PennState
Applied Research Laboratory

Sediment Volume Search Sonar

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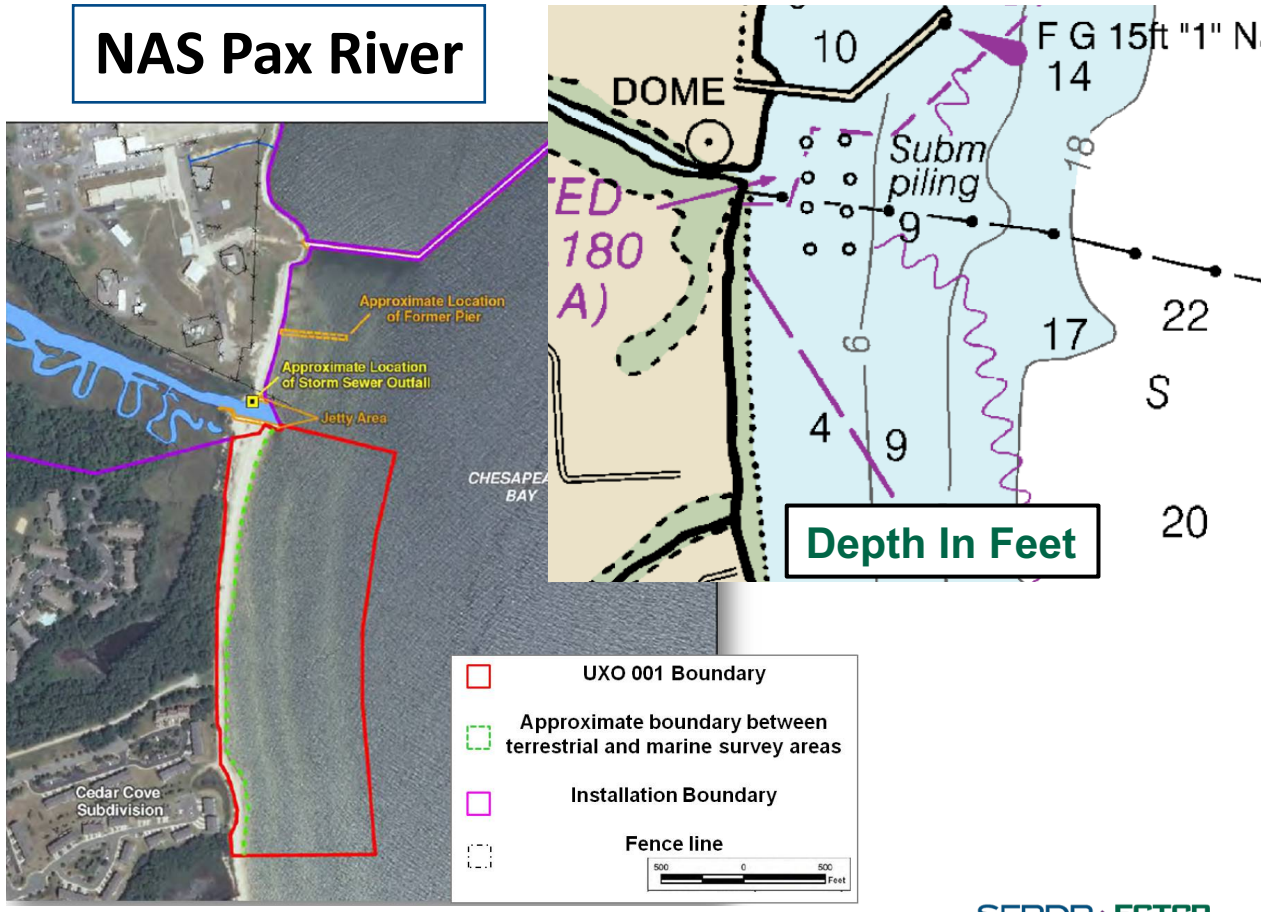
SERDP • ESTCP
SYMPOSIUM
2018 | Enhancing DoD's Mission Effectiveness

Shallow Water UXO Munitions Remediation Problem

- A capability gap exists for the detailed survey of UXO in very shallow water (1-5 meters depth)
- These shallow environments make up a substantial fraction of SERDPs sites and the potential for human/UXO interaction is high
- Current sensors and platforms are not well suited to conducting surveys in these water depths



Sediment Volume Search Sonar (SVSS)

- Program goal is the design, demonstration and documentation of a system capable of very-shallow-water, buried-UXO imaging
- Operation in < 5m of water presents a number of challenges
  - Sonar system deployment
  - Multipath interference
  - Limited area coverage
- Technology development focus
  - Surface craft in very shallow water
  - Sonar system design and signal processing for buried UXO imaging
- Project progress and results
  - Modeling and simulation effort is completed
  - Field experiments conducted analysis ongoing

