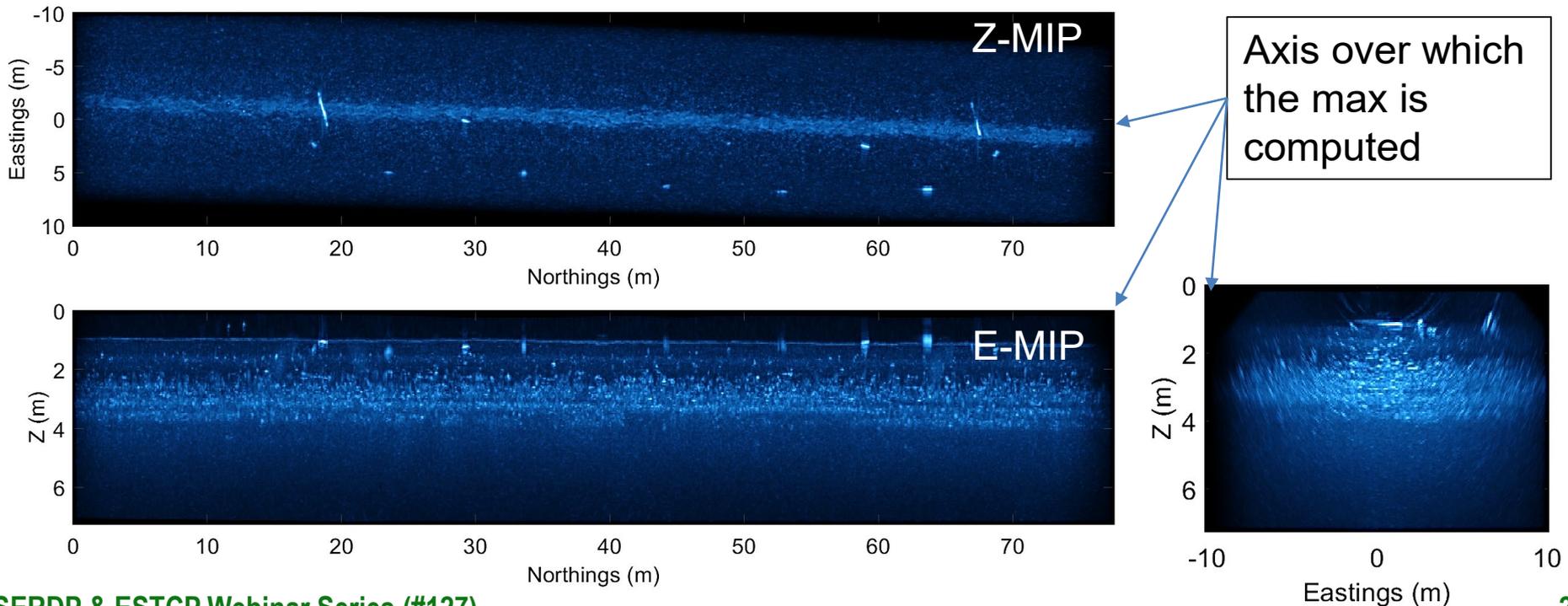
- Across-track resolution set by array length, frequency and sound-speed
- Along-track resolution set by synthetic aperture length, frequency, beamwidth and sound-speed
- Range resolution is set by the pulse bandwidth and sound-speed
- Along-track focus is achieved in post processing:



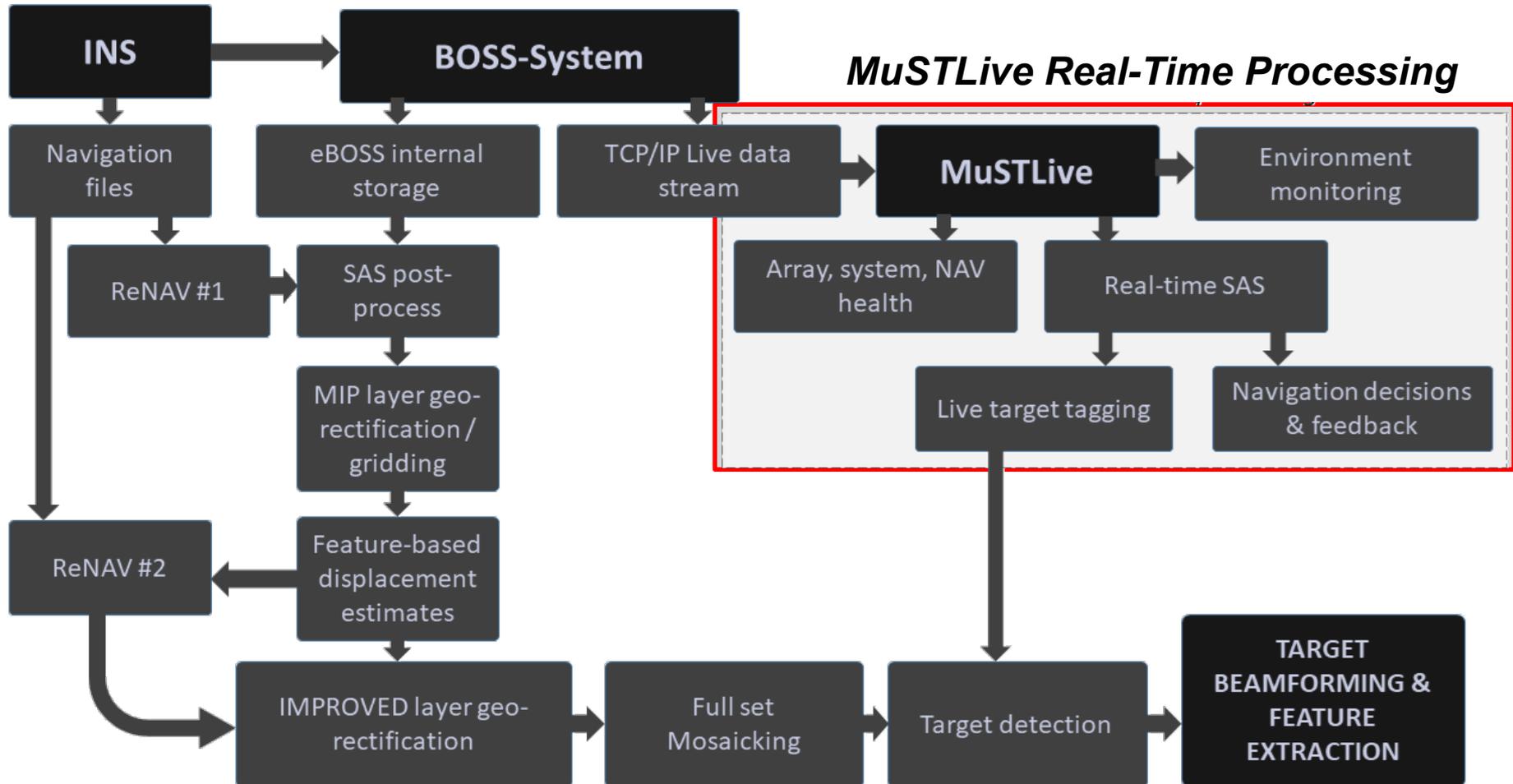
Vehicle is moving this direction →

3D Visualization Notes

- Output of the eBOSS is a 3D image volume
- How do we effectively visualize a volume?
 - MIP's: Maximum Intensity Projections



eBOSS Post-Processing Flowchart



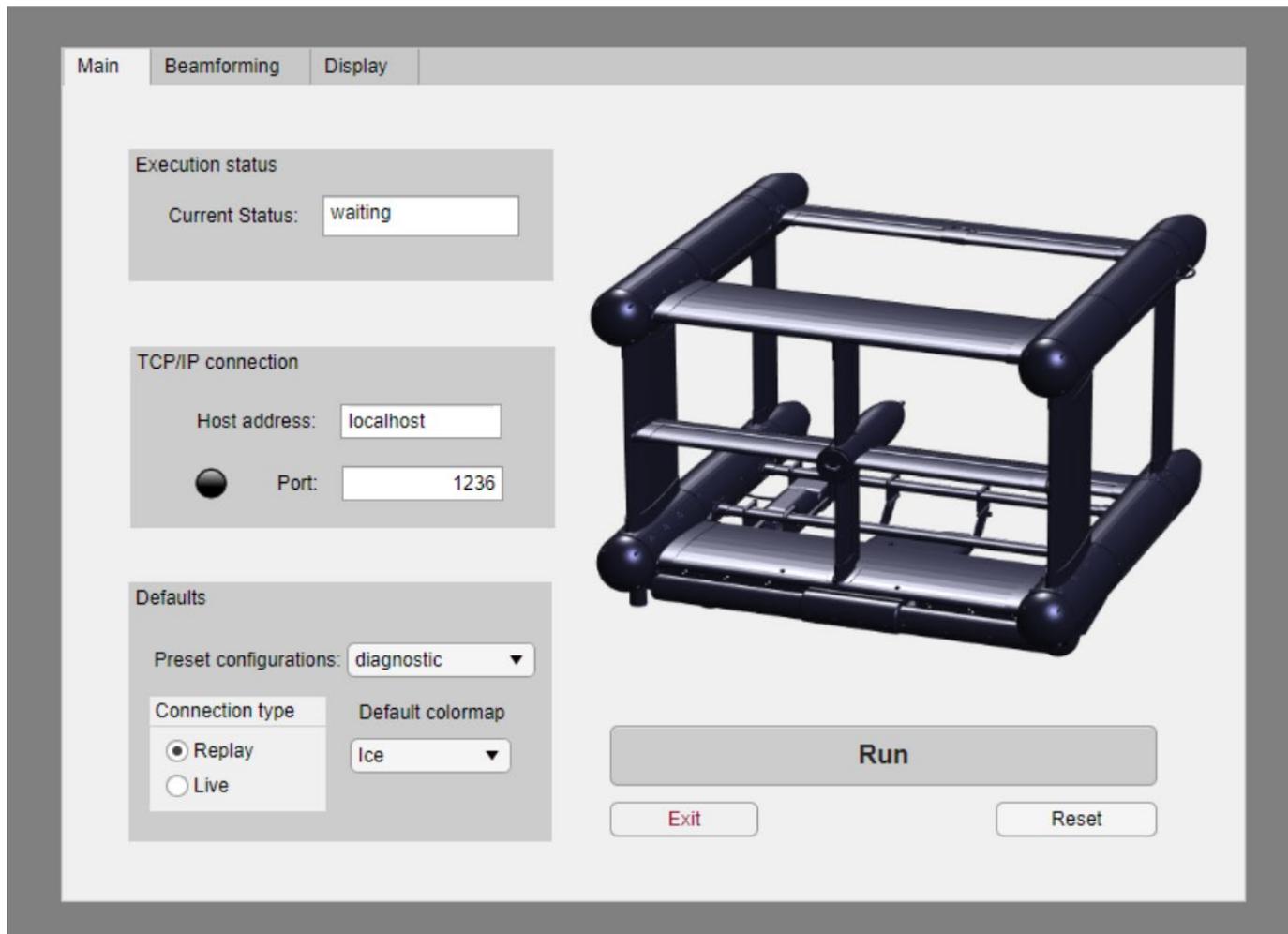
Realtime Data Visualization

- Why is live data visualization important?
 - Invaluable for determining sensor best-practices
 - Live target detection for path planning or verification
 - Data culling and acquisition management
 - Sensor health monitoring and troubleshooting

MuSTLive

- MuSTLive is a simple and intuitive tool developed to enable realtime visualization of the following:
 - Sensor, target and geographic feature positions
 - SAS MIP's, streaming in waterfall format
 - Real aperture and raw data from the eBOSS array
 - Connection and sensor diagnostic outputs for monitoring system health
- *Allows real-time tagging of regions of interest for post-processing*

MuSTLive: Main Window



MuSTLive: Beamforming Options

Main
Beamforming
Display

Do SAS

Integration settings

Number of Pings

Integration angle (Deg)

Signal band

f_max

f_min

Environment & Navigation

Autodetect from sensors

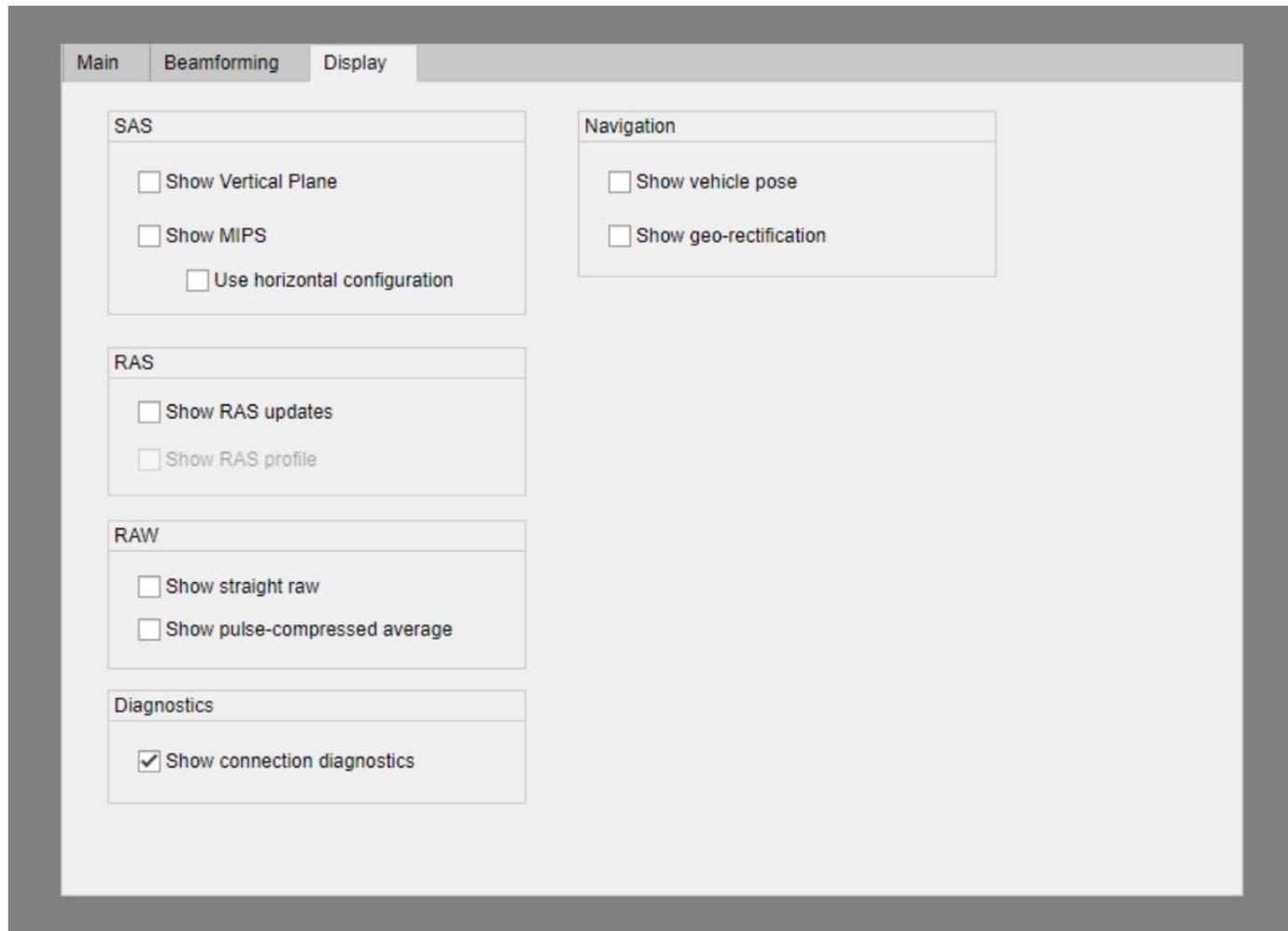
Sound velocity

Advance per ping (m)

Update from Data

Update from Entry

MuSTLive: Visualization Options



The screenshot displays the 'Display' tab of the MuSTLive software interface. The interface is organized into several sections, each with a title and a list of options:

