# Opti-Acoustic SLAM for Autonomous Docking Localization

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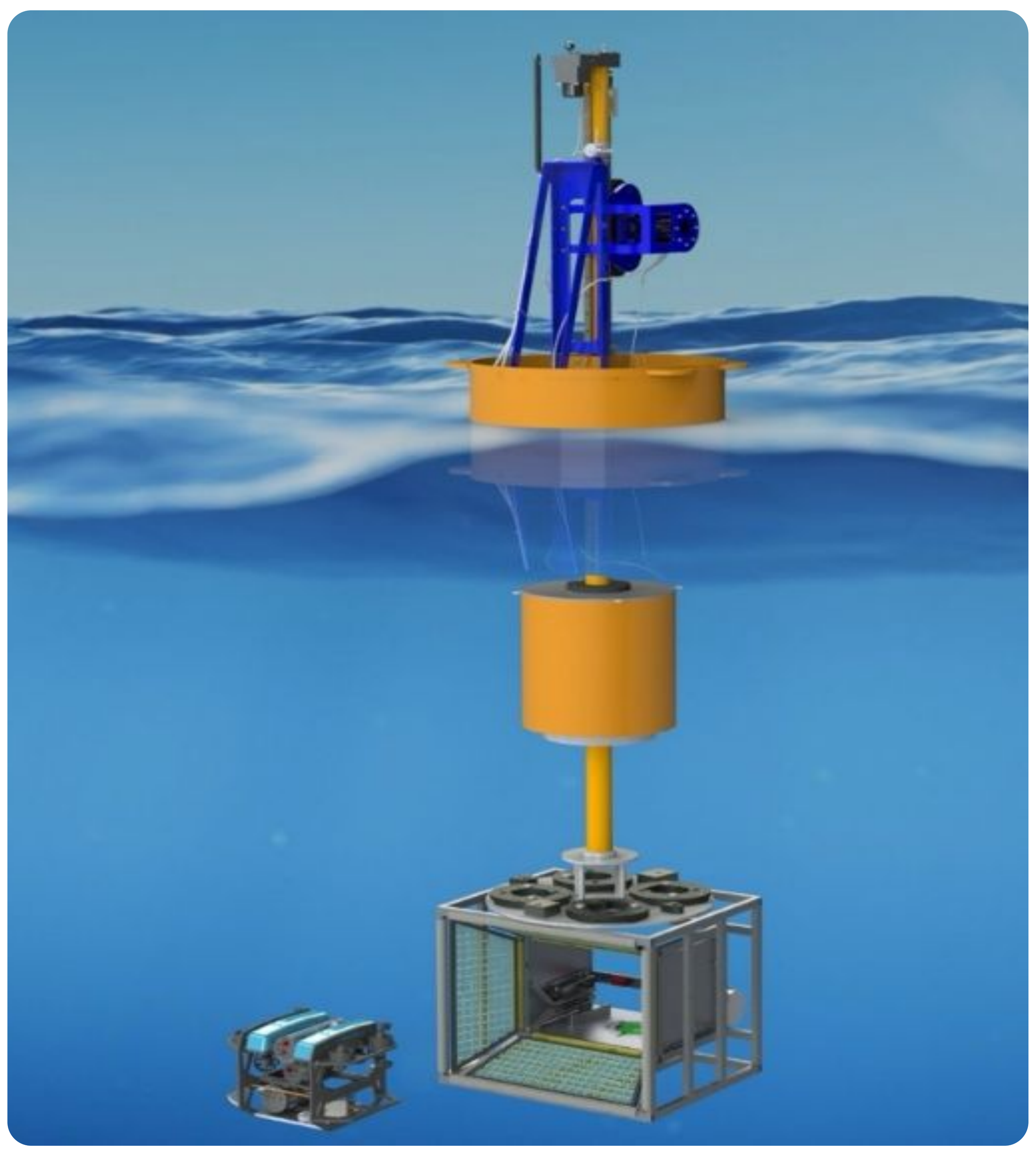
**Investigating sensor fusion for underwater mapping to enable autonomous infrastructure inspection and maintenence**