Sediment Volume Search Sonar Project Team

- Applied Research Laboratory – Pennsylvania State University
  - Daniel Brown, PI
  - Shawn Johnson, Co-PI
  - Cale Brownstead, Co-PI

- Applied Physics Laboratory – University of Washington
  - Aubrey España, PI
  - Steve Kargl, Co-PI

- Naval Research Laboratory – Stennis Space Center
  - Joseph Calantoni, PI
  - Edward Braithwaite, Lead Engineer

Technical Approach

Phase 1 Simulation and Modeling

- Leverage/extend models for producing synthetic sonar data
- Adapt existing signal processing for volumetric imaging
- Analyze and quantify expected system performance

Phase 2 Prototype Demonstration

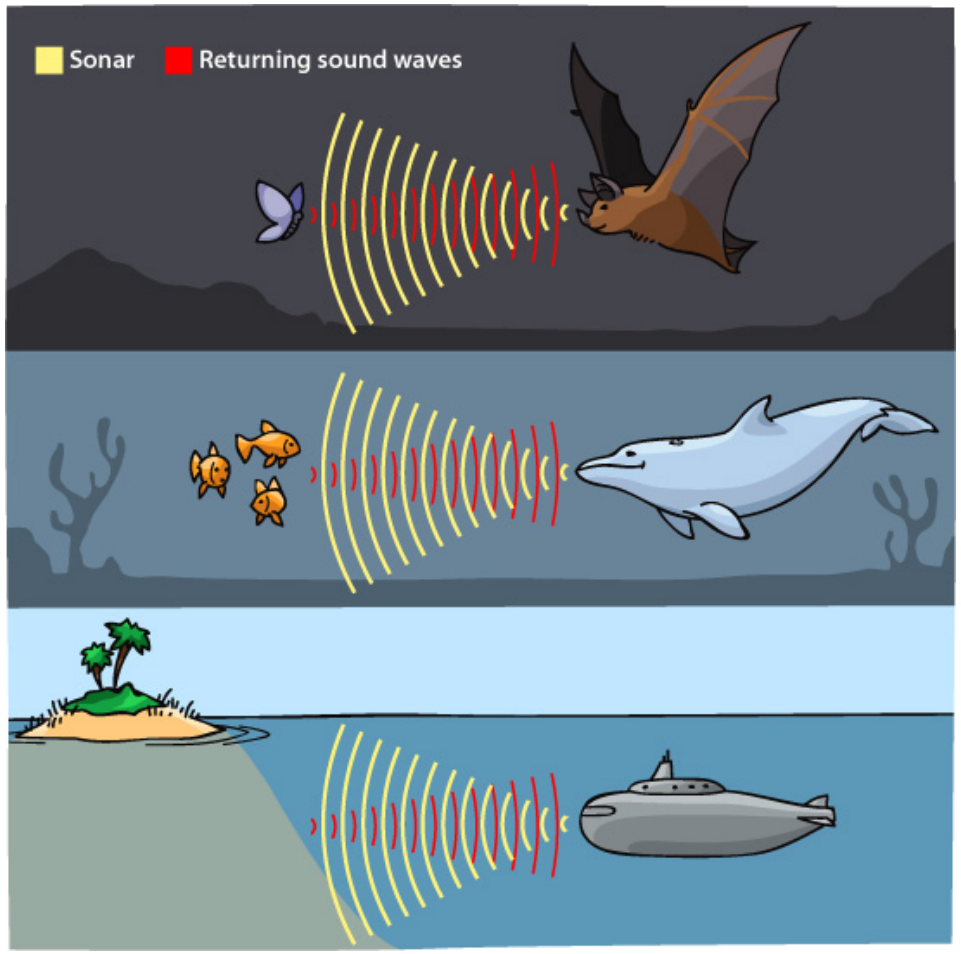
- Reconfigure existing test platform and sonar hardware
- Modify signal processing algorithms based on field data analysis
- Demonstrate performance for UXO detection

Phase 3 System Demonstration

- Purpose-built hardware design based on lessons learned
- Further refinement of signal processing and data visualization
- Demonstrate performance for UXO detection

Using Sound to Find Objects

- Sound waves are used by a number of biologic and man-made systems for object location
- Echolocation (Bats & Dolphins):
  - Direct sound and listen for echo
- Beamforming (Medical Ultrasound):
  - Uses more advanced signal processing to search a number of directions
- **SVSS studies techniques similar to medical ultrasound to detect buried unexploded ordnance**