- Main** (selected tab)
- Beamforming**
- Display**

SAS

- Show Vertical Plane
- Show MIPS
- Use horizontal configuration

RAS

- Show RAS updates
- Show RAS profile

RAW

- Show straight raw
- Show pulse-compressed average

Diagnostics

- Show connection diagnostics

Navigation

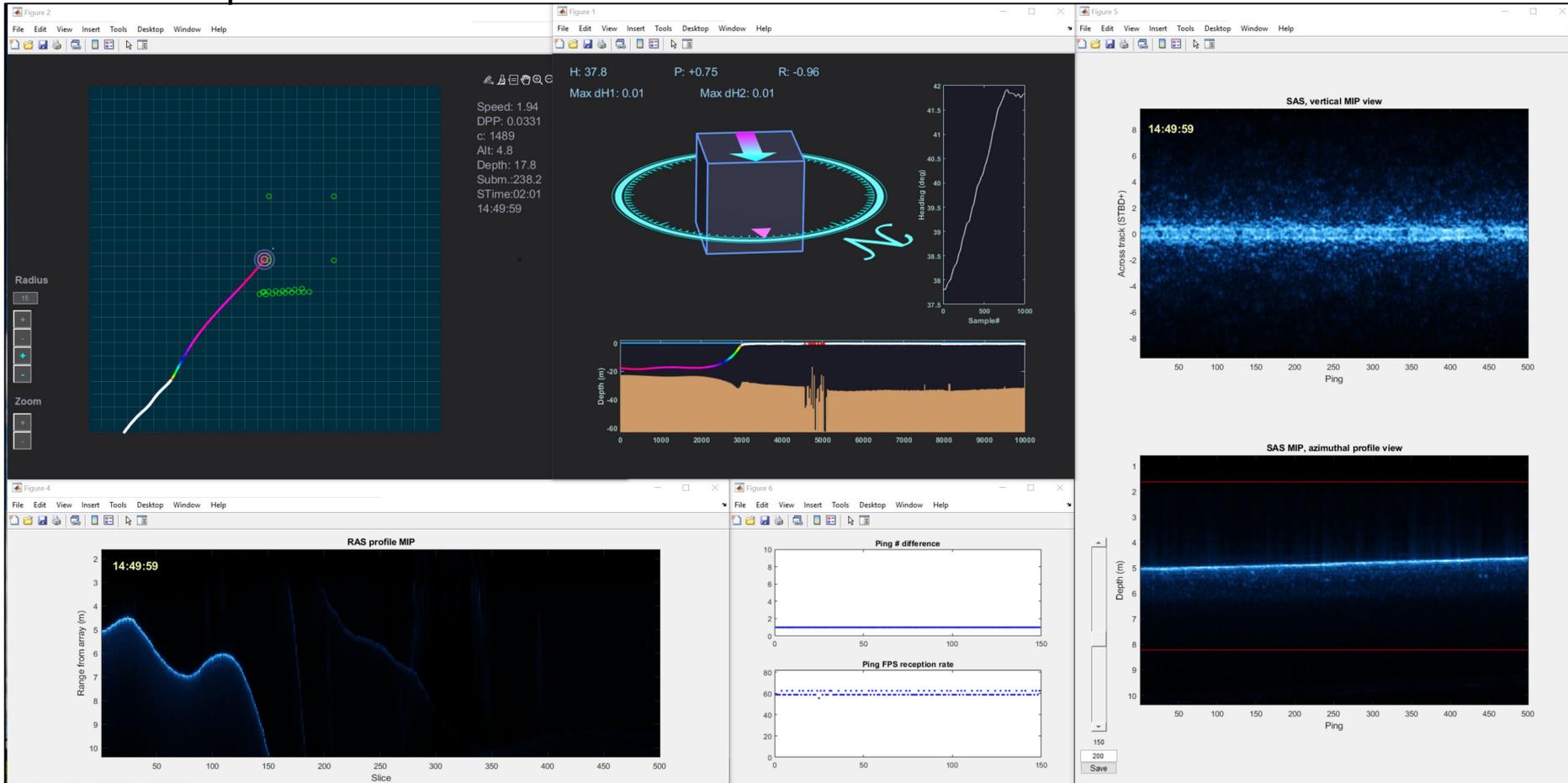
- Show vehicle pose
- Show geo-rectification

MuSTLive: Data Visualization

Map window

Orientation window

SAS MIP waterfall



RAS profile window

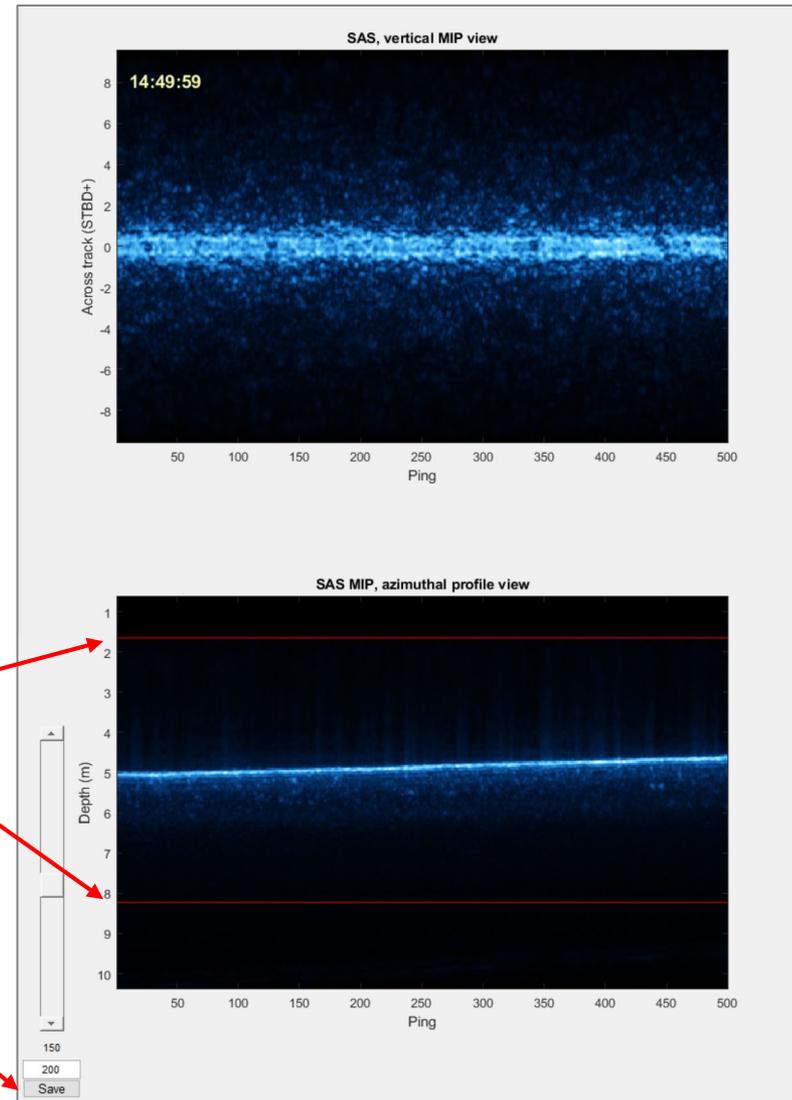
Diagnostics window

MuSTLive: SAS Window

- Scrolling MIPS through depth and across-track display the SAS volume for the last 500 pings

Bounds for vertical MIP are shown in red and are adjustable via the scrollbar and number field

Clicking “Save” button exports figure and towfish position data

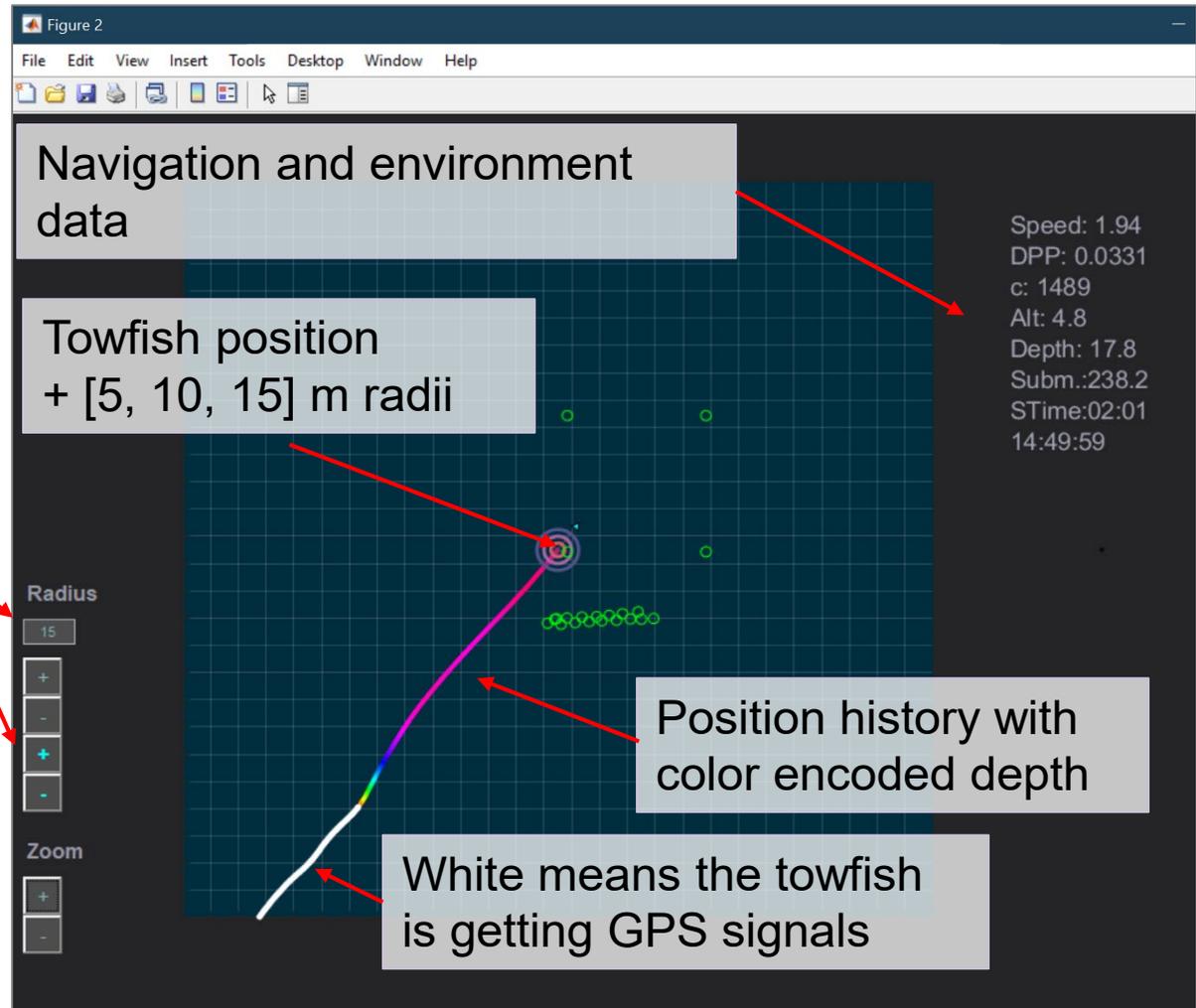


MuSTLive: Map Window

 Green circles are imported from an editable list of locations

The radius of the outer circle is adjustable, allowing distance to location markers to be estimated in the map window

The map can be zoomed in or out by pressing “+” or “-”



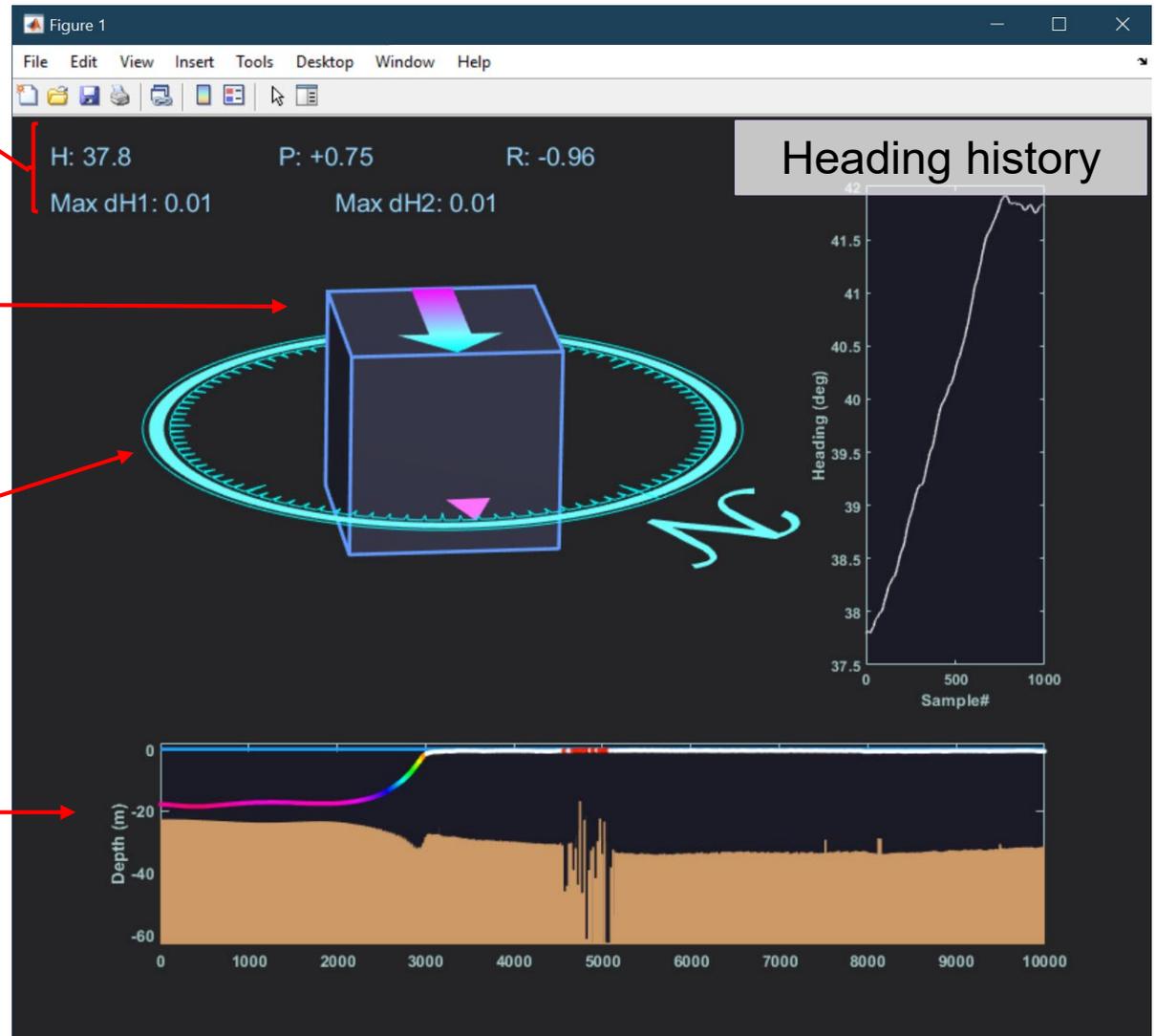
MuSTLive: Orientation Window

Roll, pitch and yaw plus recent maximum differential headings

Pose-box copies movement of towfish

Heading ring shows towfish heading relative to compass north

Depth history shows position of towfish, sediment, and water surface



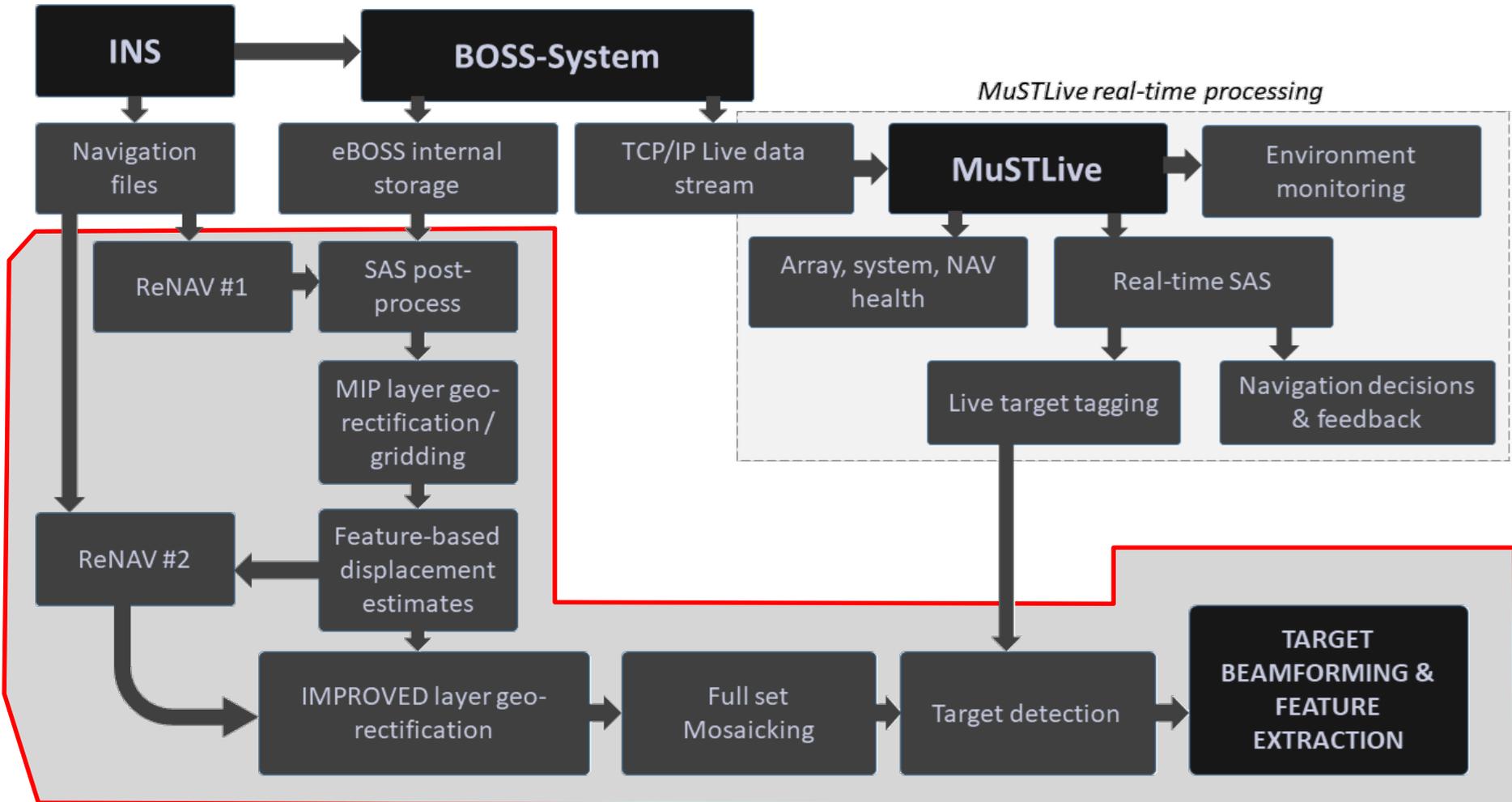
Demo: MuSTLive in Operation (Movie)



