PILOT TESTS
In Real Port Environments

May 2025

Drammen Port

Drammen Port, Norway

Vol.2

Funded by
the European Union

From Research to Innovative Results

To ensure close collaboration between the project end users (security agencies and port authorities) and the technical partners throughout the project lifecycle, SMAUG will showcase and validate the multiple solutions developed during the project in 3 pilots. These will be executed, and their outcomes will be evaluated in a real port environment, specifically at the ports of Valencia (Spain), Elefsina (Greece), Heraklion (Greece), and Drammen (Norway).

- Pilot Summary

Drammen Port

Our partners from **the University of South-Eastern Norway** & **the Port of Drammen** are sharing the collective insights and updates on the technical validations conducted so far regarding a hydrophone test in the Svelvik Narrows.

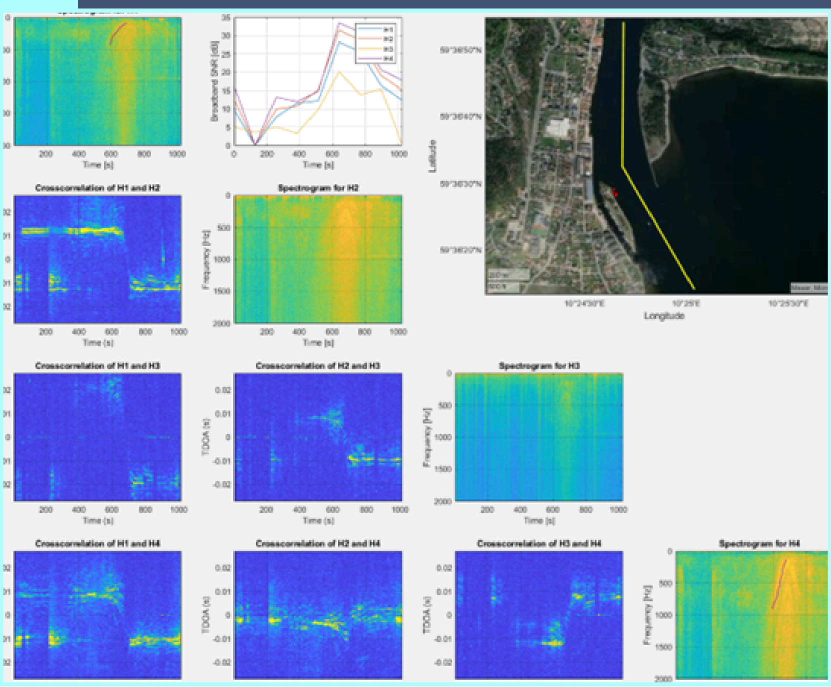
Underwater Detection in Svelvik Narrows

The figure illustrates the processed data. Spectrograms for four hydrophones (H1–H4) are shown along the diagonal panels. The upper-right panel provides a geographical overview, where red markers indicate hydrophone positions and the yellow line represents the approximate vessel trajectory.

Broadband signal-to-noise ratio (SNR) estimates for each hydrophone are presented in the top-left panel. The remaining panels display SCOT (Smoothed Coherence Transform) cross-correlation functions between all hydrophone pairs. White dashed lines denote expected time differences of arrival (TDOA) for a distant vessel located along the directions indicated by the yellow lines in the geographical plot.

Hydrophone positions were measured using RTK positioning, achieving centimetre-level accuracy. Deployment details are as follows:

- **H1:** Moored to the seafloor
- **H2:** Moored to the seafloor
- **H3:** Placed on the seafloor near the shoreline (approximate position; exact measurement unavailable)
- **H4:** Suspended approximately 1 m below the surface, attached to a buoy