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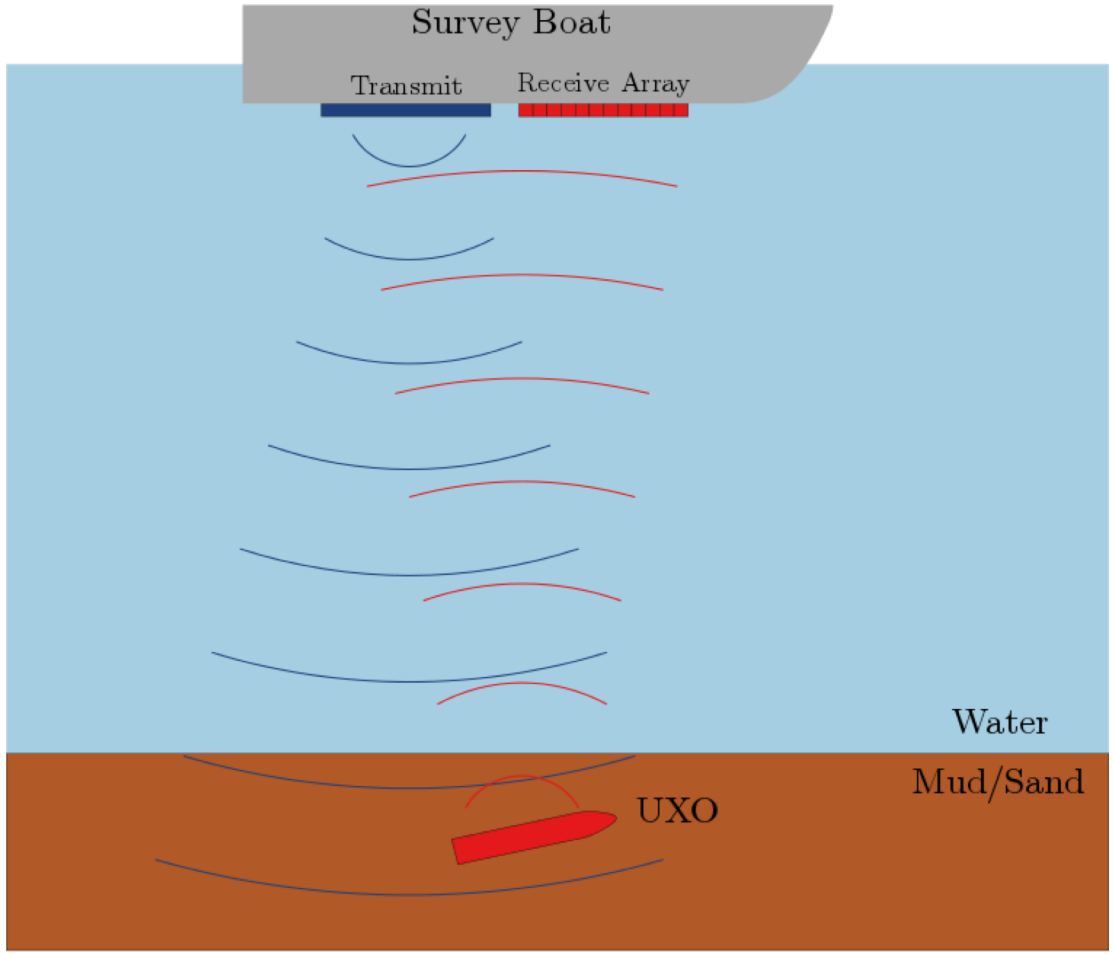
Using Sonar to Find Buried Unexploded Ordnance

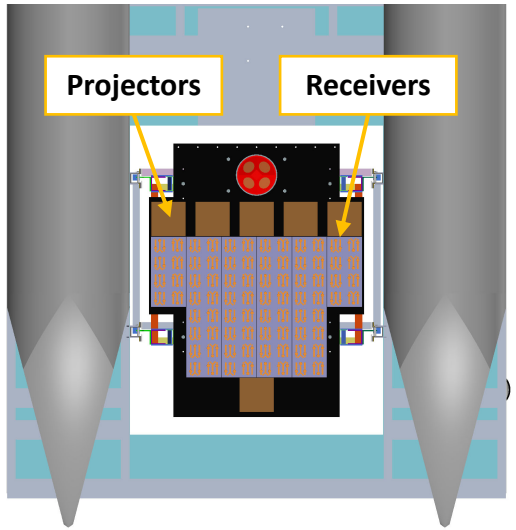
- Sonar system is integrated to a boat used to survey a remediation site
- Send out short pulses of sound from the transmitter (speaker)
- Receive echoes from the seafloor and ordnance with a set of receivers (microphones)
- Process these echoes to create imagery to find the ordnance



Sediment Volume Search Sonar: Prototype Sensor Design

- Modeling and simulation results informed the prototype sensor design
  - Significant leverage of existing hardware for demonstration
- Surface craft permits operation in water depths less than 1 m
- Reconfigurable data acquisition system for experimentation

