Team AMORE RobotX 2026 Technical Design Report

Jessica Besonen, Landon Westerby, John Kowalski, and Edoardo I. Sarda

Abstract—Team Autonomous Maritime Operations and Robotics Engineering (AMORE) at Lake Superior State University is adapting its autonomous surface vessel (ASV) and integrating unmanned aerial (UAV) and underwater (UUV) vehicles for RobotX 2026. The team targets Disruptive Safe Passage, a pipeline survey in Infrastructure Survey & Repair, and Advanced Coordinated Logistics. Magnetic probe placement and colored-tin retrieval are stretch goals. The ASV combines a four-thruster hull with vision, LiDAR, and mission-control software; the UAV supplies aerial observations, and the selected standard BlueROV2 provides the underwater platform. This report describes design trade-offs, current test evidence, and remaining integration work, including Task 3 water delivery and UAV payload handling.

Keywords – Artificial Intelligence (AI); Autonomous Surface Vessel (ASV); Unmanned Aerial Vehicle (UAV); Unmanned Underwater Vehicle (UUV); Light Detection and Ranging (LiDAR); Guidance, Navigation, and Control (GNC); Computer-aided design (CAD).

I. INTRODUCTION

Team AMORE (Autonomous Maritime Operations and Robotics Engineering) is a student-led marine robotics team at Lake Superior State University (LSSU). Its work includes RobotX, RoboBoat, the Njord Challenge, senior design projects, and published research [1], [2], [3]. Previous vessels provide the engineering baseline for the 2026 RobotX system.

For RobotX 2026, AMORE is adapting its in-house-designed ASV while integrating UAV and UUV. The engineering challenge is to allocate competition behaviors among the three platforms, establish reliable communication and safety boundaries, and verify that the vehicles can work together.

II. COMPETITION STRATEGY

A. Strategic Vision and Task Priorities

AMORE prioritizes Disruptive Safe Passage, pipeline survey in Infrastructure Survey & Repair, and Advanced Coordinated Logistics [6]. Magnetic probe placement and retrieval of the correct colored tin are stretch goals. RobotX awards additional Core points for Task 2 magnetic repair, so pipeline survey alone is a partial Task 2 effort. Task 3 Advanced requires successful ASV docking and water delivery before UAV delivery; a water-spray subsystem is not documented here, and the UAV has no gripper or dropper. These remain capabilities to establish and test.



Figure 1. ASV design iterations for RoboBoat

For RoboBoat 2023, AMORE adapted a kayak hull and used the control system from its 2022 WAM-V. A wooden deck and added flotation supported the competition hardware (Fig. 1).

For RoboBoat 2024, AMORE developed a dedicated ASV control system and used a hull and deck created with Florida Atlantic University. That work informed later hull and payload integration.

The RoboBoat 2025 iteration retained proven 2024 components, upgraded the main processor, and introduced a modular 6000-series aluminum-extrusion deck. The team also improved its perception system.

The current ASV uses additional transverse thrusters to provide direct lateral control. This design responds to the need for precise positioning near gates and other course features, while adding hardware and controller complexity. The team intends to evaluate that trade-off through on-water control tests.

The team retained its LiDAR and stereo-camera mast and upgraded the onboard vision computer from a Jetson TX2 to a Jetson AGX Orin to support the combined perception workload.

B. Course Approach and Vehicle Roles

The ASV hosts the mission controller and coordinates the other vehicles. For Safe Passage, the UAV is planned to locate the entry, exit, and markers and send updates while the ASV transits. For Infrastructure Survey & Repair, the UAV can identify the surface starting indicator, while the standard BlueROV2 is assigned the underwater pinger and pipeline survey. For Coordinated Logistics, the ASV must dock in the indicated bay, spray the active window, identify the subsequent delivery target, and task the UAV. Water delivery and UAV tin handling remain development items [6].

The planned vehicle heartbeat reports a position estimate and current task state to the ASV mission controller. A shared object map may allow detections to support later navigation, provided that the team defines a common coordinate frame and rejects stale observations.

C. Complexity and Reliability

The four-thruster ASV gives the controller direct lateral authority that a two-longitudinal-thruster arrangement lacks, at the cost of more actuators and control allocation. Reusing ROSBOAT reduces low-level software work, while selecting the documented BlueROV2 avoids developing an underwater vehicle within one competition year. These choices leave more integration time for the three-vehicle mission but require tests on the final configuration.

III. DESIGN STRATEGY

A. System of Systems Architecture

The ASV is the proposed mission authority for the ASV, UAV, and UUV. It selects tasks and distributes commands and status over the ROS 2-based system, while each vehicle retains its own motion control and safety responses. The ground station supervises the run. The ASV is also integrating acoustic localization to provide the BlueROV2 with underwater position estimates.