Q&A Session 1



eBOSS Post-processing Flowchart



MuST eBOSS Toolkit

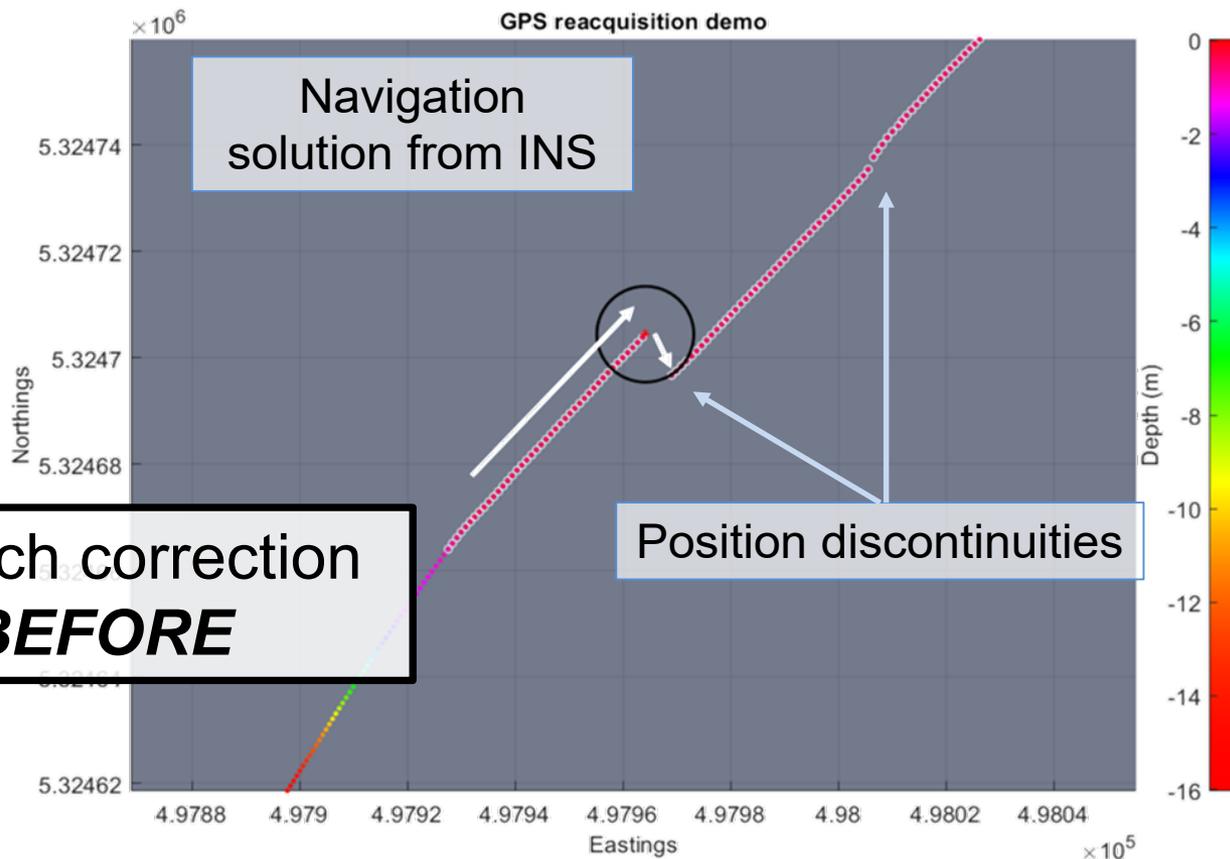
- A series of Matlab scripts and GUI's for performing critical post-processing operations, including the following:
 - Fast full-track volume imaging
 - INS re-navigation (including feature-based)
 - Mosaicking
 - Patch beamforming
 - ROI data retrieval and multi-aspect visualization

Notes: GUI = graphical user interface; INS = inertial navigation system, ROI = region of interest

Re-Navigation

Re-Compute Navigation Data to Improve Accuracy

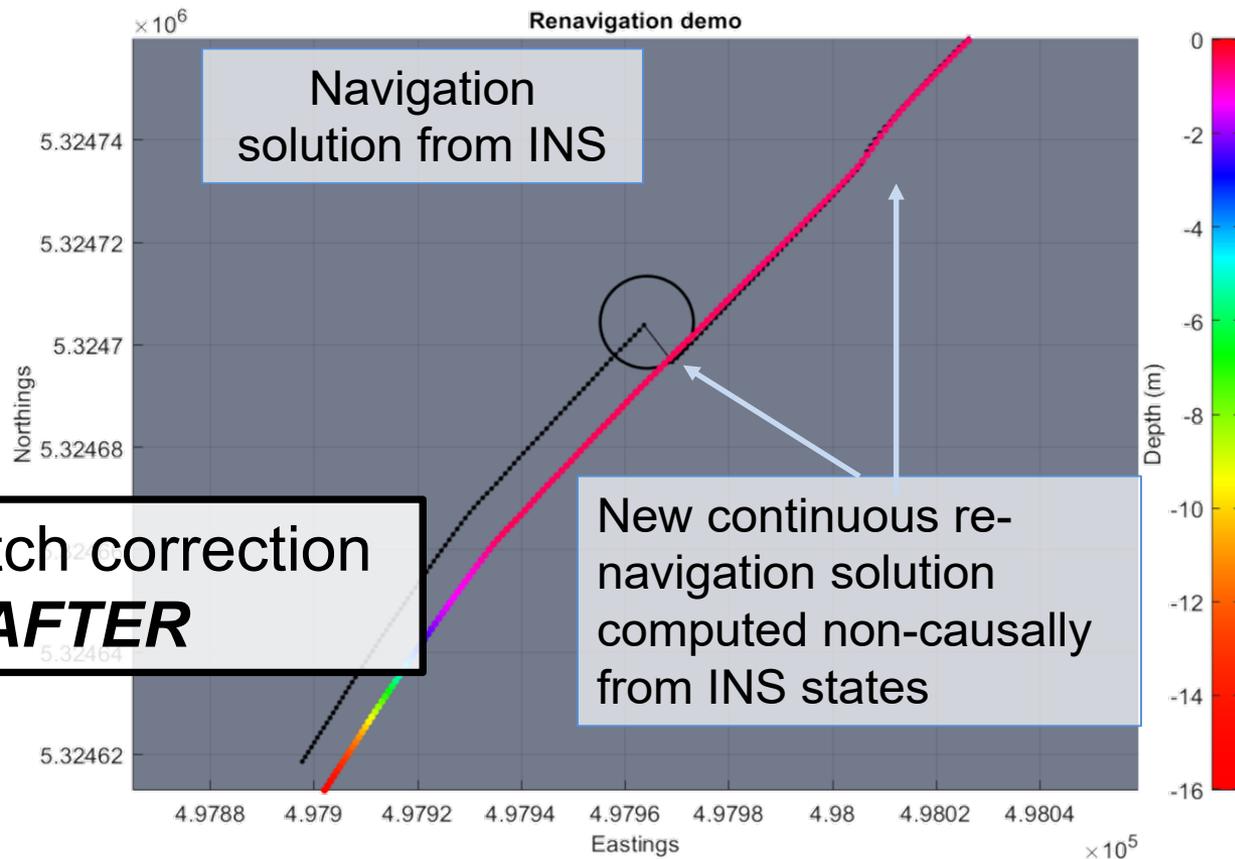
- Stage 1: Continuous non-causal solution using INS state data



Re-Navigation

Re-Compute Navigation Data to Improve Accuracy

- Stage 1: Continuous non-causal solution using INS state data



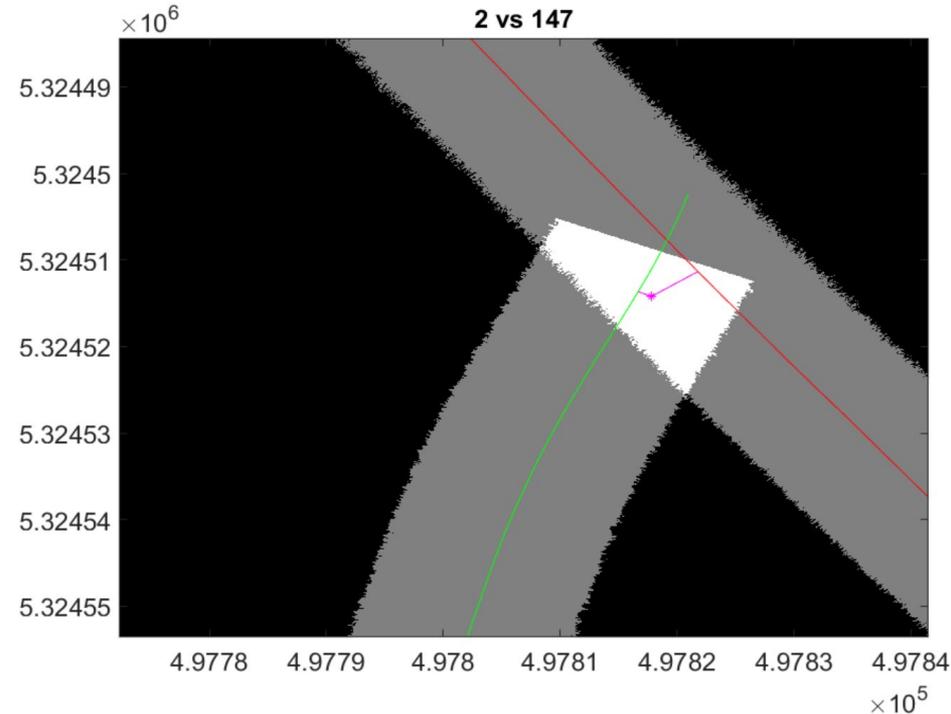
Re-nav glitch correction
example: **AFTER**

New continuous re-
navigation solution
computed non-causally
from INS states

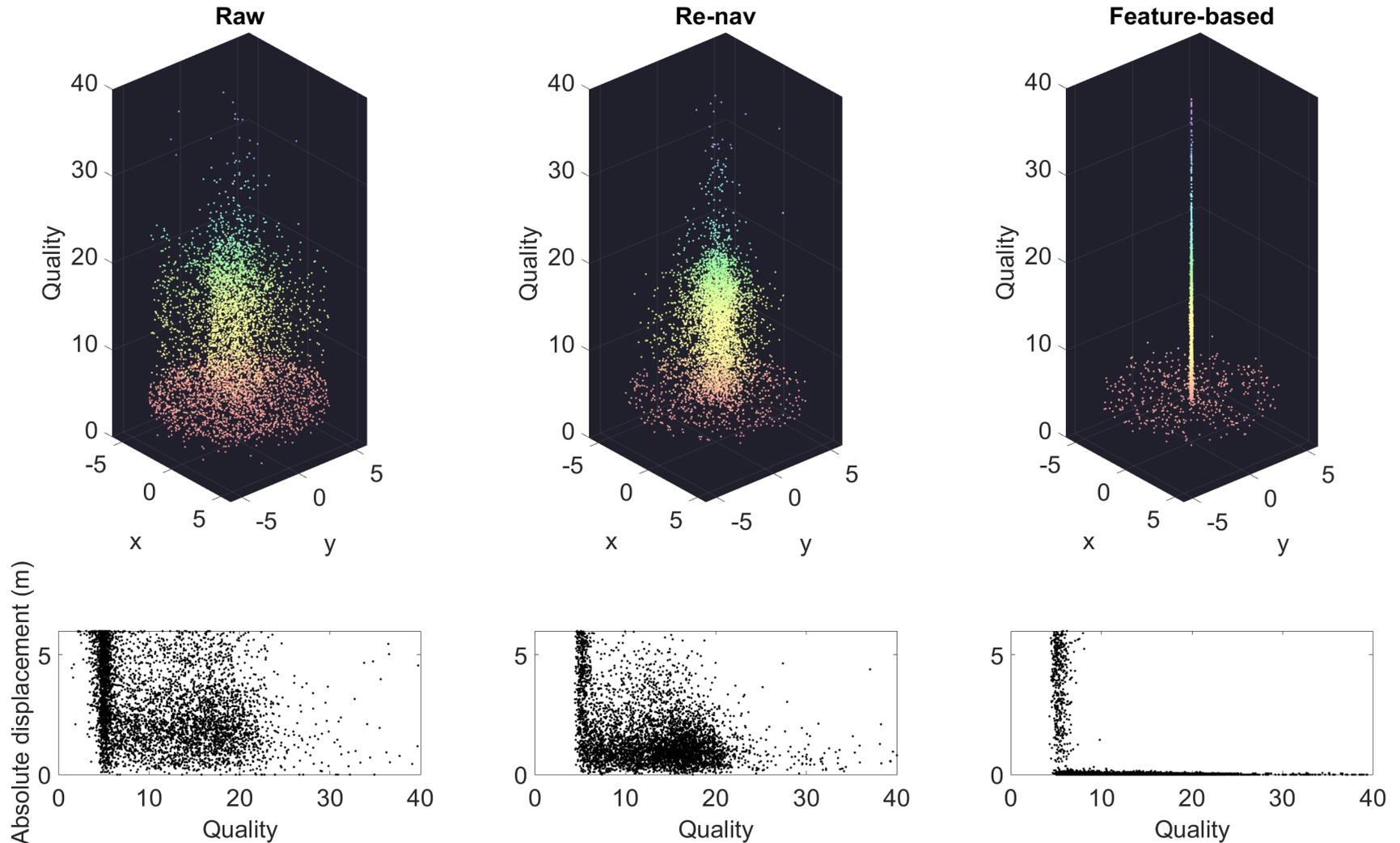
Re-Navigation

Re-Compute Navigation Data to Improve Accuracy

- Stage 2: Feature-based navigation features in MIP layers stored for each file are aligned
- A continuous navigation solution is computed from the estimated feature offsets in a regularized IRLS framework