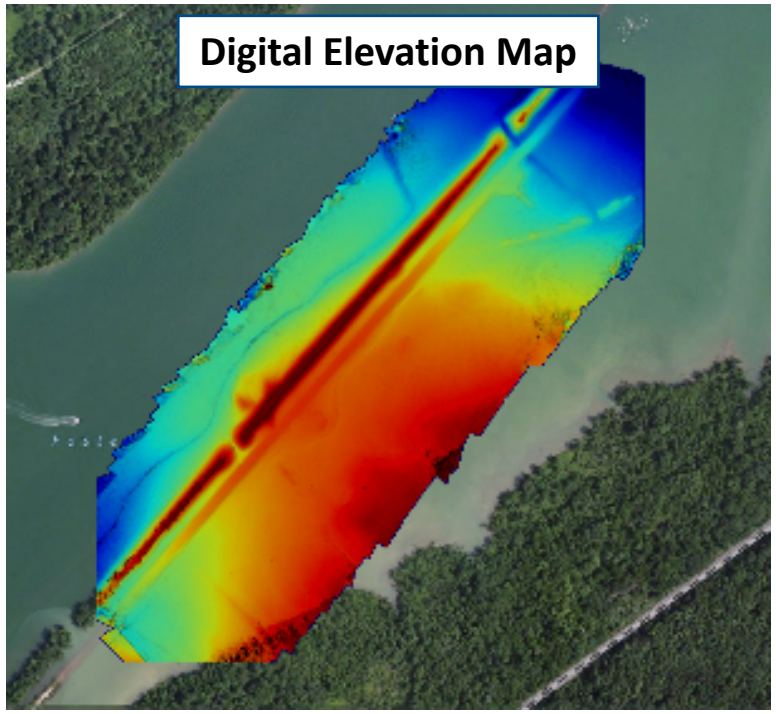
Sonar Array Schematic



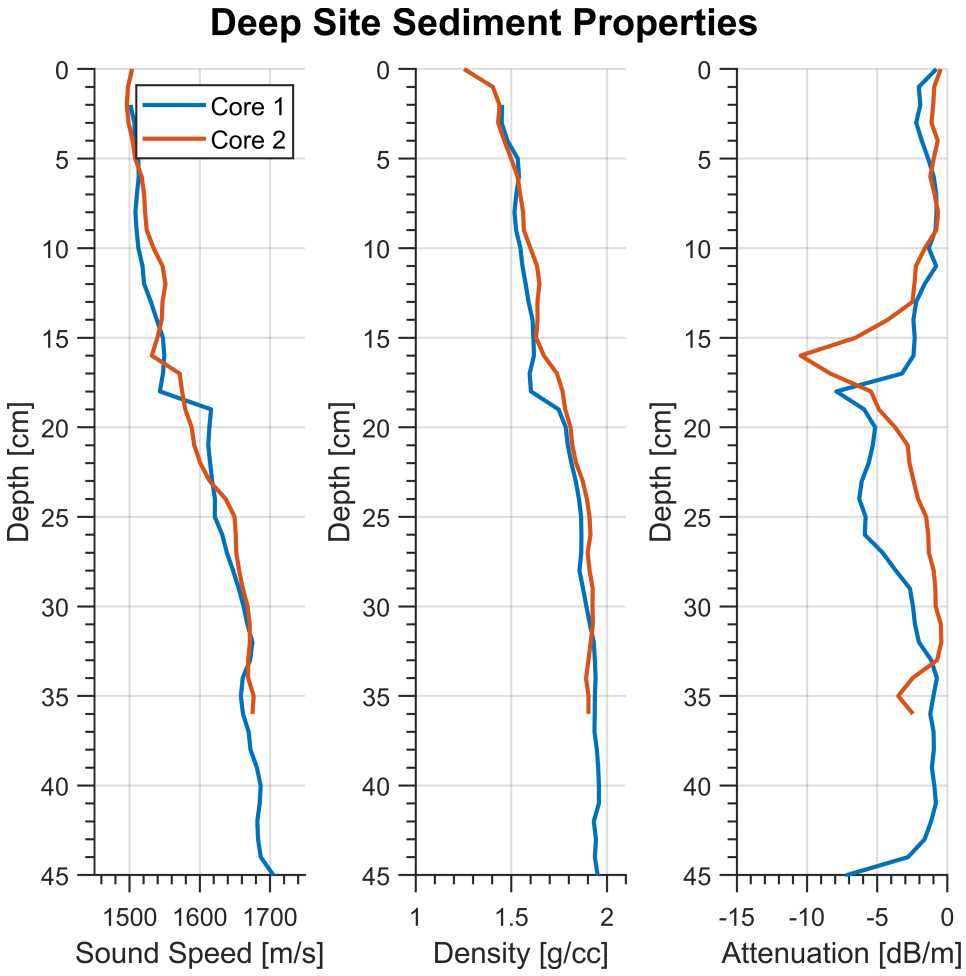
Sound Hunter Test Platform

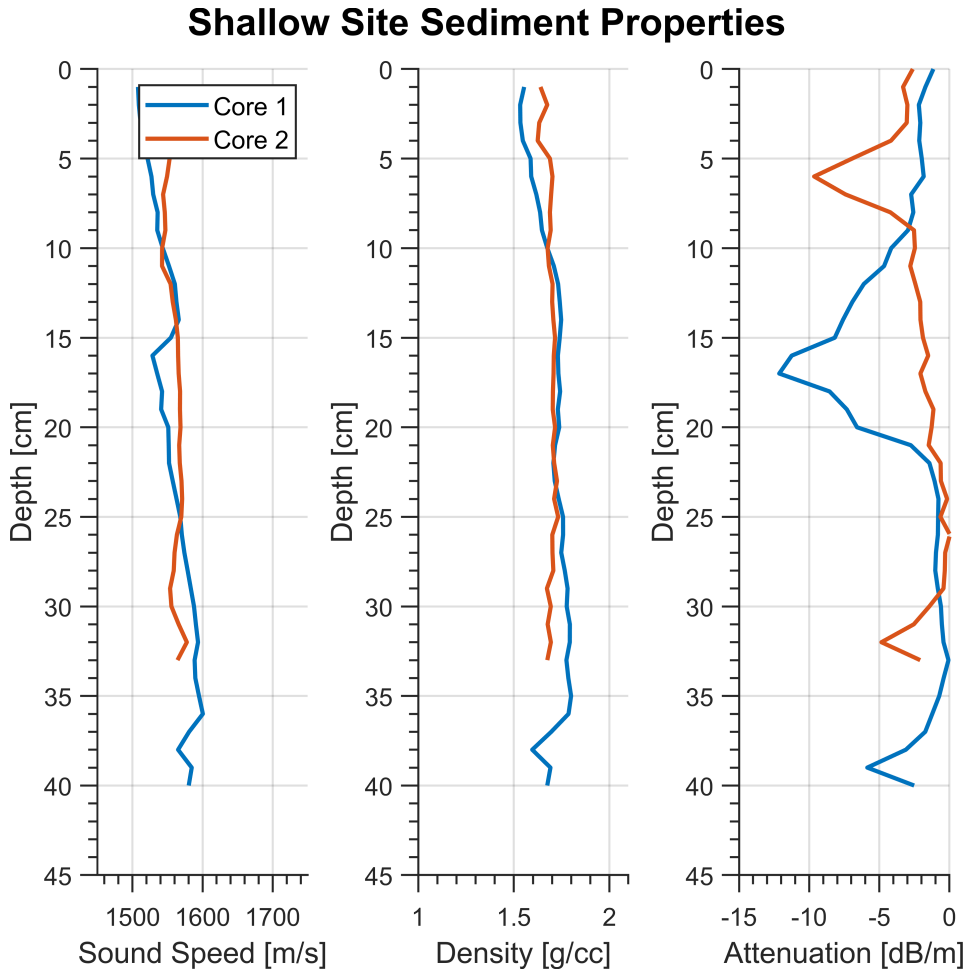
80 channel receiver	Real-time kinematic GPS	Water temperature sensor
6 channel transmitter	Fiber optic gyroscopic navigator	40 TB data storage
High-frequency sidescan	Acoustically quiet battery power	Gas and electric propulsion