## Project Objective

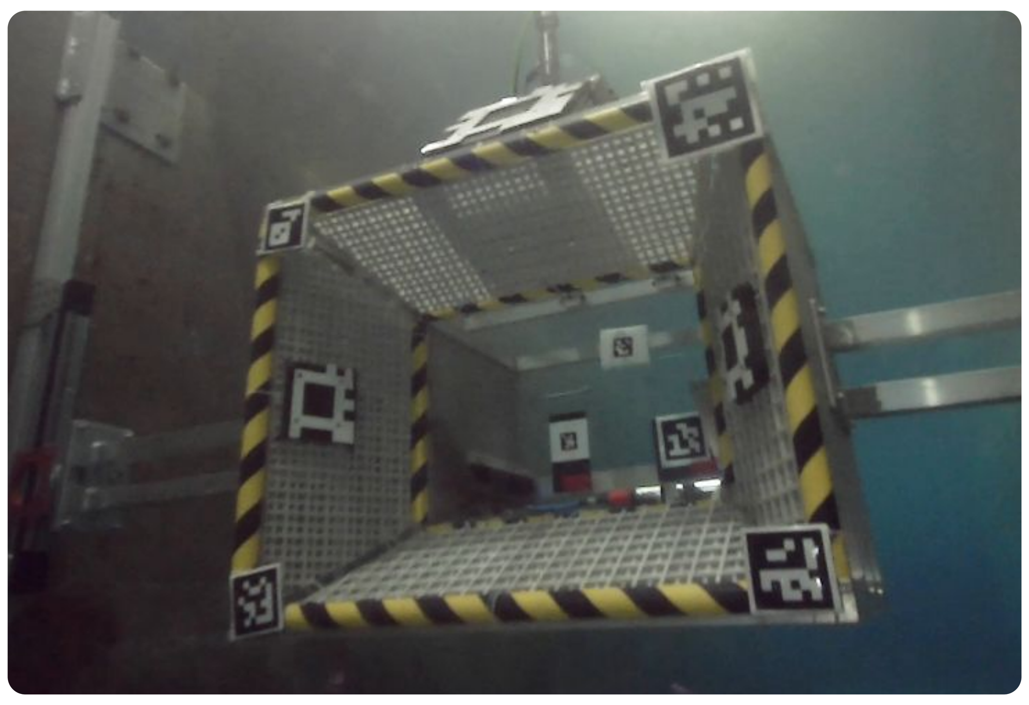
- Construction of offshore energy systems will lead to an increase in infrastructure requiring maintenance and inspection
- Autonomous Underwater Vehicles (AUV) can reduce maintenance workload, but have limited communication and power without a physical tether
- Docking stations on WEC units fix the tethering problem, but introduce the new problem of docking when the AUV must recharge or send more data to the surface
- Autonomous docking with a WEC is complicated by dock oscillation, water turbidity, and limited visibility
- Our lab has worked with Model Predictive Control (MPC) to predict wave movements and accurately path-plan to the dock, but these methods rely on accurate localization