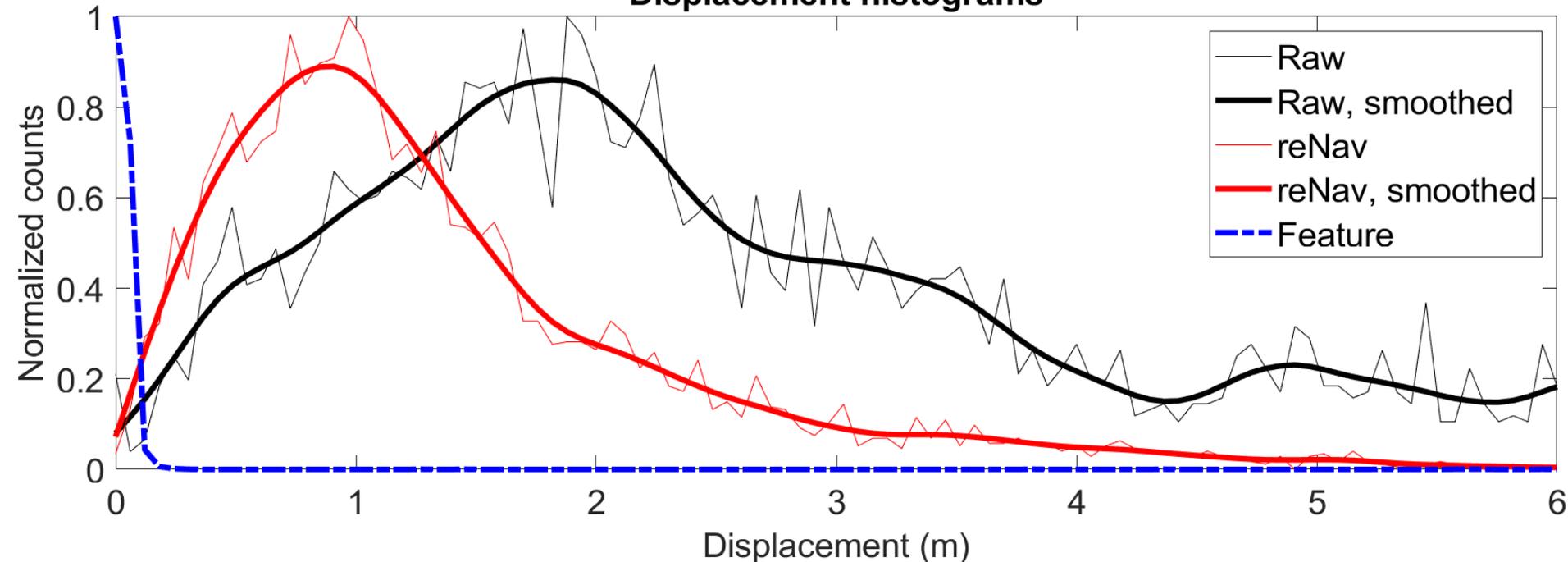
Re-Navigation Precision



Re-Navigation Precision

Feature Based >> Re-nav > Raw INS

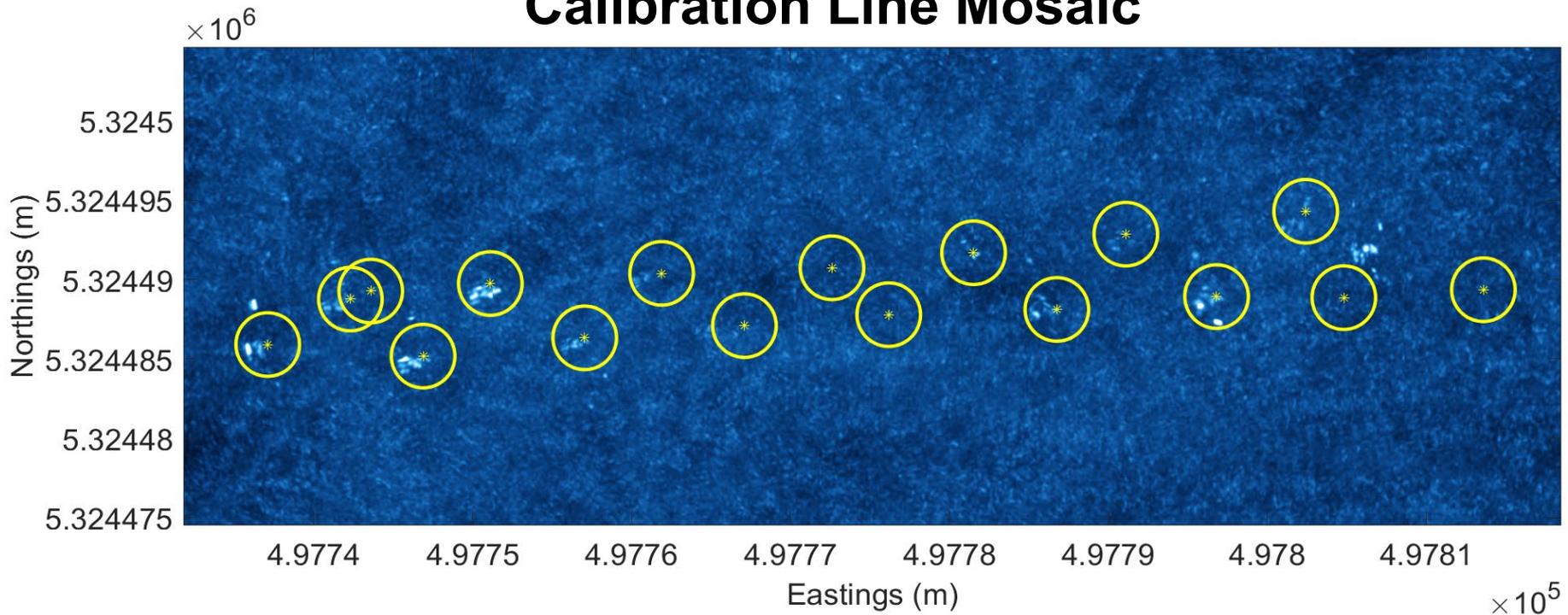
Displacement histograms



	RMS (m)	MAE (m)	Radial 95% (m)	Quality %
Raw	2.81+	2.11+	5.3+	62
Re-navigation	1.70	1.10	3.45	83
Feature-based	0.22	0.00	0.06	85