Targets Installation and Characterization



Characterization of the Testing Environment

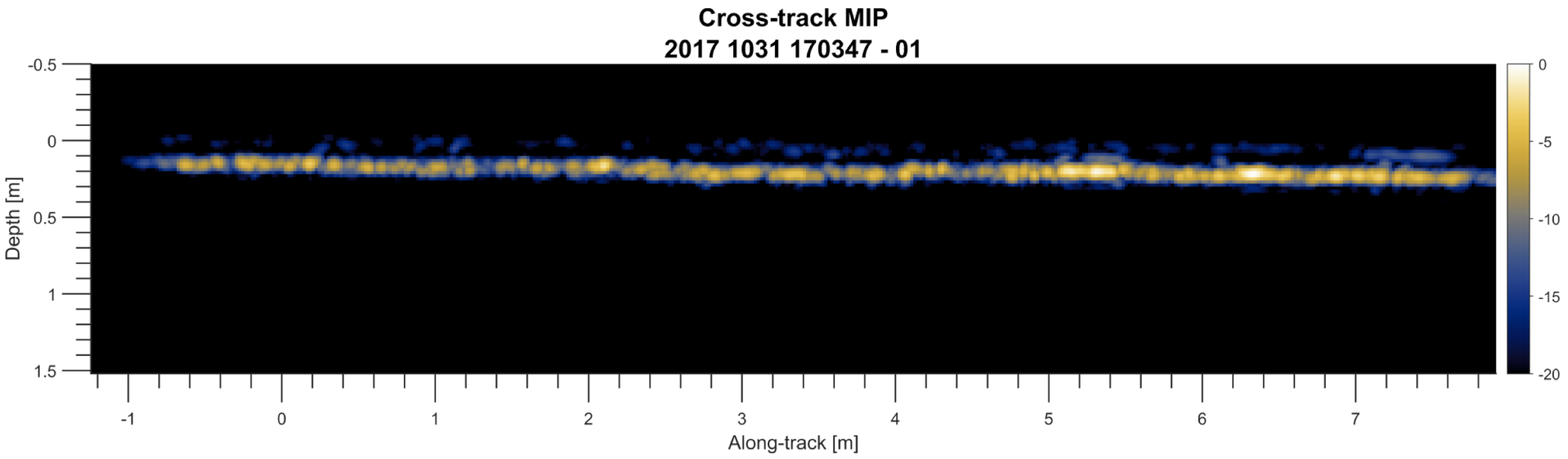




Sediment Properties Create Unwanted Imagery Effects

- Reflection and scattering at the boundary are proportional to contrast in sound speed and density
  - Strong Sediment Contrast → Strong Image Contrast
- Two negative effects: Targets obscured and wide image dynamic range

Raw Image
- 20 dB Logarithm Scale
- Thin upper layer visible
- Targets obscured



Making Wide Dynamic Range Imagery Visible to Humans

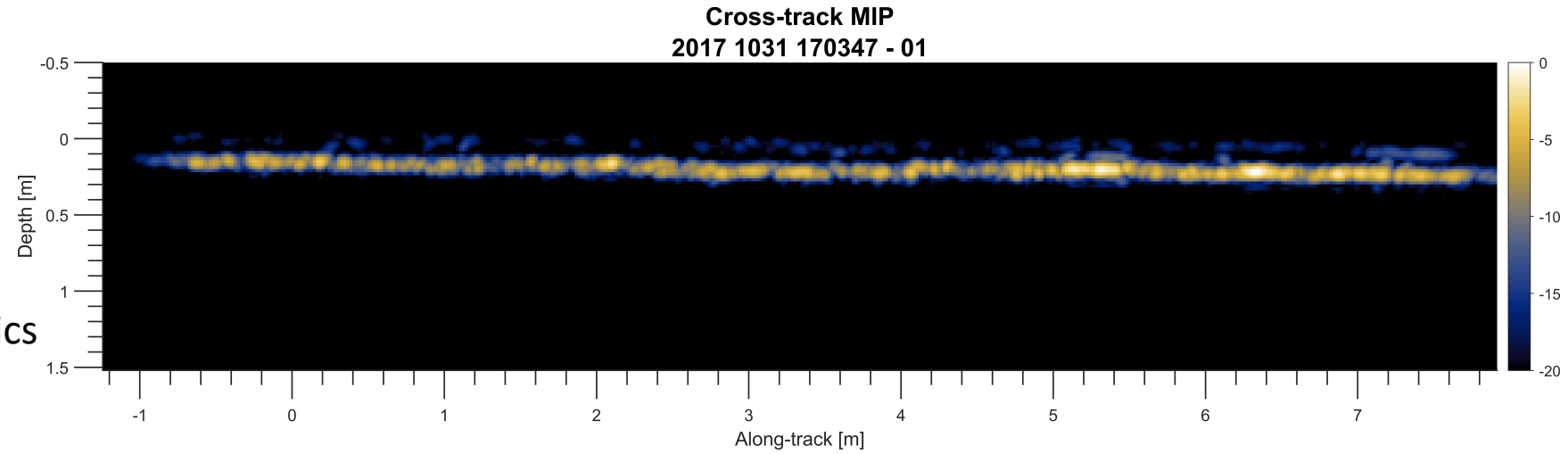
- Background estimation
  - Sliding window median calculated throughout the image
  - Divide original image by background estimate to "normalize" the data
- Dynamic range compression
  - Raw data: >80 dB
  - Computer displays: 30-40 dB
  - Scale data from large dynamic range to smaller dynamic range