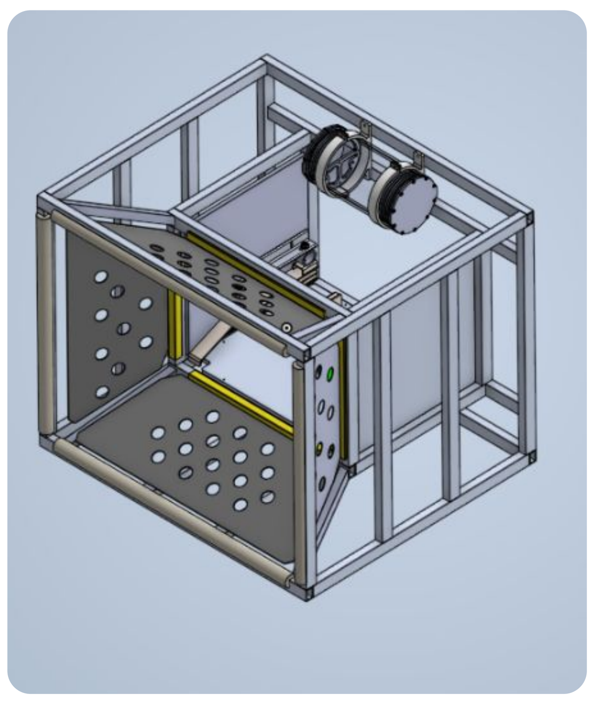


*Example of a docking station mounted to a WEC*

## Docking Localization and Challenges

- Autonomous docking requires knowing AUV location relative to dock as well as locations of any obstacles, need mapping algorithm that can:
  - Accurately reconstruct the docking station in 3D using camera, Forward Looking Sonar (FLS), and 9 DoF Inertial Measurement Unit (IMU)
  - Identify dock within reconstruction, then calculate AUV pose relative to the docking station entrance
- Minimal existing work takes advantage of all three sensors