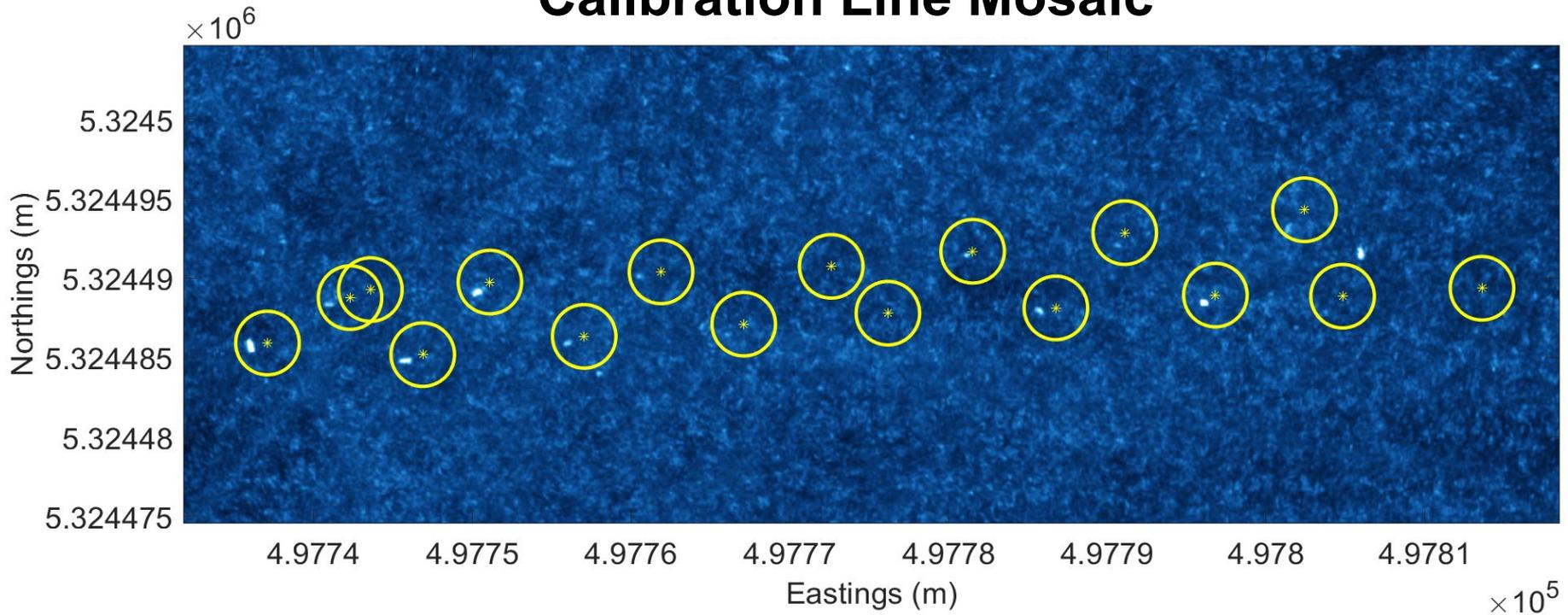
Compare with Sequim Calibration Line

Stage 1 Re-Navigation: Calibration Line Mosaic



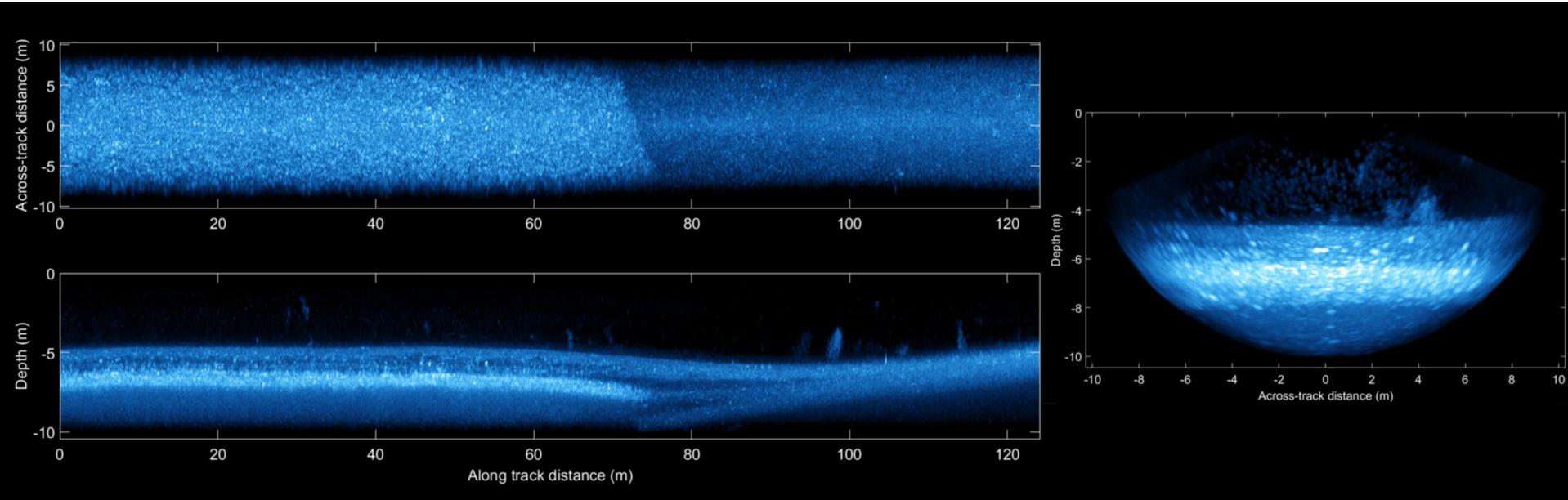
Compare with Sequim Calibration Line

Stage 2 (Feature) Re-Navigation: Calibration Line Mosaic



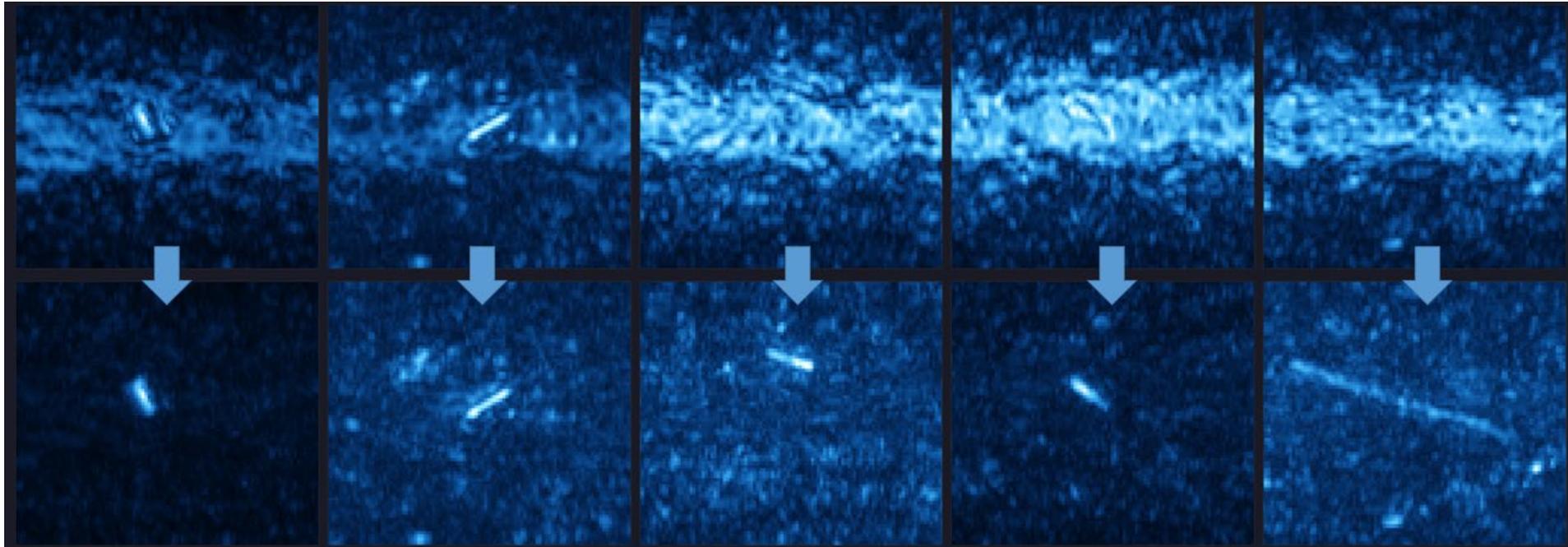
Full-Track Volume Imaging

- Fast and accurate full-volume SAS beamforming



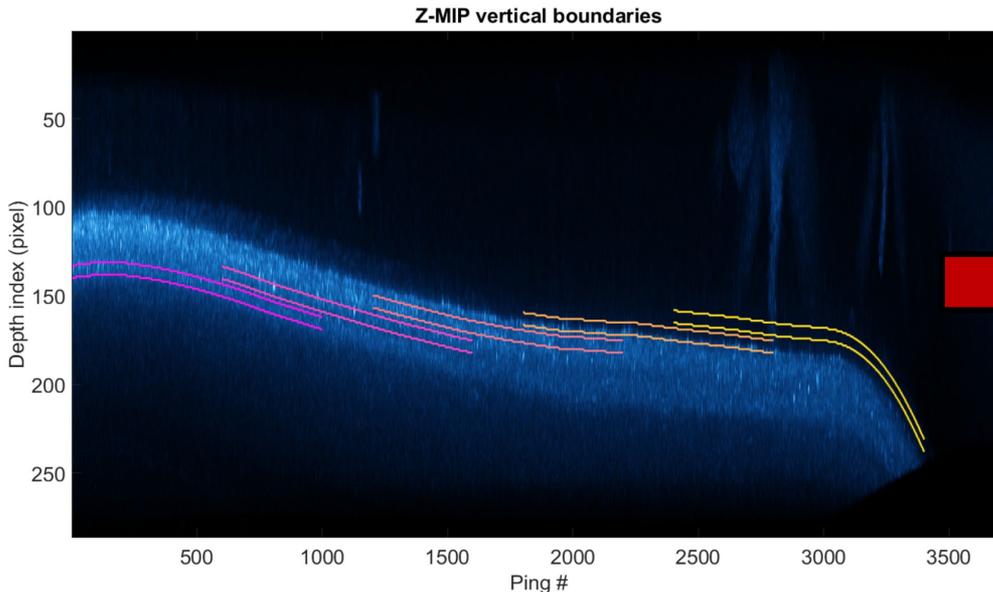
Full-Track Volume Imaging

- De-glinting for improving the visibility of near-nadir targets



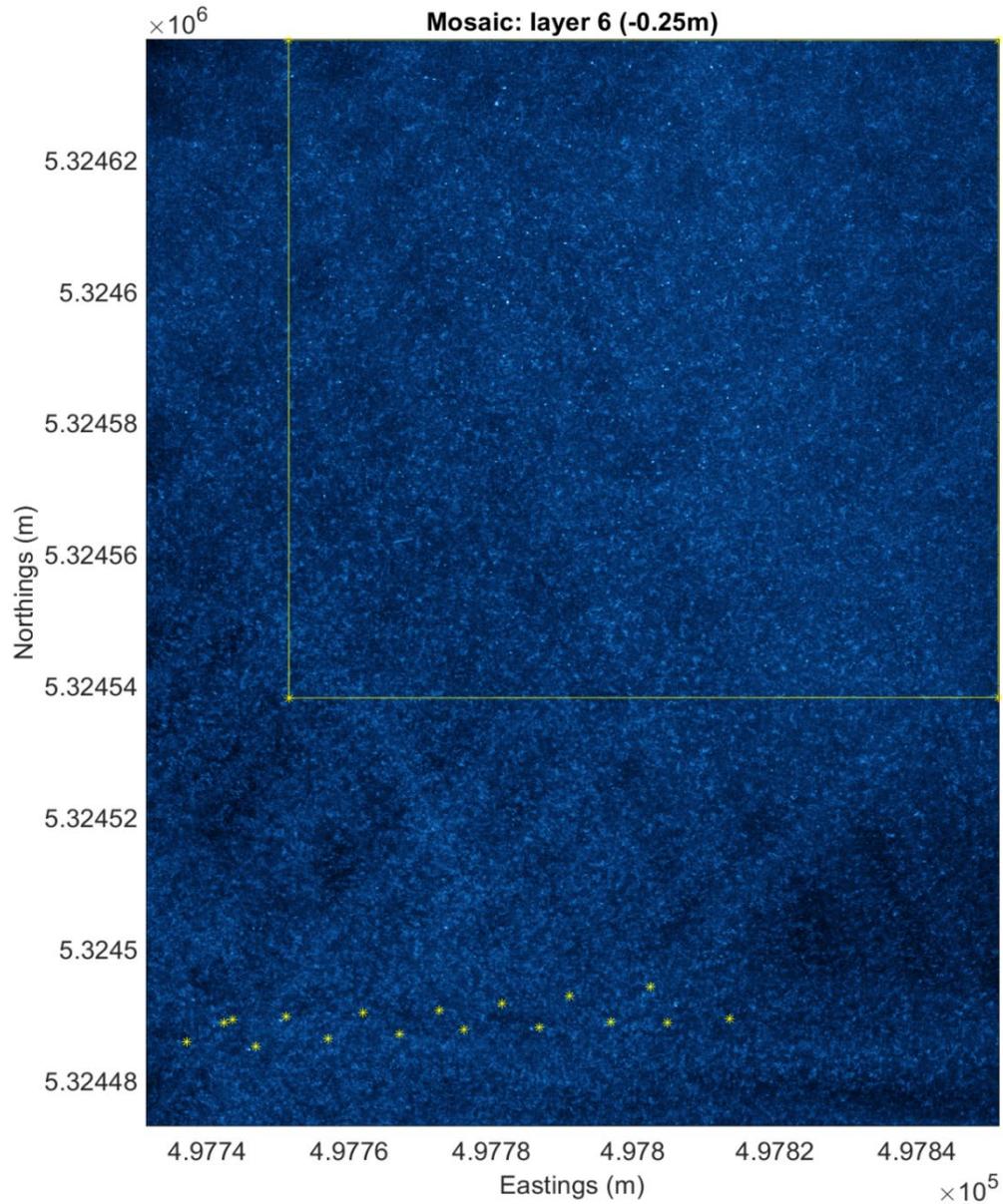
Full-Track Volume Imaging

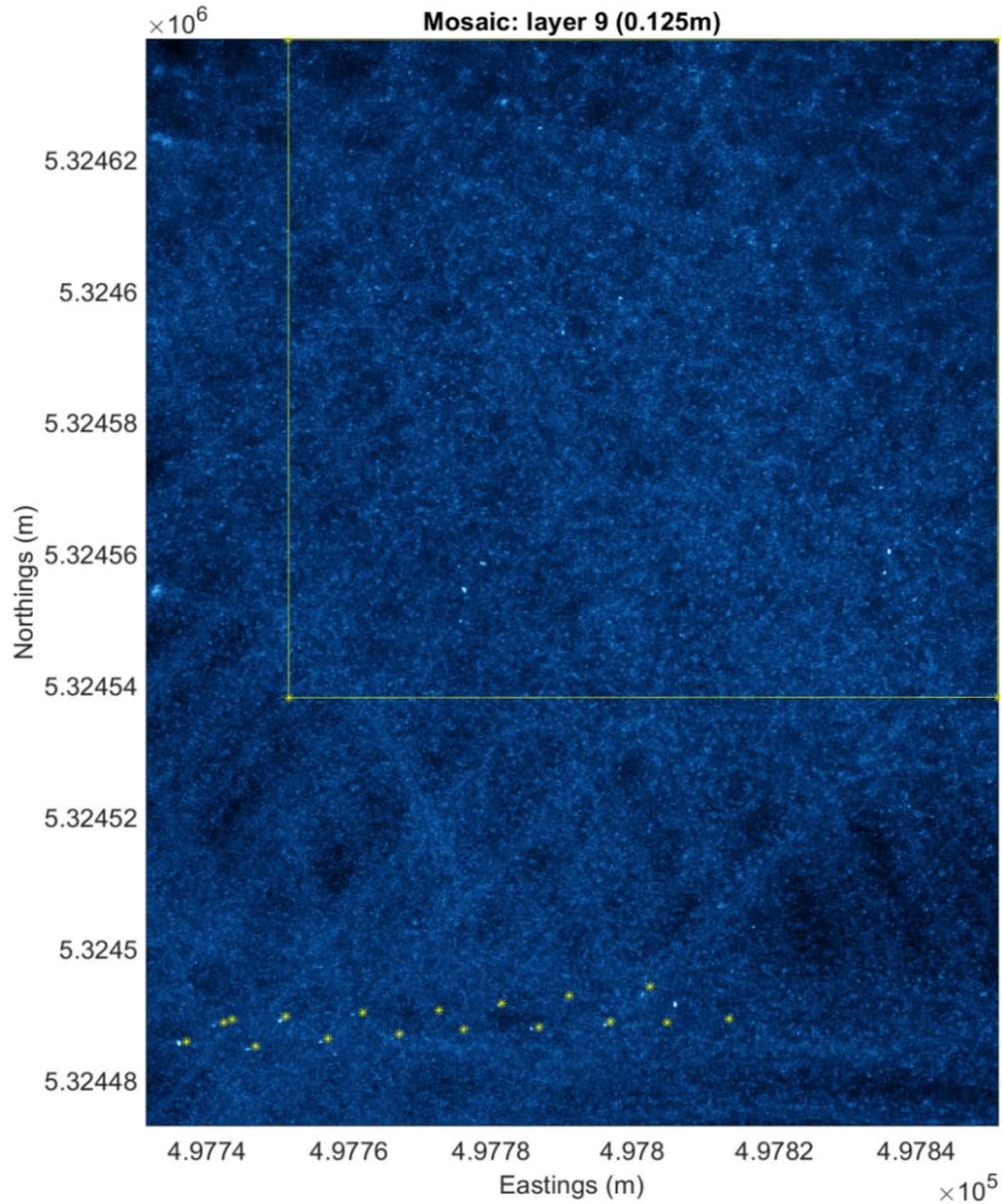
- Track data is stored as a set of layer MIP's, navigation data and meta-data

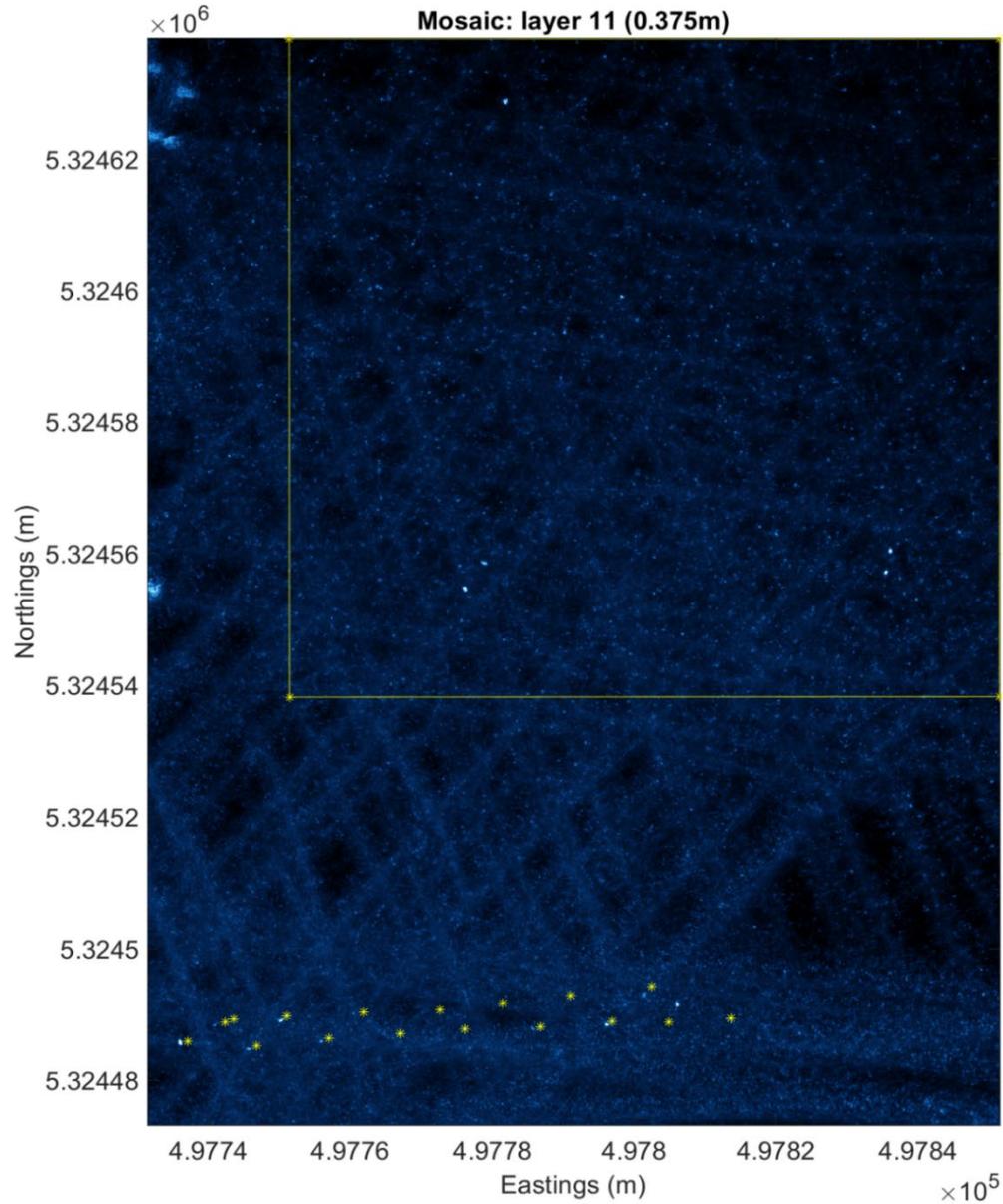


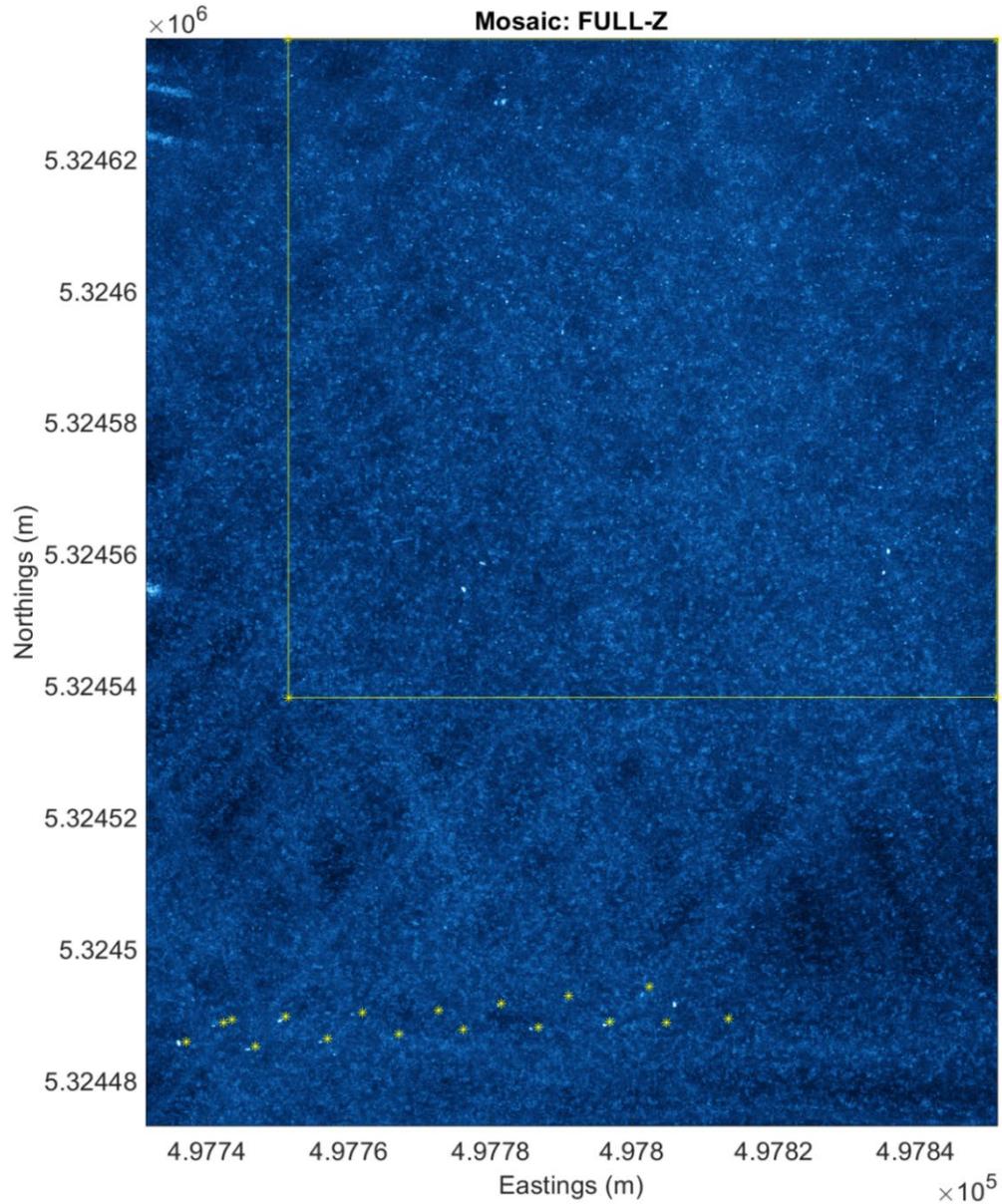
Mosaicking

- Saved layer data is combined with re-navigation data for geo-rectification
- Scans are combined via MIP operations to reduce artifacts
 - Weighted power-sums are in the works
- Mosaics for individual layers are generated and a “full-Z” MIP
- Sequim Bay sediment was virtually homogeneous over the testbed







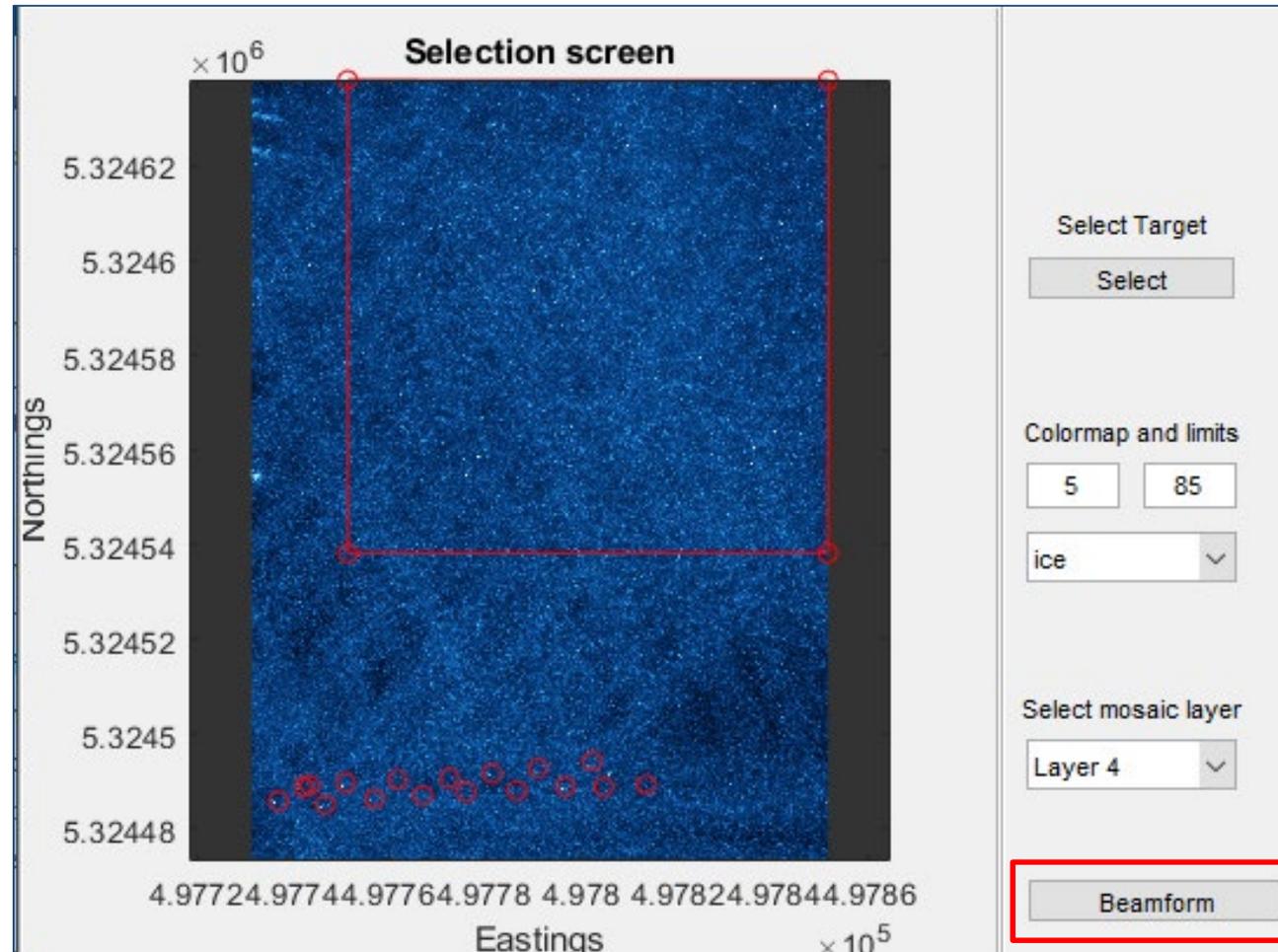
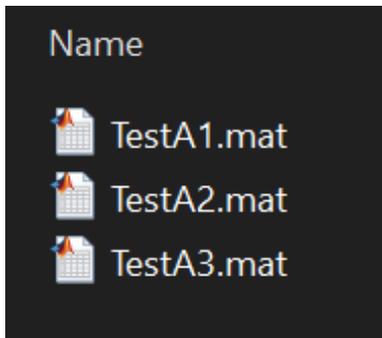


ROI Data Extraction Tool

- GUI based program allowing users to
 - Point-and-click on regions of interest
 - Swap between layers
 - Zoom in, out, change color pallet
- After ROI selection
 - Tool searches through eBOSS file database
 - Beamforms patches using all relevant files
 - Saves 3D data + all relevant metadata for visualization and post-processing