Wide Dynamic Range Obscures Dark Regions

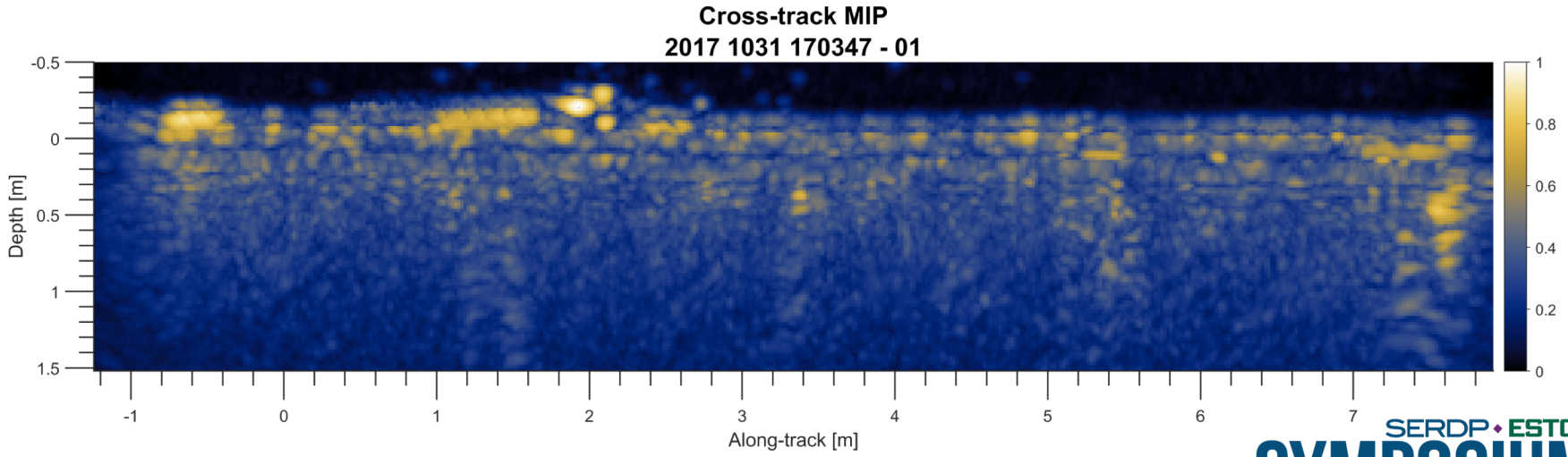
High Dynamic Range (HDR) Processing Reveals Details in Dark Regions

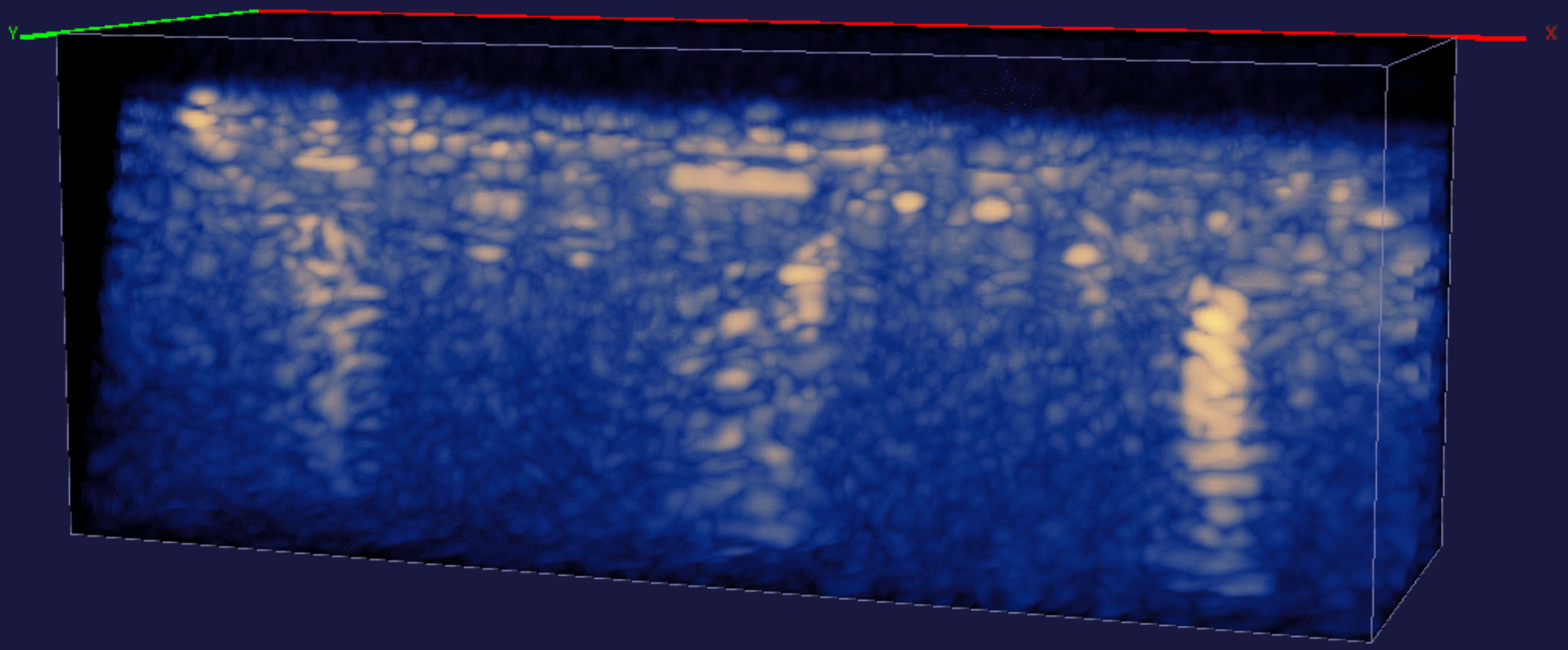
3D HDR Processing Applied to Reveal Targets