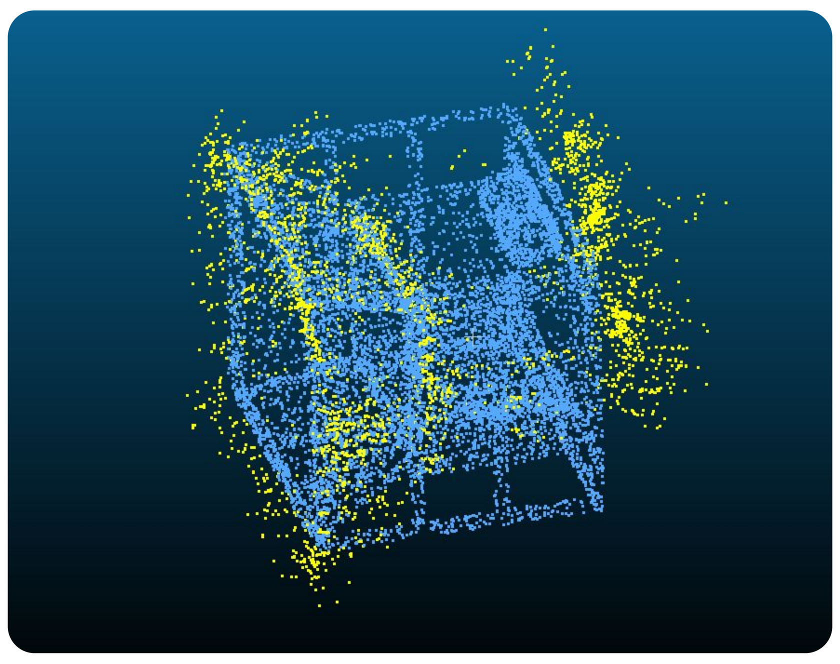




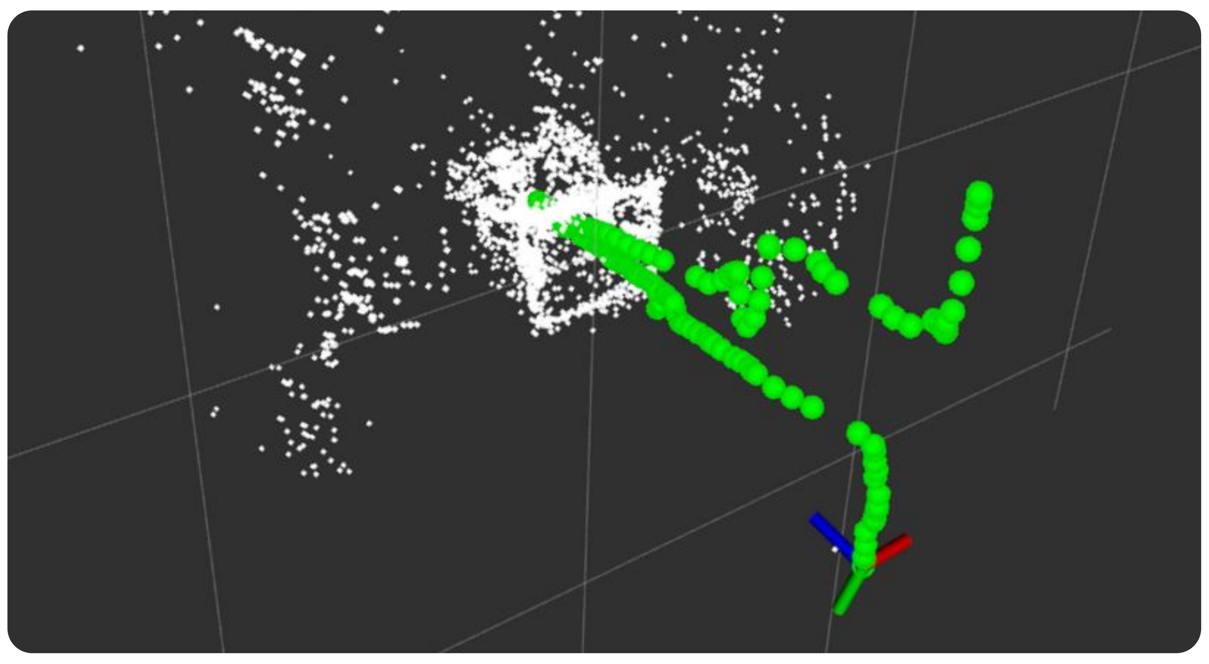
*Dock used during testing as seen in data collection at the Hinsdale Wave Research Lab (left) and the design in CAD (right)*