B. Autonomous Surface Vessel

The ASV hull consists of extruded-polystyrene foam sheets shaped on a three-axis CNC router, bonded in layers, and covered with fiberglass. The foam provides a light, formable core, and the fiberglass forms a waterproof exterior. Two transverse thrusters add lateral authority to the longitudinal pair (Fig. 2).

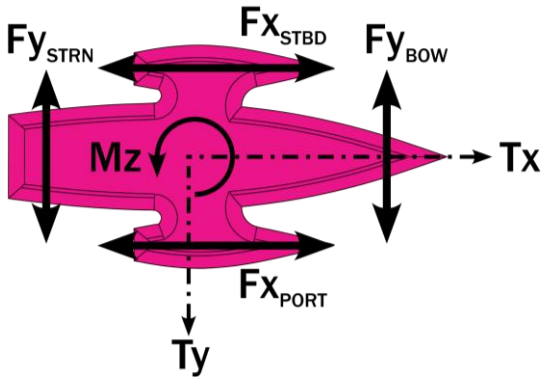


Figure 2. Free-body diagram of forces acting on the ASV.

At RoboBoat 2026, the hull rode high enough that the thrusters drew air. Adding approximately 55 lb of sandbags improved immersion but made handling the ASV more difficult. The mechanical team used the CAD model to estimate the volume

of material to remove and targeted approximately 65 lb less displacement. After the hull modification, the thrusters still sat close to the surface, so their mounts were lowered by approximately 1.5 in. These changes addressed two observed causes of thruster ventilation.

The team also moved equipment away from the electronics-bay lid so it can be removed for battery changes and on-water troubleshooting without disconnecting multiple cables. Nine 10-10 T-slot aluminum bars around the upper hull now provide modular mounting points. Figure 3 shows the hull changes.

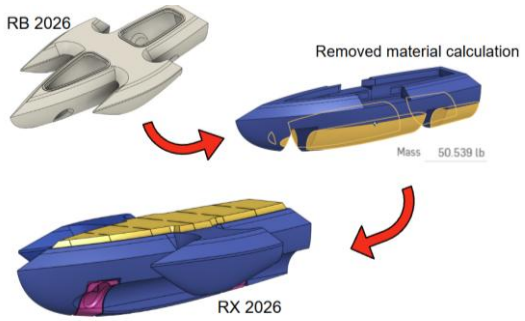


Figure 3. ASV buoyancy changes for RobotX 2026

1) Guidance, Navigation, and Control

The ASV guidance, navigation, and control system includes a Jetson AGX Orin, two Teensy 4.1 microcontrollers, a Pixhawk 6C, and dedicated safety hardware. The Jetson runs mission planning and navigation; USB links connect it to the first Teensy and the Pixhawk. The Teensy boards communicate over serial and provide low-level actuation and safety functions. The Pixhawk supplies GNSS position and orientation data to the Jetson.

A custom printed circuit board (PCB) connects the Teensy boards to the RC receiver, thruster controls, status lights, and emergency-stop circuit. The current ASV powers the board from a 12 V converter, so the PCB battery-monitoring function used on other vessels is not used here.

The emergency-stop circuit removes a 12 V enable signal from three relays that supply 24 V to the thrusters: one relay serves the transverse pair, and the other two serve the longitudinal thrusters. The physical stop button, RC stop switch, and RC disconnection are designed to disable this signal.

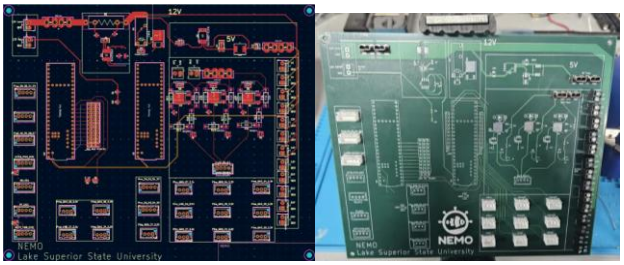


Figure 4. GNC PCB design and initial prototype.

2) Propulsion and Control

Two longitudinal thrusters provide surge and differential yaw; bow and stern transverse thrusters provide direct sway control for close maneuvering and station keeping. This four-actuator design avoids mechanical steering but requires additional wiring and thrust allocation (Fig. 5).



Figure 5. Longitudinal and transverse ASV thrusters.

The low-level controller uses heading-and-speed and station-keeping modes with proportional–integral–derivative (PID) feedback. The thrust allocator accounts for the four actuator directions during station keeping.

3) ROSBOAT Low-Level Software

ROSBOAT, developed by Aquirix, supplies reusable ROS 2 interfaces for the ASV's low-level control, navigation, and operator display. Its modular design also allows components to be tested independently and reused on other vessels.