Raw Image
- 20 dB logarithmic scale
- Thin upper layer visible
- Targets obscured
- Pixel intensity linked to physics

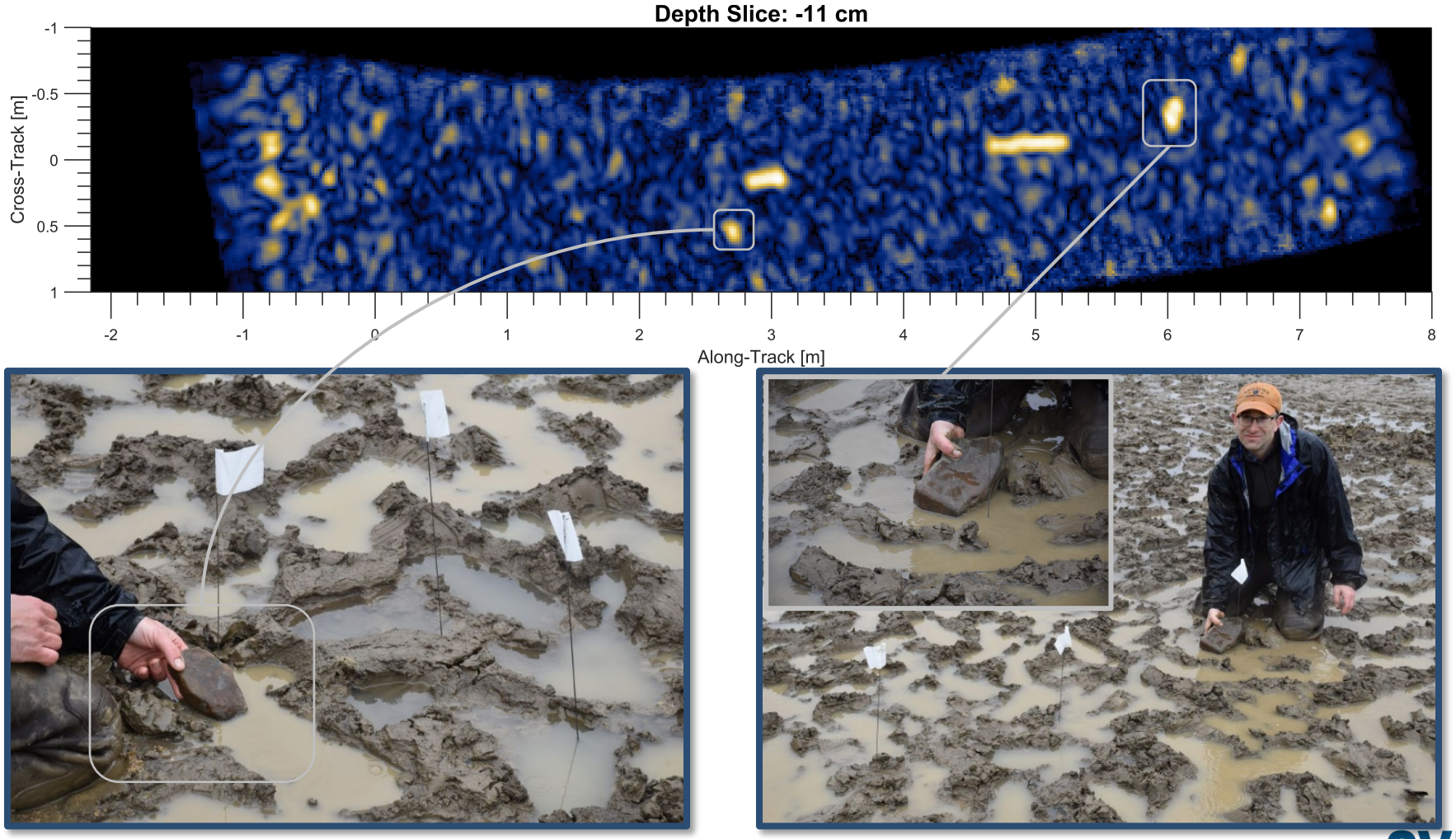


Compressed Image
- Non-linear scaling
- Layering removed
- Targets observable
- Pixel intensity is non-physical




Y
X

Identifying and Locating Clutter Observed in Imagery



Conclusion

Current Status

- Ordnance targets deployed in the shallow field
- Initiating a new projector design for improved response
- Sediment cores collected and characterized
- Improved survey operations
  - Operator Heads-up Display (HUD)
  - Improved ping timing
  - Real-time Kinematic GPS operations

Future Efforts

- Improve signal processing and data visualization tools
  - Adaptive data normalization
  - Target strength estimation
- Model-data comparison
  - Use cores and Phase 1 modeling to compare results
- Labeling collected data
  - Characterize performance
  - Building a detector