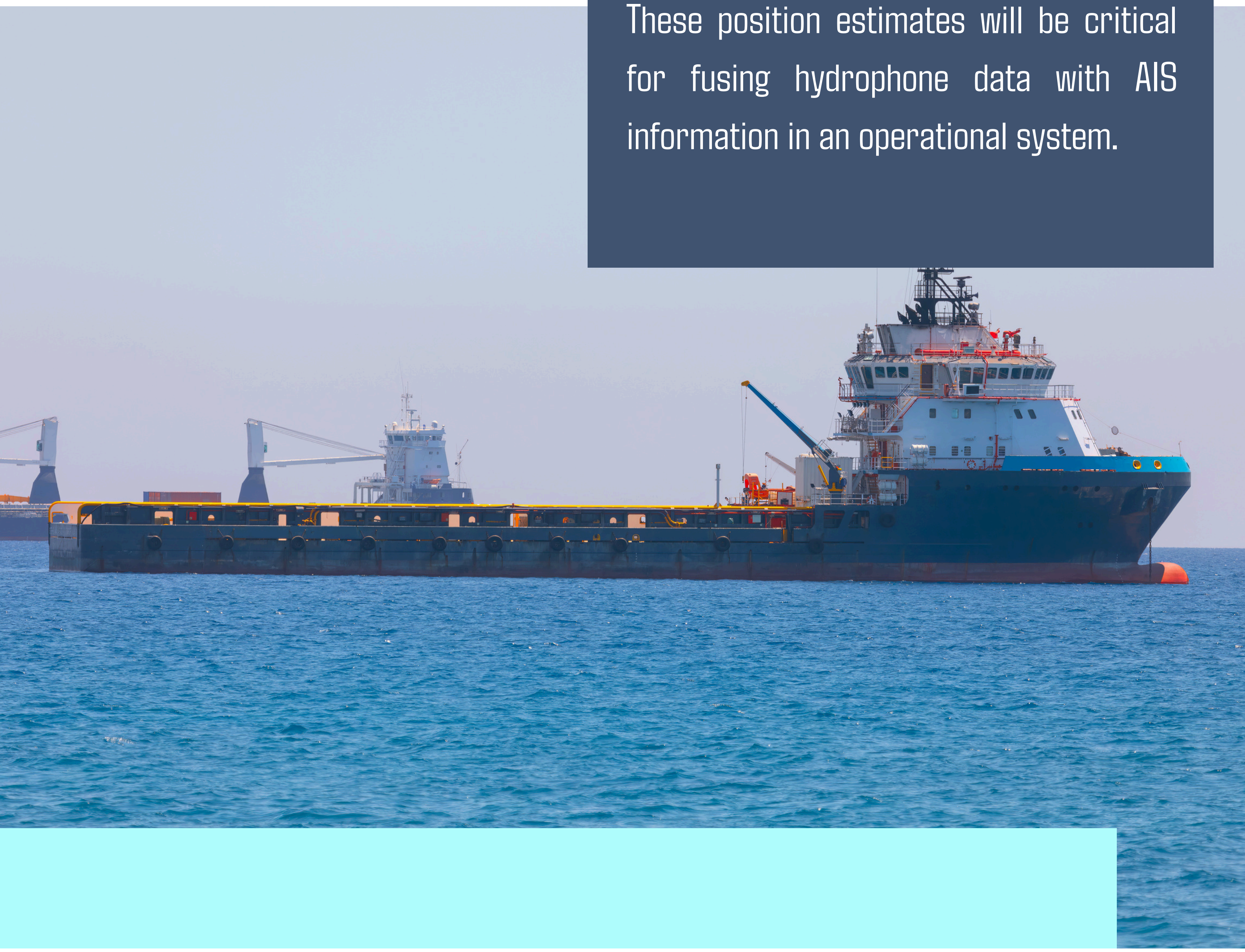
The buoy-mounted hydrophone (H4) exhibited the highest SNR, with H3 showing an SNR approximately 14 dB lower. Both seafloor-moored hydrophones (H1 and H2) also recorded significantly lower SNRs. These results strongly suggest that buoy-mounted hydrophones should be prioritised in future tests to improve data quality.

Spectrograms reveal pronounced striation patterns, highlighted in purple on the H1 and H4 panels. These patterns likely result from interference between propagation modes. Notably, the striation angles differ between H4 and the seafloor hydrophones, reflecting the influence of hydrophone depth. The visibility of these patterns is minimal for H3 due to its low SNR. By reciprocity, such patterns may vary if the target is submerged, suggesting potential utility for distinguishing surface vessels from submerged targets. However, electrically driven AUVs with low acoustic signatures may not exhibit such pronounced patterns, which could limit this approach.

SCOT cross-correlation plots reveal a sudden TDOA shift at approximately 650 s (e.g., from 0.012 s to −0.013 s for H1 relative to H2), corresponding to the vessel passing the hydrophone array. Multiple parallel maxima along the y-axis indicate multipath propagation, consistent with the observed striation patterns. Additionally, at approximately 200 s, the H1–H2 correlation maximum shifts to −0.013 s, likely caused by noise from a ferry located north of the hydrophones.

Next Steps
Underwater Detection

The next step involves estimating the vessel's position from these data. While high accuracy is not expected, determining the closest point of approach should be feasible. Cross-correlation analysis will likely provide the most reliable estimates, though broadband SNR and spectrogram data may also yield useful approximations. These position estimates will be critical for fusing hydrophone data with AIS information in an operational system.



Aerial Detection in Svelvik Narrows

The **DJI Mavic 3T** was flown manually during the test to maintain full control over positioning and image capture. The flight reached the maximum altitude permitted under the Open Category regulations, 120 meters above ground level (AGL). All operations were conducted in compliance with local aviation guidelines.

The wide-angle camera was used for image acquisition to provide a broad field of view suitable for vessel detection tasks. Images were captured from two key perspectives:

Side view: To document the vessel's profile and structural details.

Nadir view (straight down): To replicate the top-down perspective present in the dataset used for training the detection model.

These perspectives were selected to ensure consistency between the new data and the existing training dataset, supporting accurate model validation and performance evaluation.

Figure : Isometric view: The vessel is detected accurately with a bounding box covering the entire hull

Environmental Conditions

Weather: Clear skies, light wind

Lighting: Daylight, minimal glare

Flight Parameters

Altitude: 120 m AGL

Camera: Wide-angle lens, standard resolution settings

The collected imagery will be used to assess the model's ability to generalise to real-world conditions and maintain detection accuracy across different viewpoints.

Aerial Detection in Svelvik Narrows

Model Performance Results:

The evaluation of the detection model on previously collected data showed mixed performance depending on the image perspective. Frontal views of the vessels resulted in poor detection accuracy, with inconsistent bounding box placement and lower confidence scores. In contrast, top-down (nadir) and isometric views demonstrated significantly better results, with stable detection and accurate bounding box alignment.

This indicates that the model is more robust when processing images captured from elevated angles rather than head-on perspectives. The difference is likely due to the training dataset, which primarily consisted of top and angled views, making frontal perspectives underrepresented.

Figure : Top-down view: Detection remains precise, with minimal background interference (see second image).

Figure : Frontal view: Detection quality decreases, with partial coverage and reduced confidence

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