On the AMORE ASV, the ROSBOAT stack provides the following functions:

- Exchanges commands and status between the PCB microcontrollers and ROS 2.
- Passes GNSS position and navigation goals to the planner and station-keeping controller.
- Displays available power telemetry to the operator; the PCB battery monitor is not used on the current ASV.
- Selects heading-and-speed or station-keeping control from the mission controller's task data.
- Provides PID-based thrust commands and controller-tuning functions [4].
- Displays vessel state and sensor data in a web interface.

This existing stack lets AMORE focus development on task logic and integration, subject to validation on the current ASV hardware.

4) Perception and Localization

The ASV carries a ZED 2i stereo camera and Velodyne VLP-16 LiDAR on its perception mast (Fig. 6). A second Jetson AGX Orin handles ASV perception and vision processing. The UAV uses a Jetson Orin Nano for its own vision pipeline.

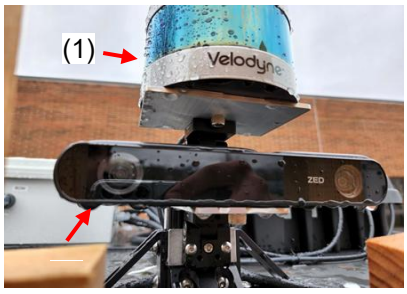


Figure 6. Perception mast previously mounted on an AMORE vessel.

Detections are positioned relative to the ASV and transformed into a common frame before they are shared with the planner or another vehicle. The Pixhawk 6C supplies GNSS and orientation data to ROS 2; the camera and LiDAR do not independently provide a global pose. The planner requests synchronized object-map updates.

The planner requests detection updates at 2 Hz to limit data traffic. The team reports network latency of approximately 40 ms with this setting, compared with approximately 60 ms before the change.

In reported ZED camera tests, the YOLO11n detector performed best at approximately 3–10 m, with detection confidence of 40–60% and average inference time of 30 ms [5].

Camera and LiDAR detections are assigned classes and positions in a two-dimensional planner grid. The map compares each new observation with previous positions: a displacement exceeding 1 m reduces confidence in the old entry by 10%, while a repeated observation at the expected position restores confidence to 100%.

This ASV perception pipeline identifies nearby course objects and maintains a local map ahead of the vessel. The UAV's different viewing geometry requires its own detection and localization validation before its reports can be merged with the ASV map.

5) Mission Control and Path Planning

The ASV mission controller selects a task and sends its navigation goals to the planner when autonomy and safety checks allow. The planner uses detected objects and relevant gates to generate a traversable route.

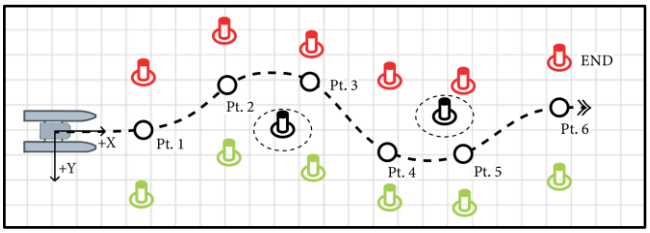


Figure 7. Example gate approach and navigation concept.

The team considered Dijkstra, A*, and D* variants for grid-based route planning and selected A* for the current ASV implementation. The planner generates a new route as the object map changes.

Breaking a large task area into smaller local grids is a possible future optimization, subject to a measured comparison with the current planner.

The ASV mission controller selects and executes task behaviors, monitors completion or failure, and requests work from the UAV and UUV after autonomy is enabled.

The ASV assigns tasks, while the UAV and UUV report their status to its mission controller. Autonomous task execution stops or changes state after any of these events:

1. The ASV or RC emergency-stop switch is activated.
2. A task-end instruction arrives from RoboCommand.
3. The RC operator switches from autonomous to manual mode.
4. The task completes or reaches its configured termination condition.
5. The operator stops mission software through GUI.

6) ASV Acoustic Support for UUV Localization

AMORE is integrating an ASV-mounted acoustic localization system to estimate the BlueROV2's position when GNSS is unavailable underwater. The intended interface transforms each estimate into a common frame and sends position updates to the UUV; its integrated performance has not yet been established.

C. Unmanned Aerial Vehicle

The UAV is planned to identify and localize Safe Passage markers, report their positions to the ASV, and remain on station as the markers change. In Infrastructure Survey & Repair, it can locate the surface starting indicator for the ASV–UUV handoff [6]. AMORE intends to develop a gripper or dropper for Coordinated Logistics, but the current UAV cannot yet pick up or release a tin.