ROI Selection

- Files are exported containing beamformed ROI data and metadata

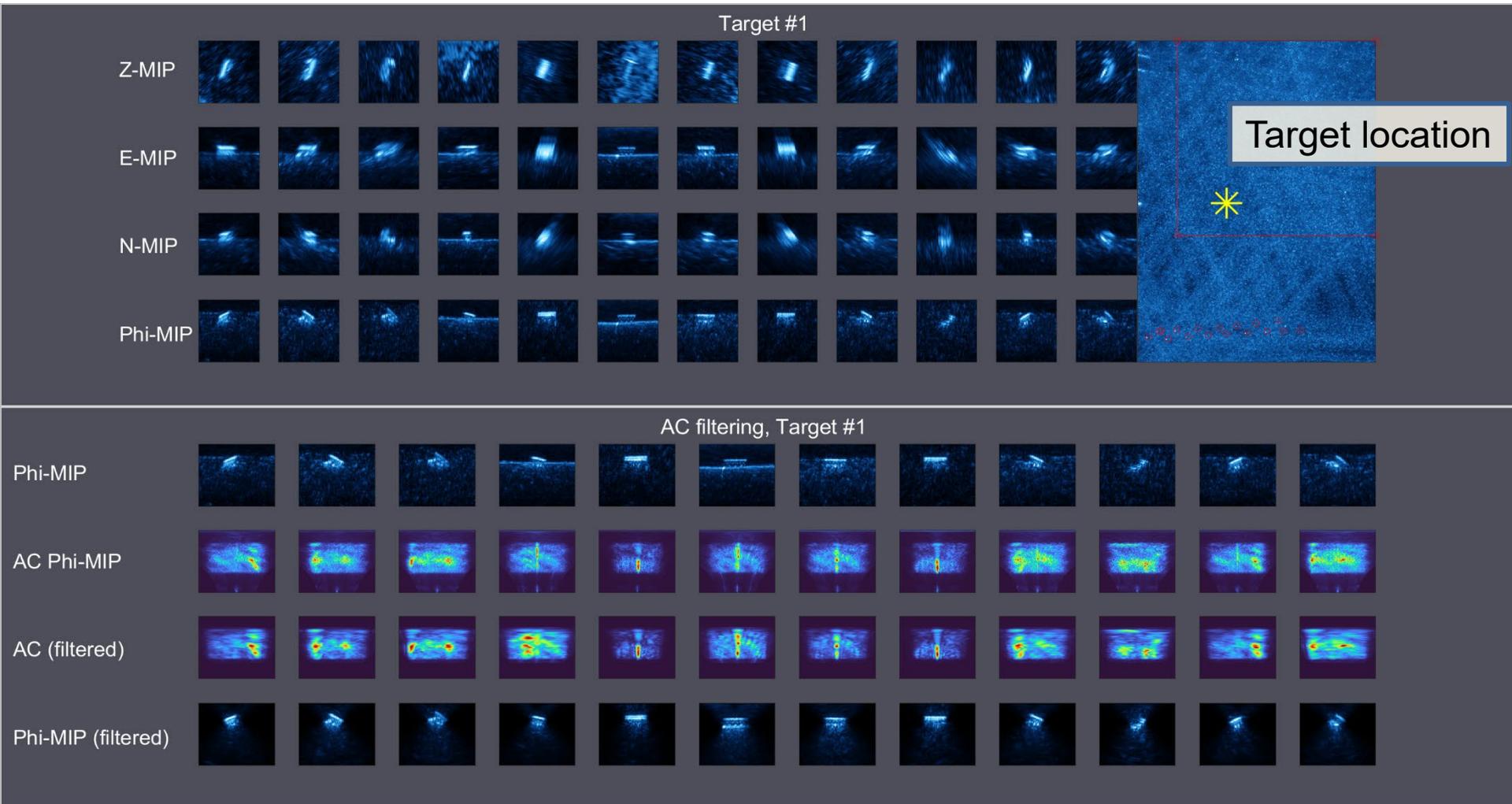


ROI Visualization and Data Extraction

- Tools
 - Patch MIP full-set data display
 - Simultaneous 3D ROI rotations for all observations
 - Acoustic-response data extraction

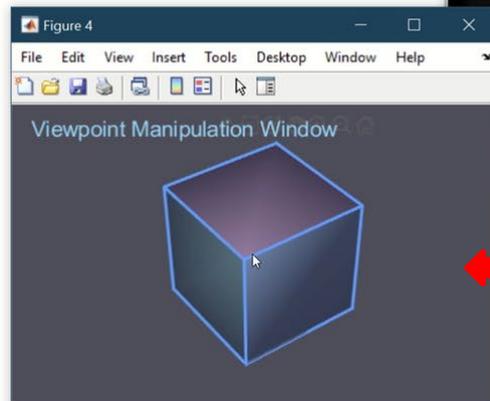
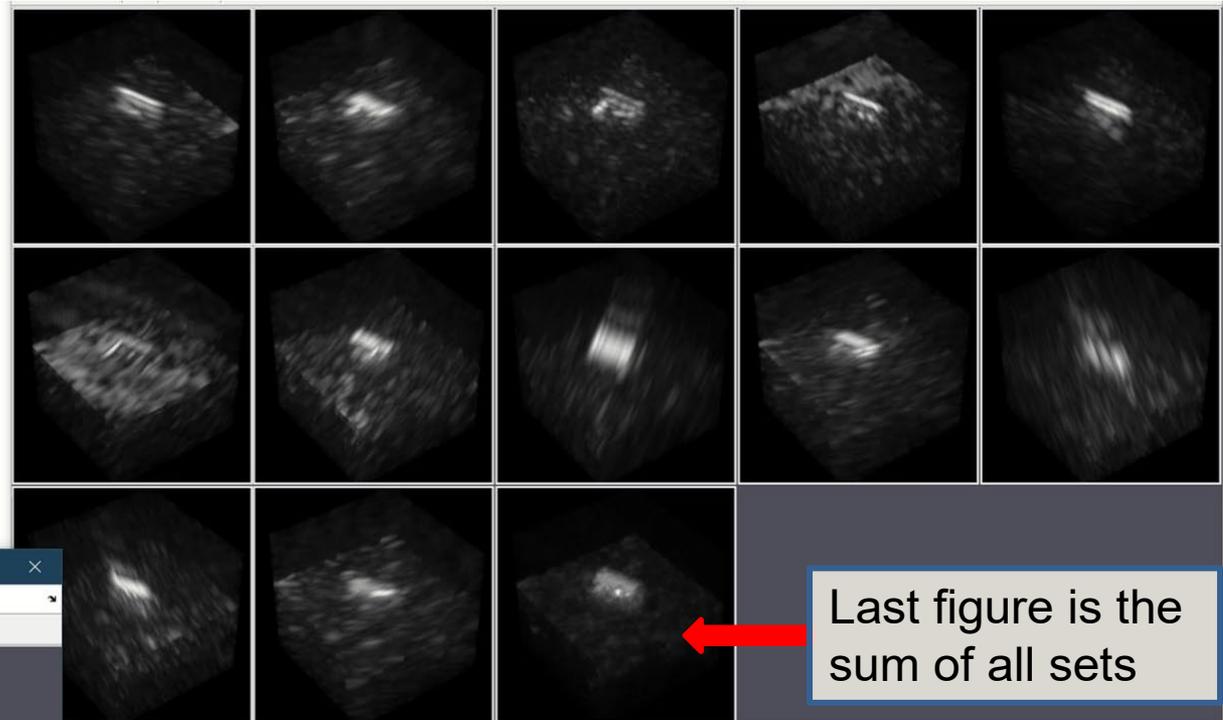
ROI Data Visualization: Full Set MIPS

All Observations of a Single Target



3D Visualization and Rotation

Simultaneous

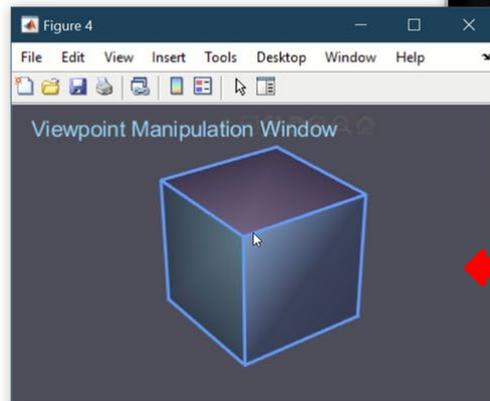
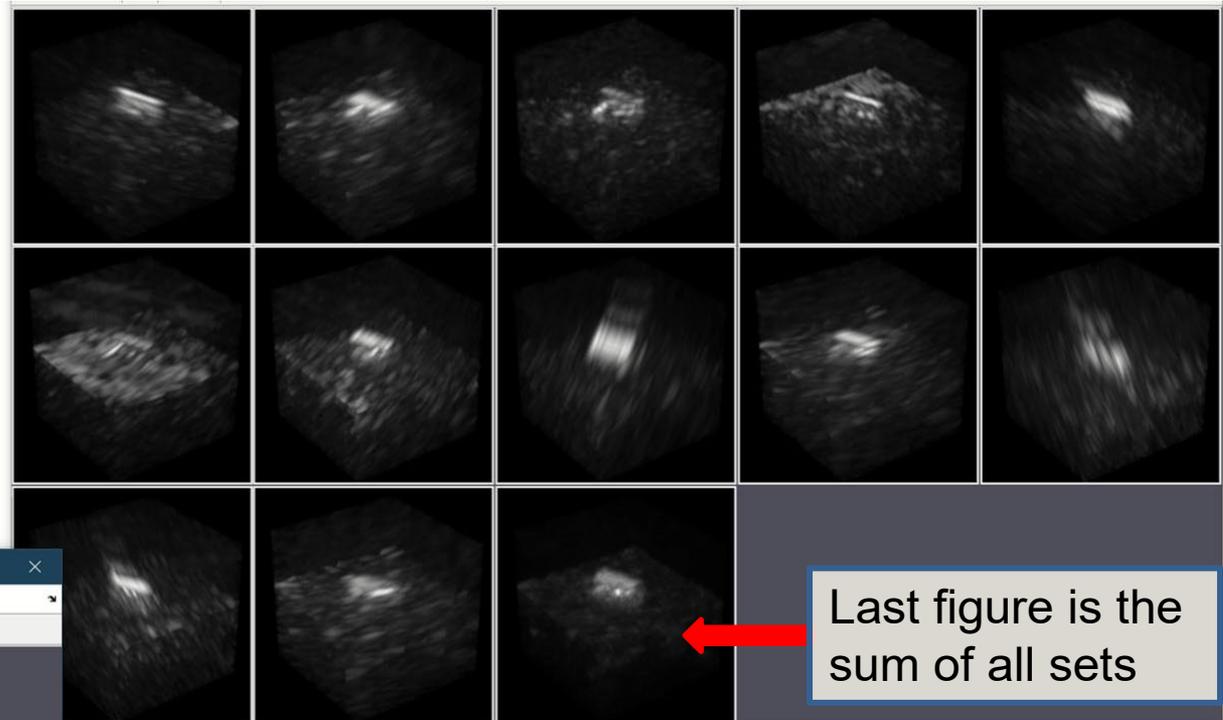


Last figure is the sum of all sets

View-point manipulation window:
drag to change perspective

3D Visualization and Rotation

Simultaneous

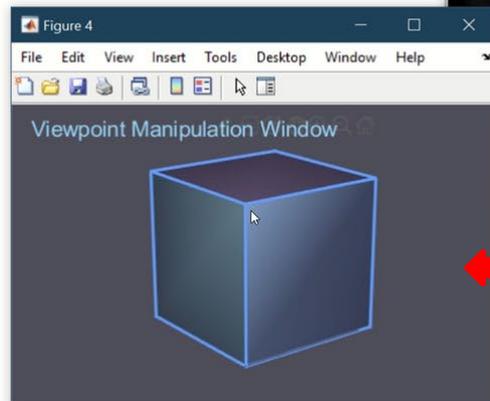
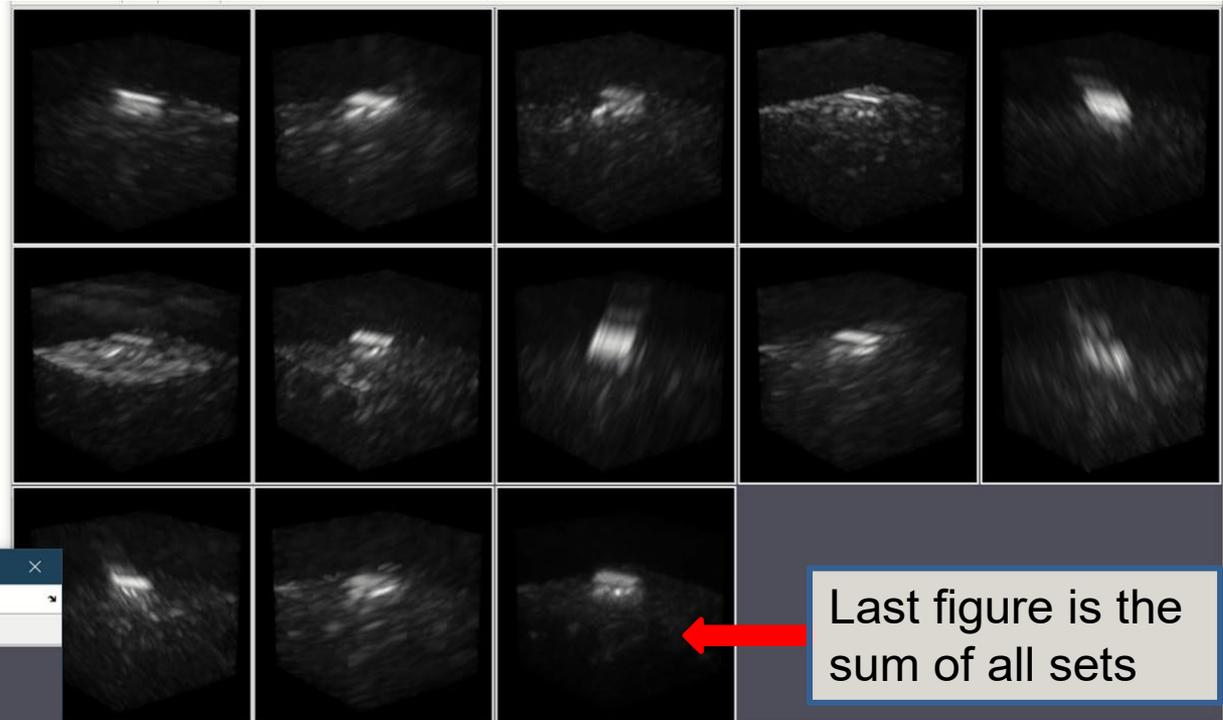