## Baseline Method Results

### ORB-SLAM + Scaling

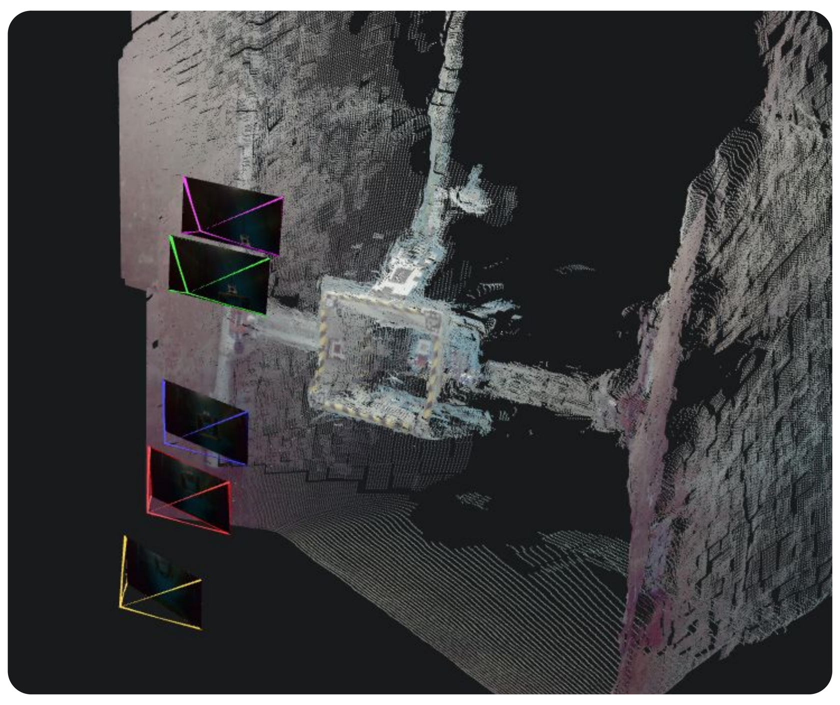


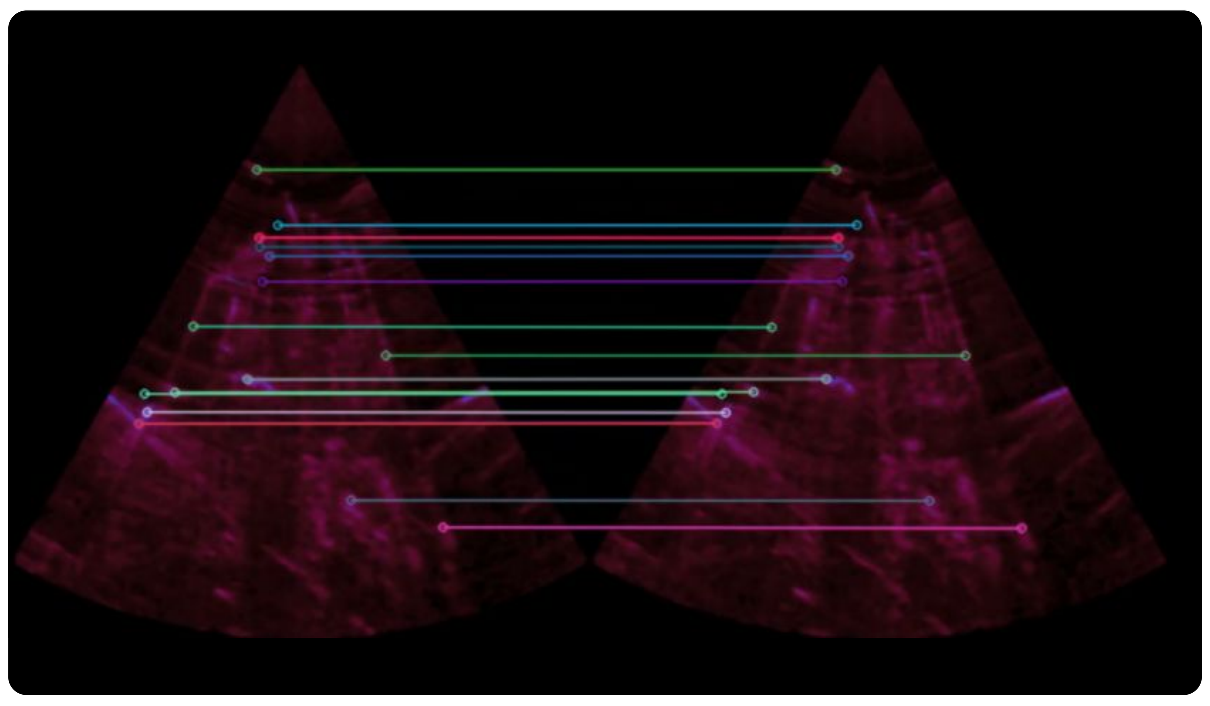
*The ORB-SLAM reconstruction (yellow) overlaid on the dock CAD model (blue)*



*The AUV trajectory (green) and dock reconstruction (white) after the AUV has successfully docked before existing again*