The aircraft uses a Tarot 650 Sport frame, Tarot 4112/320KV motors, 15-in propellers, and a 6S 6000 mAh LiPo battery. Its approximately 9 lb mass reflects the larger propulsion system chosen for future payload capacity. In tests without the ZED 2i and Jetson Orin Nano, it flew for approximately 40 min.

A Pixhawk 6C running PX4 controls flight, and a Jetson Orin Nano supports the planned YOLO11s and ZED 2i perception pipeline. The PX4–ROS 2 interface uses uXRCE-DDS instead of the earlier MAVLink/MAVROS companion link. PX4 handles configured battery, RC-link, companion-link, and geofence responses. RC-loss and geofence behavior were demonstrated in proof-of-readiness videos.

D. Unmanned Underwater Vehicle

AMORE selected a standard Blue Robotics BlueROV2 as its UUV using a RoboNation grant. Reusing a documented platform reduces the time needed to design underwater propulsion and control, although it constrains custom electrical integration. The planned Task 2 survey requires the UUV to locate the active starting point, follow the pipeline, and report the light sequence. Magnetic repair is a stretch goal that earns additional Core points [6].

E. Inter-Vehicle Collaboration and Safety

The ASV distributes task commands and receives status and position estimates from the other vehicles. Messages need timestamps and common coordinate frames so the mission controller can reject stale reports.

ROS 2 is the team's inter-vehicle middleware, and the ASV's Ubiquiti link supports surface communication. The BlueROV2's underwater communication and position-update path remains an integration item. Emergency stops are handled primarily by vehicle hardware. The ASV mission

controller monitors vehicle status and can change or end a task when a vehicle goes offline or reports a stop.

IV. TESTING STRATEGY

The team is progressing from component and bench tests through single-vehicle trials toward integrated, timed RobotX tasks. Earlier platform demonstrations are identified separately from current-hull results; multi-vehicle work remains in progress.

A. ASV Tests

1) Propulsion and Control

Completed ASV stages include bench checks of the controller and thrusters, YOLO object-detection tests, PID heading-control tests, and channel-navigation integration trials. Multi-vessel communication, task startup, and complete three-vehicle mission trials remain in progress. Completion of a subsystem test does not establish performance of the full RobotX configuration.

Winter conditions near Sault Ste. Marie limited on-water access during development, so the team used controller and hardware checks before full-system trials.

2) Perception and Navigation

Earlier AMORE work used red and green buoy detections to generate gate midpoints and navigation goals. These trials inform the RobotX detector, provided that their platform and test conditions are identified.

In an earlier on-water buoy trial, the system classified markers and estimated their relative positions. Figure 8 shows a recorded path and the detected objects.

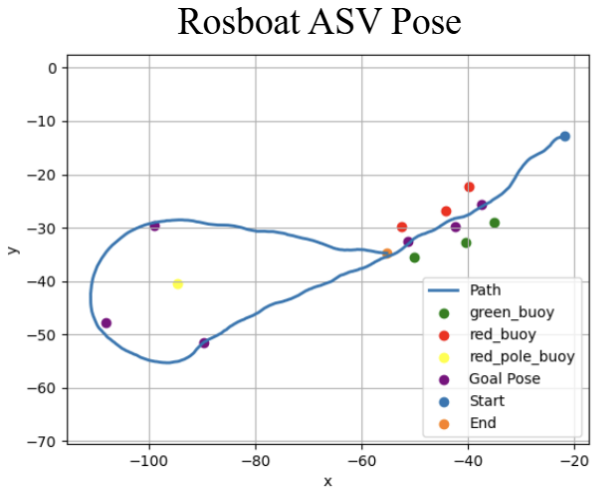


Figure 8. Recorded ASV path and detected object positions.

The team reports object-position error of approximately ±0.5 m for camera detections and ±0.2 m for LiDAR detections. It selected a 1 m × 1 m planning grid to accommodate that uncertainty and reports consecutive completion of five channel-navigation configurations. These results characterize the reported trials and do not yet establish performance of the integrated RobotX system.

B. UAV Tests

The UAV flew for approximately 40 min without its final camera and companion-computer payload. Team proof-of-readiness videos demonstrate RC-loss and geofence responses.

V. CONCLUSION

AMORE's current ASV combines a revised hull, four-thruster control, ROSBOAT interfaces, and camera–LiDAR perception. The UAV has demonstrated basic flight and selected safety responses, and the team has selected a standard BlueROV2 for the underwater role. Task readiness depends on three-vehicle integration, acoustic and aerial position exchange, final UAV payload testing, and the Task 3 water-delivery and tin-handling functions.

VI. ACKNOWLEDGEMENTS

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The team thanks faculty advisor Dr. Edoardo Sarda for his technical guidance and support.

VII. REFERENCES

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