View-point manipulation window:
drag to change perspective

Last figure is the
sum of all sets

3D Visualization and Rotation

Simultaneous

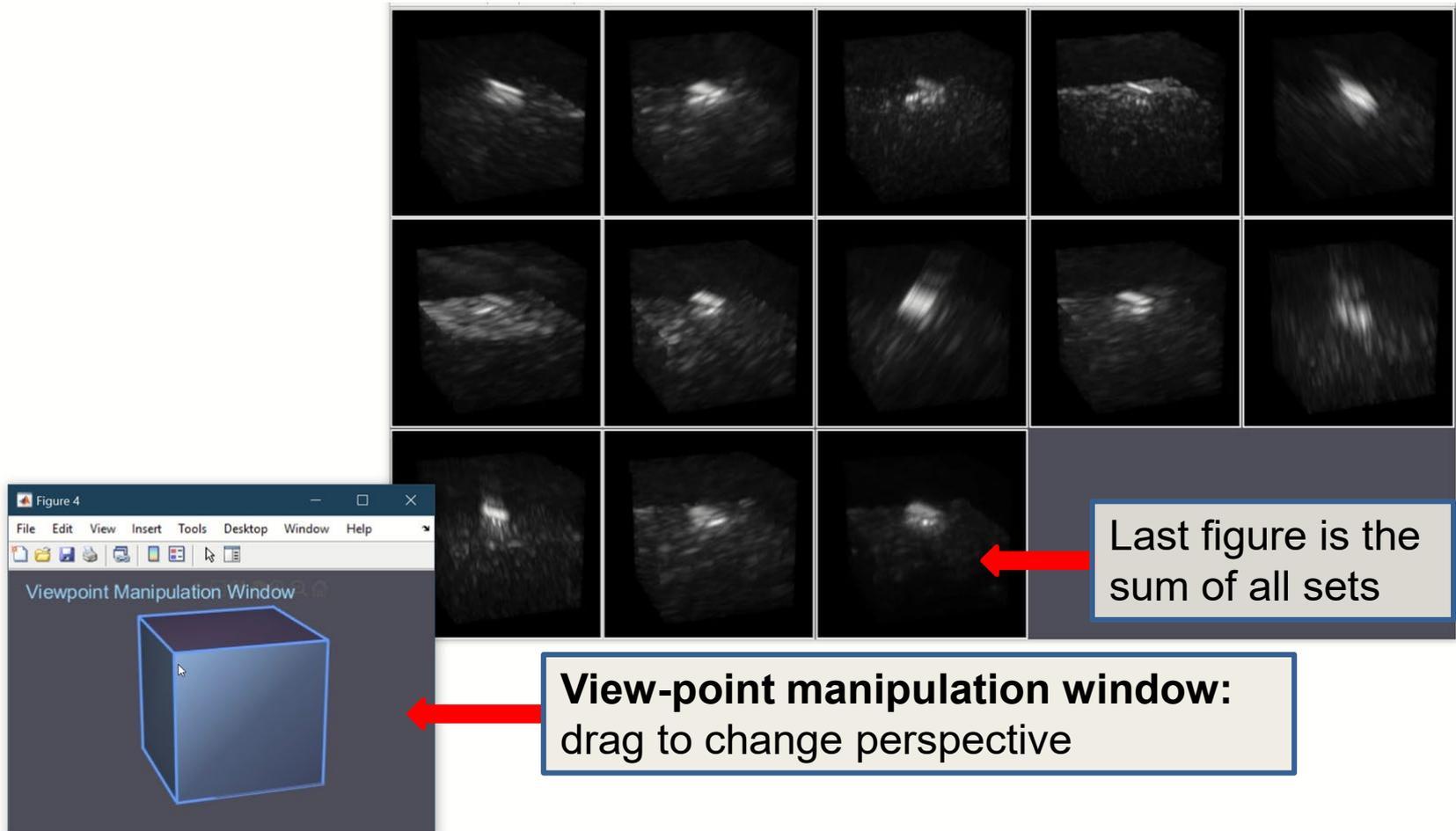


View-point manipulation window:
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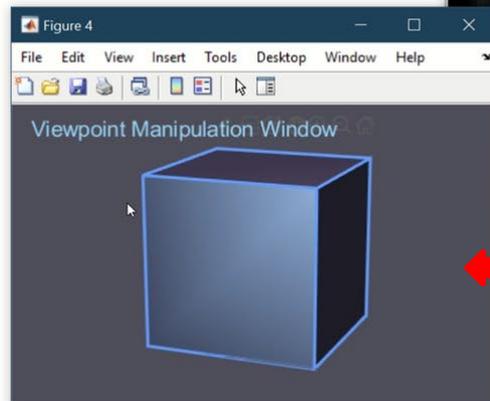
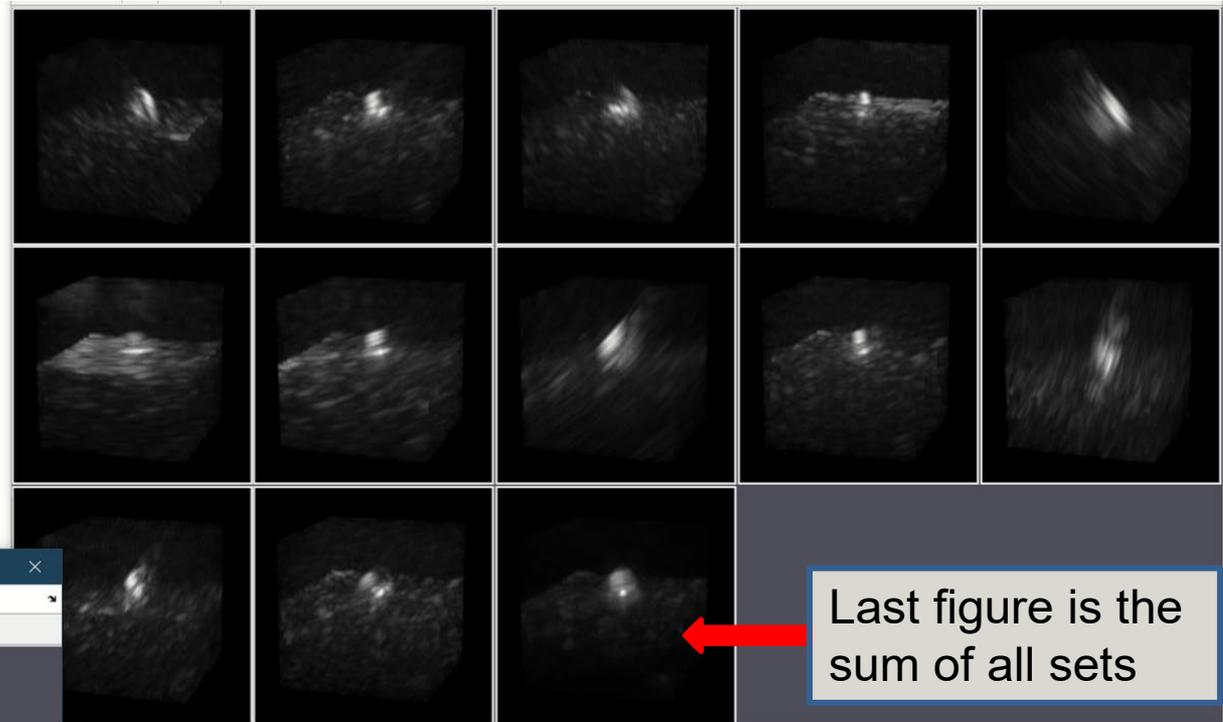
3D Visualization and Rotation

Simultaneous



3D Visualization and Rotation

Simultaneous

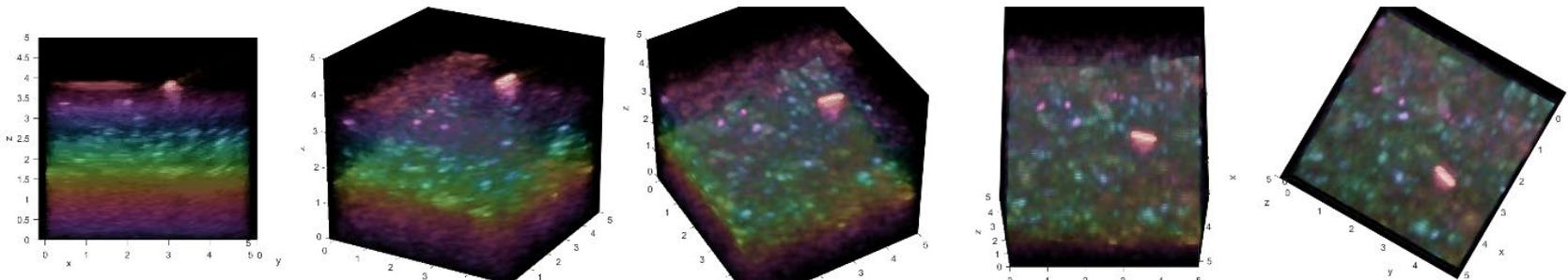
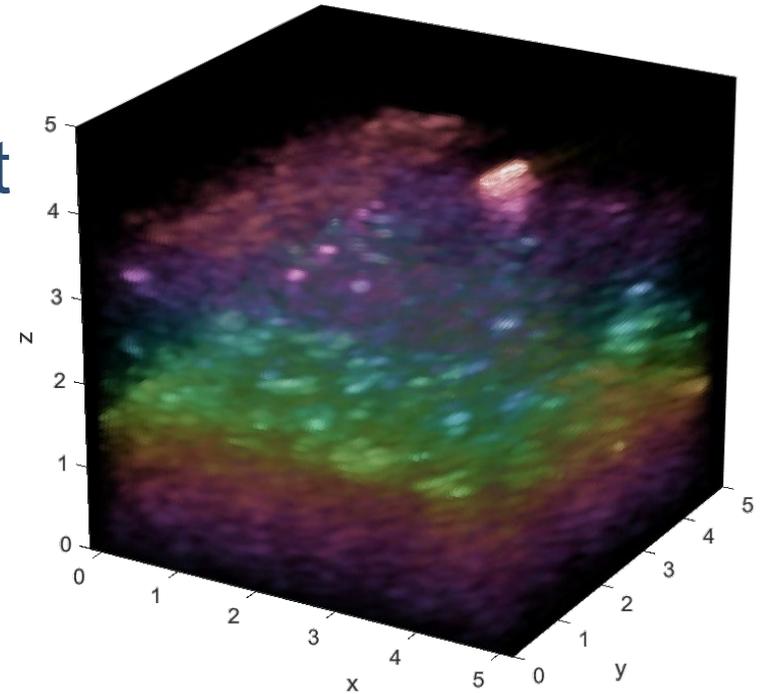


Last figure is the sum of all sets

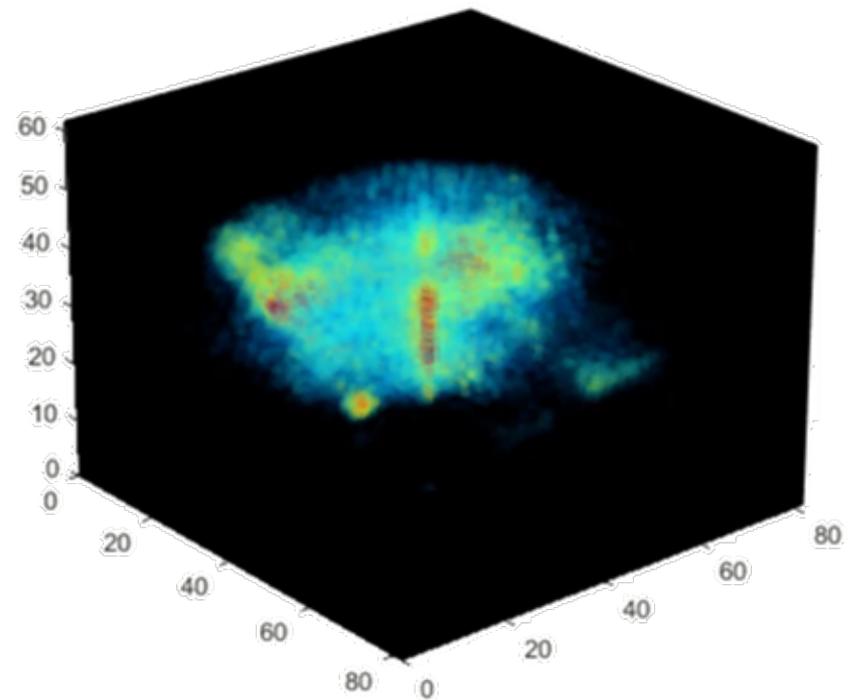
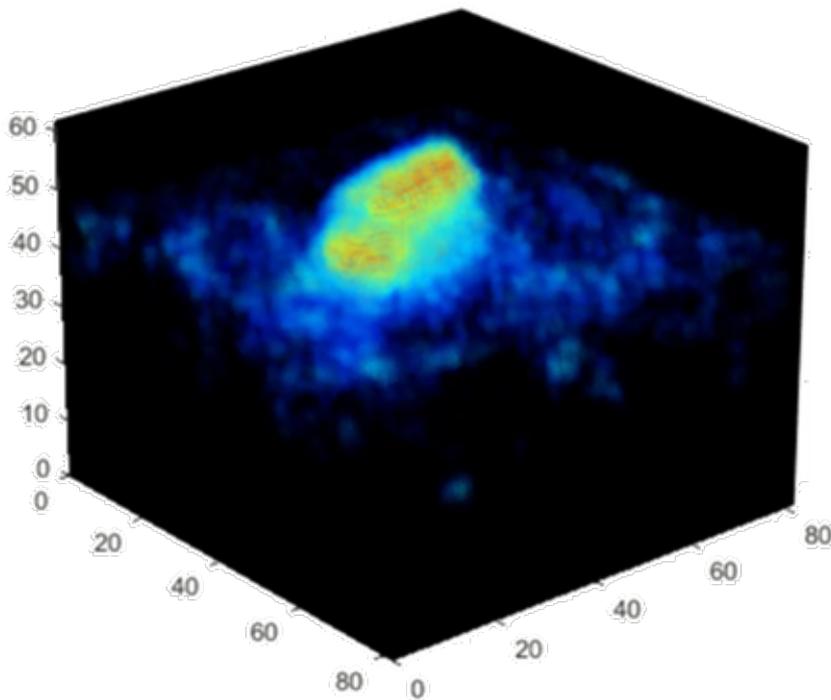
View-point manipulation window:
drag to change perspective

3D ROI Visualization with VOXview

- 3D rendering tool
 - Developed in this project
 - Uses alpha-rendering
 - Provides improved coloration options



3D ROI Visualization with VOXview



So... Sequim Bay Results?

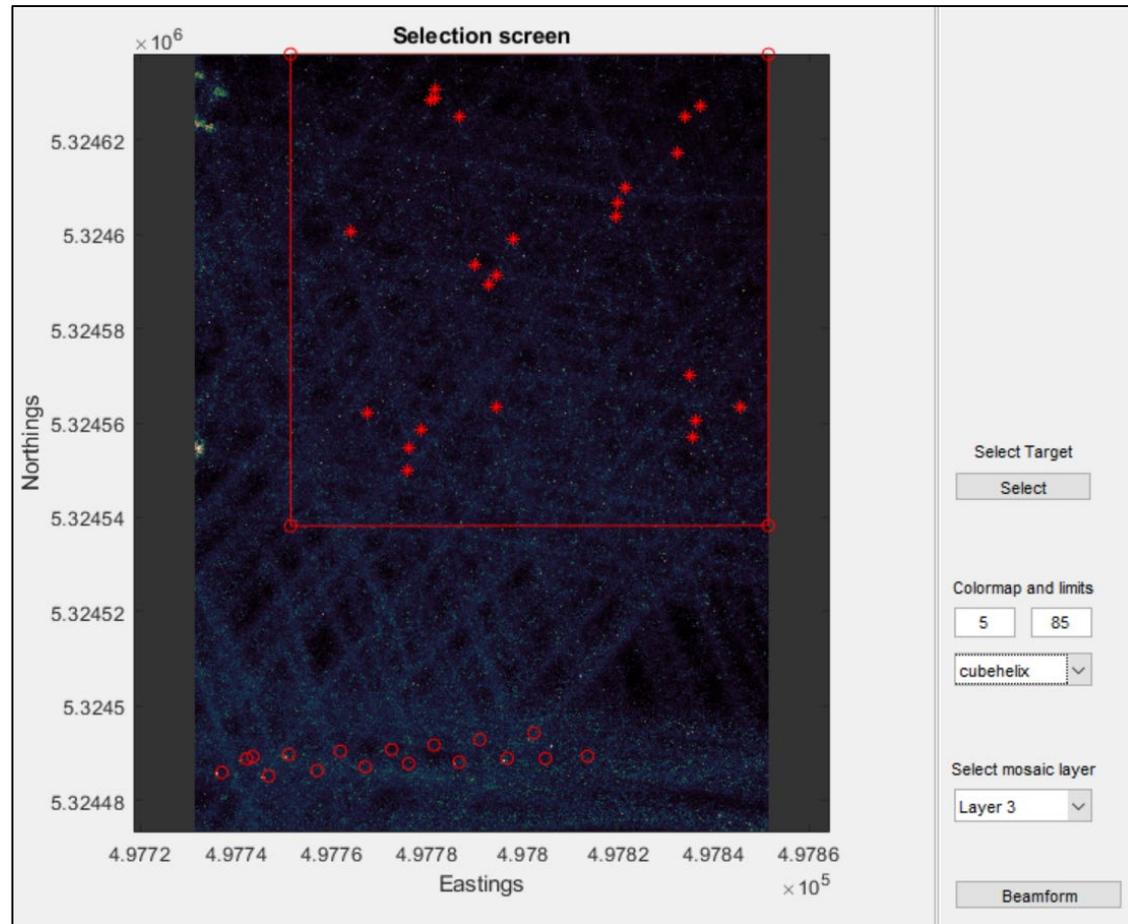
- Process
 - 4 mosaic layers used for target detection
 - No ATR was incorporated: All ROI's were selected manually
 - ROI's are best guesses based on the hunches of this tool designer!

Notes: ATR = automatic target recognition

Initial Detections

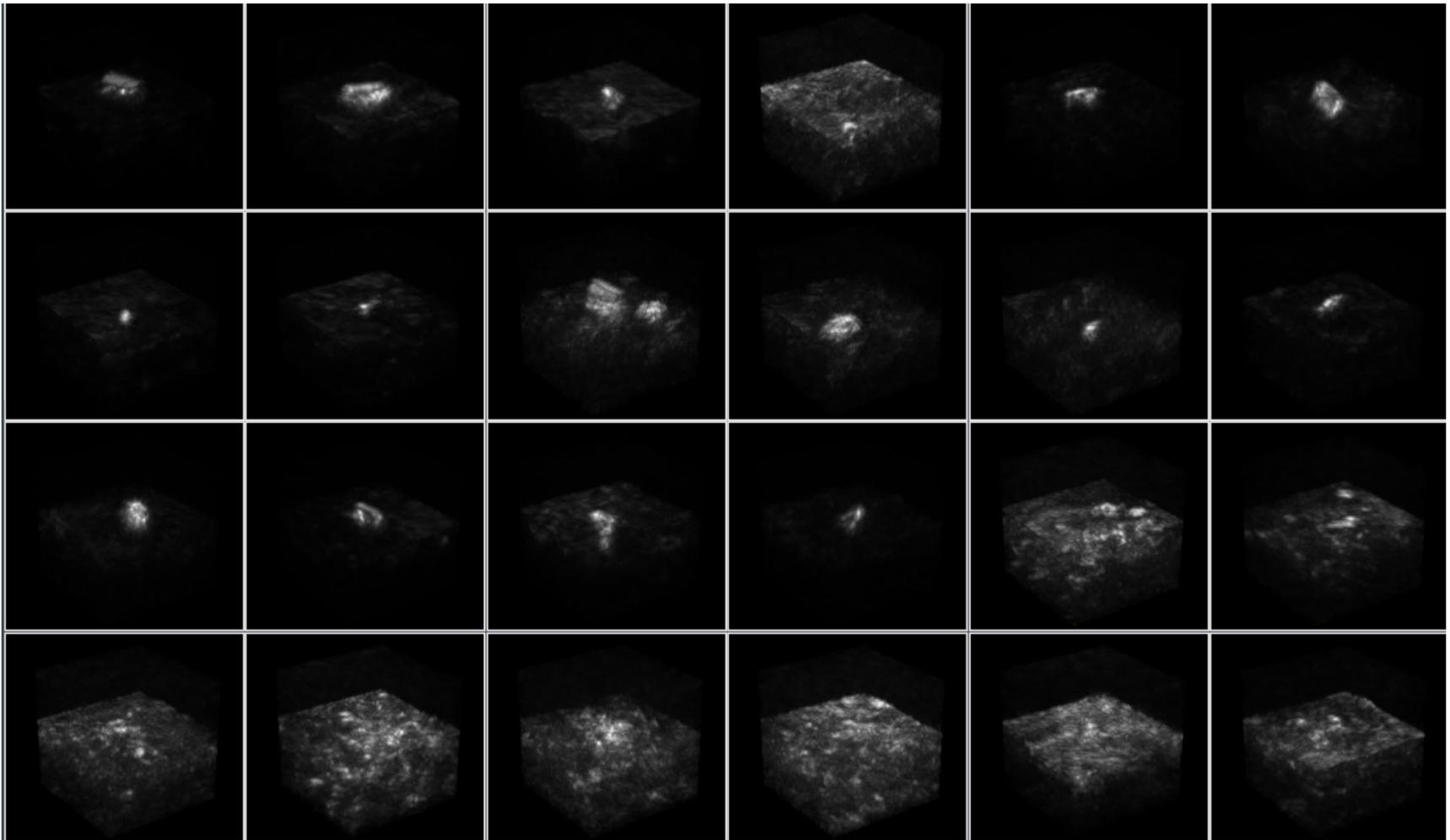
Using the ROI Selection Tool

- 24 manual detections
- 98 contributing scans
- 271 looks processed
- 542 volumes beamformed
- 28 minutes of computation time