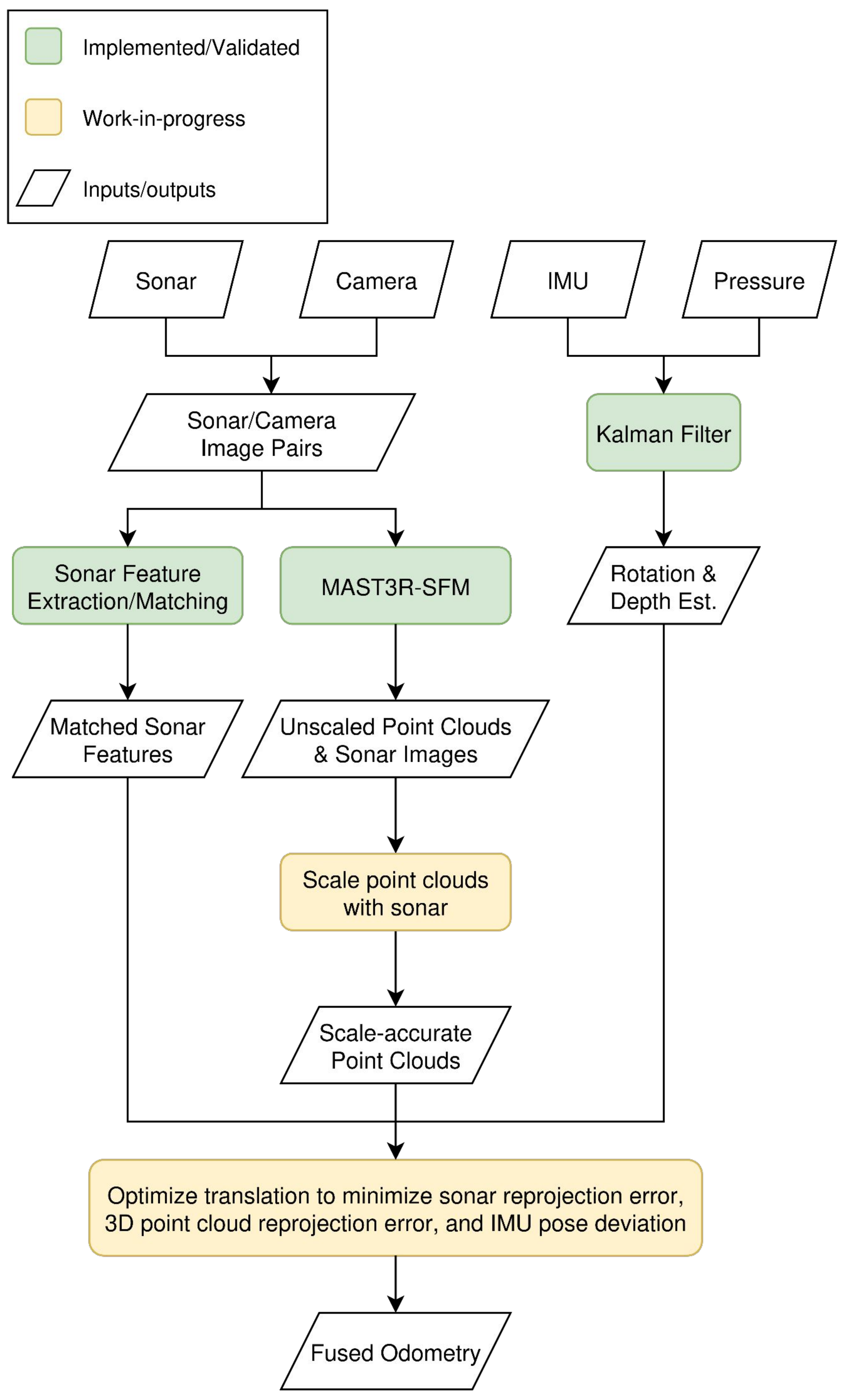
### MAST3R and Sonar Odometry





*MAST3R provides very dense, detailed reconstructions and pose estimates (left), but easily loses tracking when used in MAST3R-SLAM. Sonar is much noisier but maintains feature tracking when visual features fail (right)*

## Ongoing Work




*Proposed sensor fusion pipeline*

**Fused Odometry**

- Combines camera and sonar while accounting for scale ambiguity
- Leverages MAST3R's higher level of detail to remove need for stereo vision

**Sonar Space Carving**

- Using MAST3R enables less frequent keyframe selection
- Once new keyframe is selected, add sonar 3D reconstruction
- Requires point cloud fusion between MAST3R output and space-carving

**Improving Sonar Feature Extraction**

- Current SOTA is AKAZE feature matching with CLAHE and median filter
- Outperforms ICP + intensity threshold, currently evaluating acoustic intensity error

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