Multilook Images

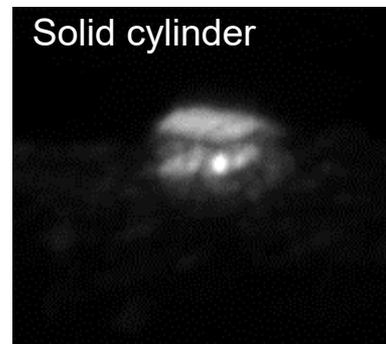
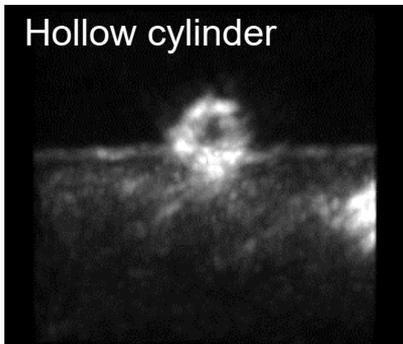
Viewed in 3D Using Vlink



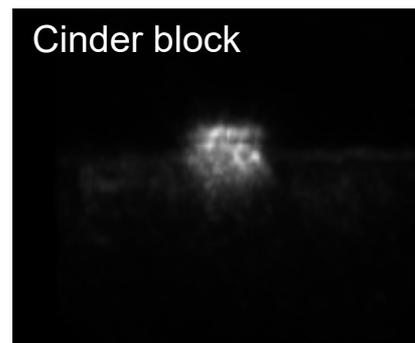
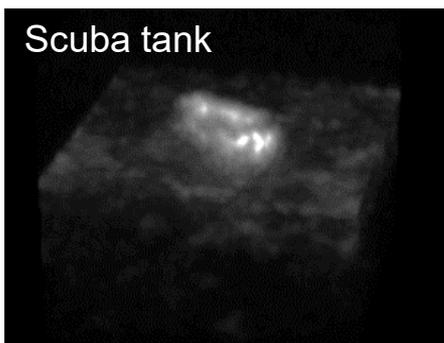
Multilook Images

Viewed in 3D Using Vlink

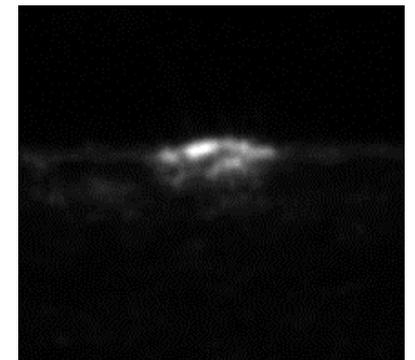
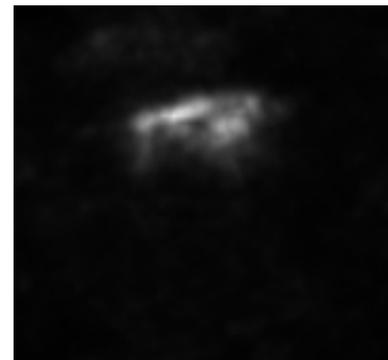
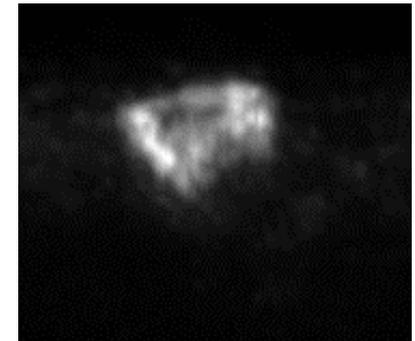
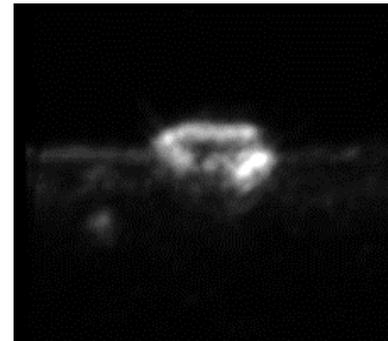
The science targets seem pretty obvious:



Some of the clutter seems potentially identifiable as well:

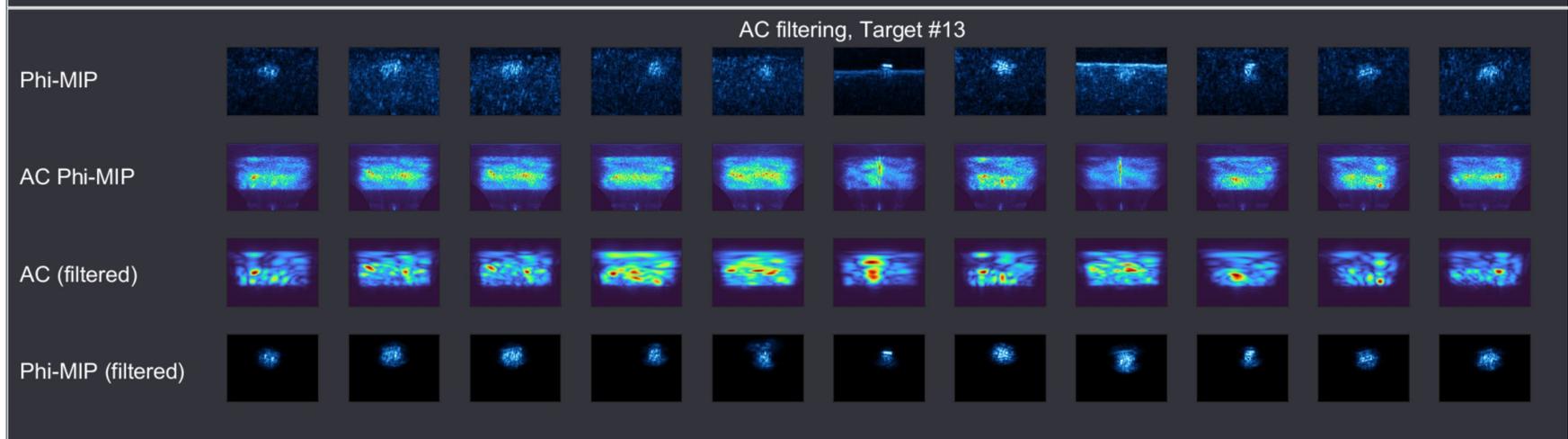
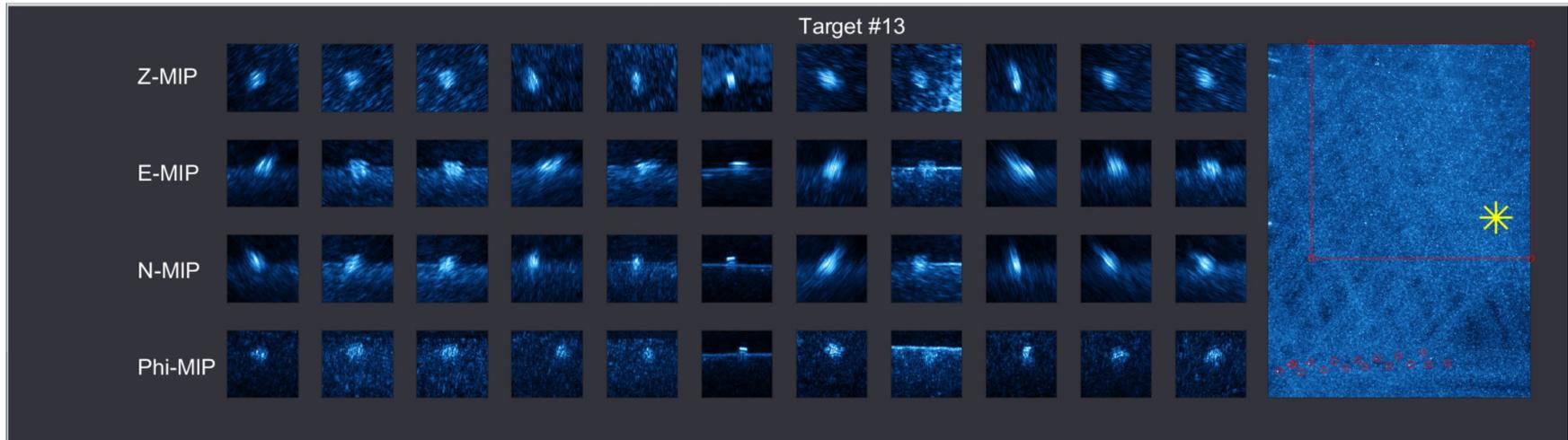
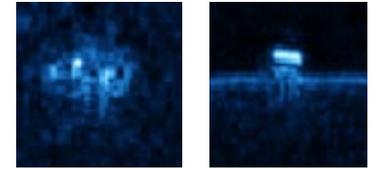


Some objects have very distinct UXO / bullet shaped profiles:

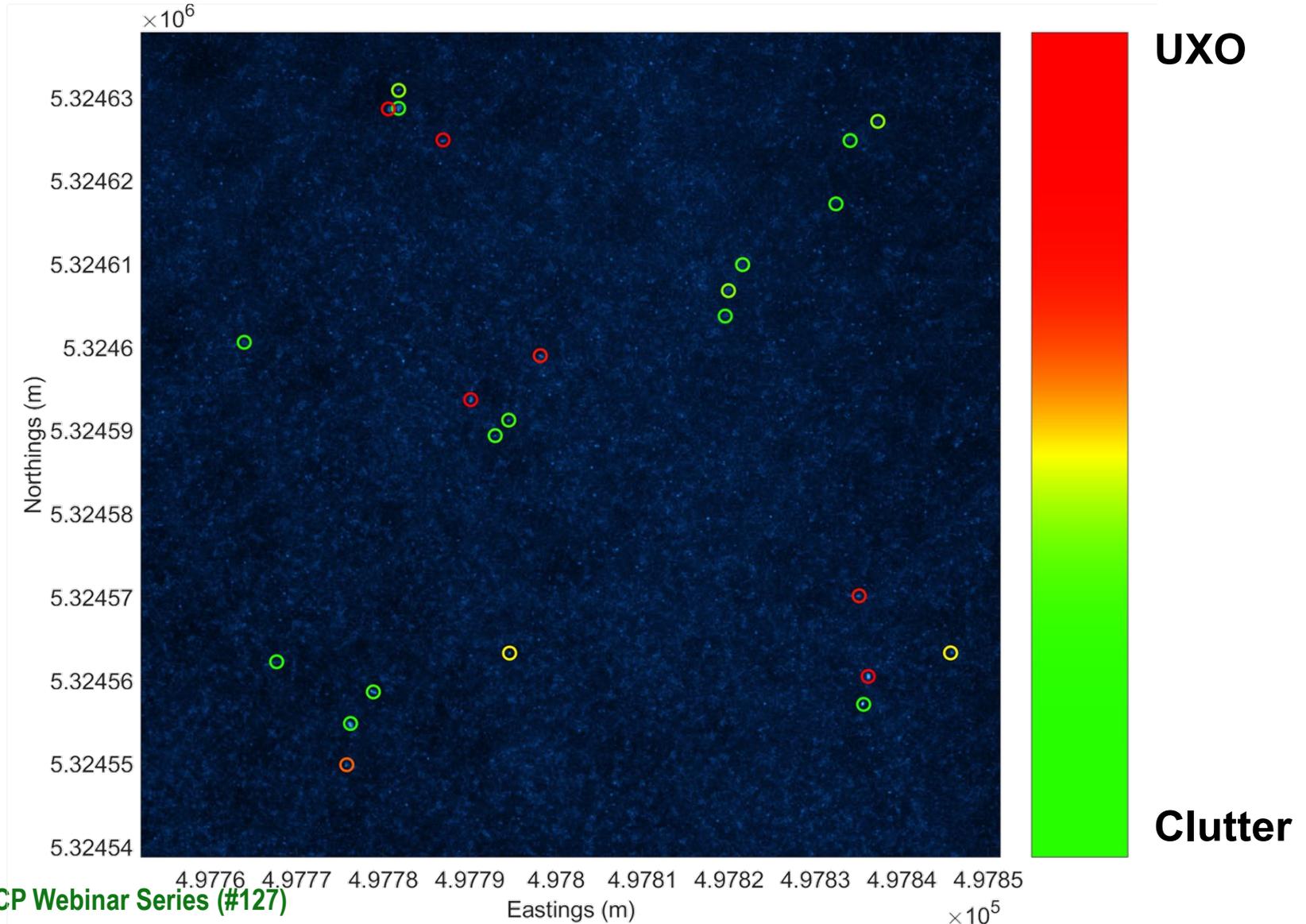


Full-Set MIP's

Cinder Block Example

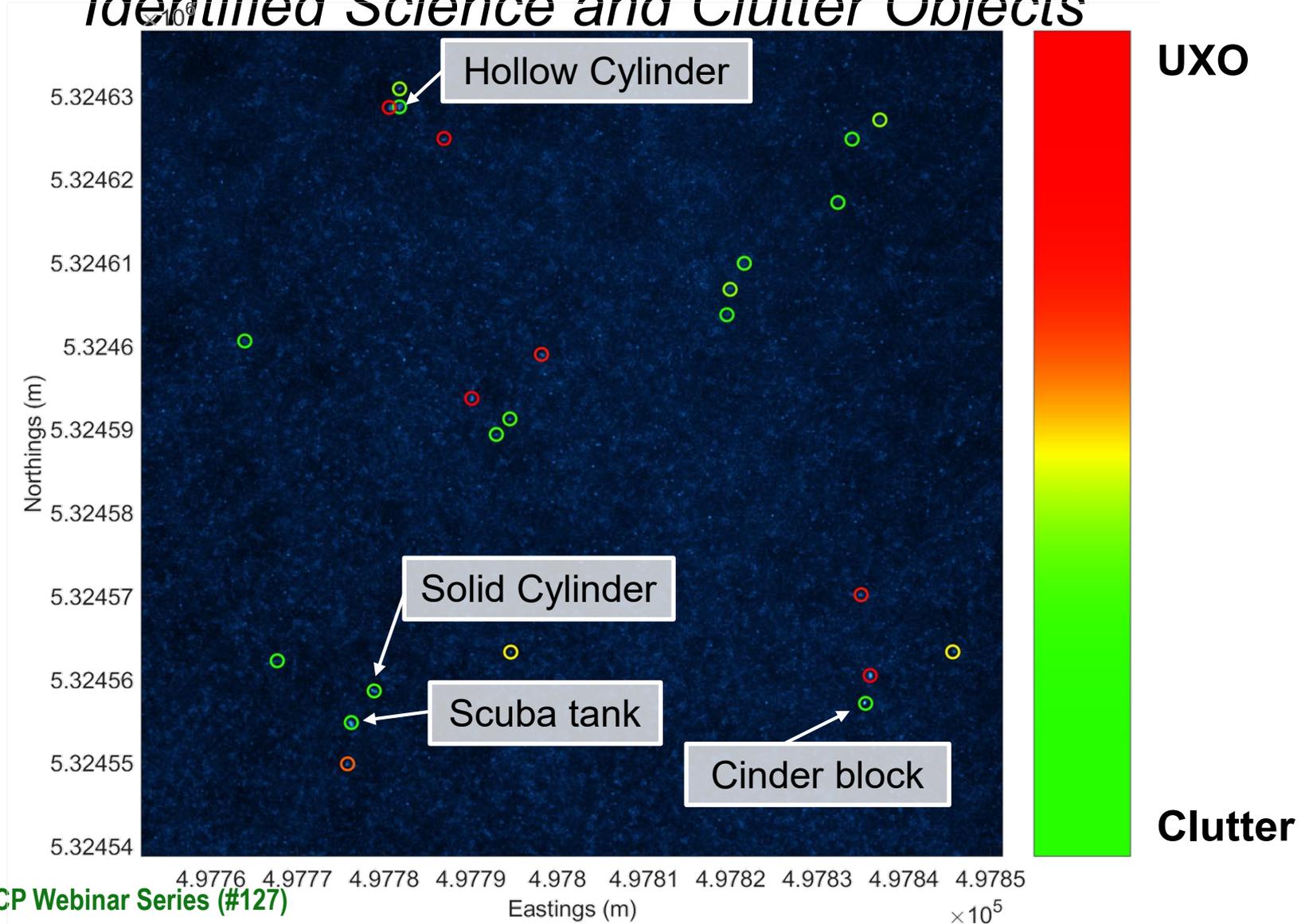


Target Class Estimation Map



Target Class Estimation Map

Identified Science and Clutter Objects



Data Classification Exercise Takeaways

- Results are best-guesses from looking at 2 data products
 - 3D summed imagery (Vlink)
 - Full-set MIPS with AC phi-MIPs
- Lots of room for improvement!
- How close am I?
 - PNNL hasn't released the answer key yet!
- Workflow was extremely simple
- ROI detection data is prepped for feeding into more advanced classifiers

Conclusions

- eBOSS Toolkit will be a convenient tool for post-processing eBOSS data captured by the MuST and identifying targets
- Additional tools, packaging, and refinement are works in progress!
- MuSTLive allows users to view and interact with data as it is being captured by the eBOSS
- The Sequim Bay testbed survey provided excellent data for tool development

Benefits to DoD

- High resolution sub-sediment imaging
- Classification of buried objects
- Data export for ATR
- Data driven mosaicking
- Major navigation improvements
- Simple tools for non-experts

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- EdgeTech (Jason Sara, Kevin Rychert)
- PNNL

Q&A Session 2



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

