AQUAHOLICS: Multisystem Autonomous Robotics and Integration for the 2026 Maritime RobotX Challenge

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***Abstract*—The AQUAHOLICS team from RMK Engineering, India, is developing an autonomous multi-domain maritime System of Systems (SoS) for the RobotX 2026 Maritime RobotX Challenge. The proposed system integrates a custom-built Uncrewed Surface Vessel (USV), DRAKEN (Mark 1), and a custom-built Uncrewed Aerial Vehicle (UAV), REVELATION, to support coordinated autonomous mission execution in a dynamic maritime environment. The USV incorporates a custom V-shaped hull, ballast-based stability system, Raspberry Pi 5 onboard computing, Pixhawk-based control, and vision-based perception. The REVELATION UAV incorporates an S500 airframe, Pixhawk 2.4.8 flight controller, Raspberry Pi 5 companion computer, Arducam IMX296 camera, RadioLink SE100 GPS, and MAVLink-based telemetry. The competition strategy prioritizes reliable execution of Core capabilities, while pursuing Advanced and Disruptive capabilities where feasible. The system is being developed to support autonomous navigation, computer-vision-based detection, obstacle avoidance, cross-domain coordination, and safe fallback behaviors. The design follows a modular approach integrating vehicle-level control, onboard computing, perception, navigation, and mission-level autonomy. Testing is planned progressively from virtual and component-level testing through relevant-environment testing and integrated system evaluation. Through this approach, AQUAHOLICS aims to demonstrate a cohesive multi-vehicle autonomous system capable of coordinated maritime mission execution in accordance with the RobotX 2026 challenge objectives.**

I. System Overview

The AQUAHOLICS RobotX 2026 system is designed as a multi-domain autonomous maritime System of Systems (SoS) consisting of a custom-built Uncrewed Surface Vessel (USV), DRAKEN Mark 1, and a custom-built Uncrewed Aerial Vehicle (UAV), REVELATION.

A. The DRAKEN Mark 1

The DRAKEN Mark 1 is the primary surface platform, designed for autonomous navigation, perception, and mission operations. It integrates onboard computing, vehicle control, camera-based perception, and navigation for competition operations.

B. The REVELATION UAV

The REVELATION UAV provides an aerial perspective and supports cross-domain mission execution. Its role is to gather information from the aerial domain and support the USV during tasks that benefit from aerial perception or coordination.



Fig. 1: Draken [Mark 1]



Fig. 2: REVELATION

The two vehicles are intended to operate as a coordinated system rather than as independent platforms. Information obtained by one vehicle can be used to support the decision-making and actions of the other, enabling cross-domain cooperation during mission execution. The detailed inter-vehicle communication architecture is under development.

At the autonomy level, the system follows a general perception–decision–action approach. Sensor and camera data are processed onboard to detect relevant objects and environmental conditions. The autonomy system then determines the appropriate vehicle action, such as navigation, stopping, path replan-

ning, or coordinated operation. Manual control and safety fallback mechanisms are retained to handle autonomous-system or communication failures.

The overall architecture is designed to progressively integrate vehicle autonomy, computer vision, navigation, obstacle handling, communication, and cross-domain coordination to support the RobotX 2026 objective of demonstrating an integrated multi-vehicle maritime system.

II. Competition Strategy

A. Overall Competition Approach

AQUAHOLICS will approach RobotX 2026 as an integrated System of Systems consisting of the DRAKEN Mark 1 USV and REVELATION UAV. The competition strategy prioritizes reliable execution of all Core capabilities, followed by the pursuit of Advanced capabilities and selected Disruptive capabilities where technically feasible. DRAKEN Mark 1 will serve as the primary surface platform, while REVELATION will provide aerial support and information to enable cross-domain mission execution. The team will prioritize autonomous operation while retaining manual control and predefined safety fallback behaviors for communication loss, unexpected obstacles, or autonomous-system failures. The overall strategy is to establish a reliable autonomous baseline first and progressively integrate higher-level autonomy and USV–UAV coordination while maintaining system safety and reliability.

B. Course and Mission Approach

AQUAHOLICS will approach the RobotX 2026 mission as a coordinated multi-domain operation in which the DRAKEN Mark 1 USV performs the primary surface mission activities and the REVELATION UAV provides complementary aerial support. The approach is aligned with the 2026 competition emphasis on integrated multi-vehicle autonomy and cross-domain coordination. The mission will be executed through a structured sequence of perception, navigation, decision-making, and task execution. The USV will use onboard sensing and vision-based perception to understand the surrounding environment and determine its next action. Where aerial information is beneficial to a mission element, the UAV will be deployed to observe the environment and provide relevant information to support the USV.

The team will initially establish reliable execution of the required Core capabilities and subsequently extend the system toward Advanced and Disruptive capabilities. Mission execution will remain autonomous as the primary operating mode, with predefined fallback behaviors available for communication loss, unexpected obstacles, or autonomous-system failures. This course approach allows AQUAHOLICS to progressively demonstrate individual capabilities while building toward the integrated multi-domain behavior required for the complete mission.

C. Mission Task Strategy

AQUAHOLICS will approach the four RobotX 2026 mission tasks as interconnected elements of a multi-domain recovery operation. The DRAKEN Mark 1 USV will serve as the primary surface platform, while the REVELATION UAV will provide aerial perception, information exchange, and logistics support where required. The team will prioritize reliable execution of Core capabilities and progressively attempt Advanced and Disruptive capabilities as system integration and testing mature.

1) Task 1 – Safe Passage: The objective of Task 1 is to autonomously transit a hazardous buoy field from the designated entry point to the exit point while identifying the beacon states and passing obstacles on the required side. At the Core Tier, DRAKEN Mark 1 will use onboard vision-based perception to identify the relevant light beacons, determine the required transit path, avoid obstacles, and autonomously navigate through the course. The USV will report the relevant task status through the RoboCommand interface. For the Advanced Tier, REVELATION will perform an aerial overflight to identify the safe passage information that is not available to the surface system. The UAV will communicate the identified entry, exit, and route information to the USV, which will use the shared information for autonomous path planning and execution. For the Disruptive Tier, the UAV will additionally provide persistent observation of the course and communicate changes in the safe passage to the USV. The USV will adapt its path based on the updated information, demonstrating dynamic cross-domain coordination.

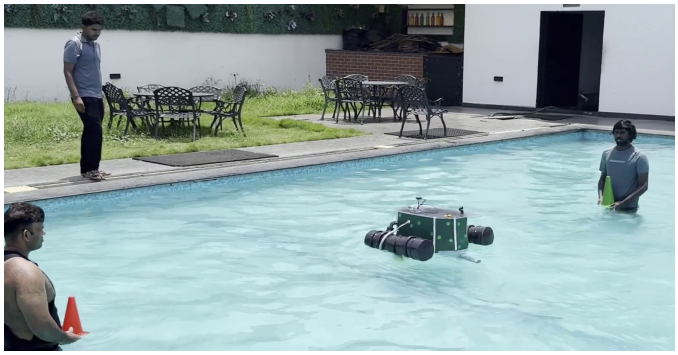


Fig. 3: Task 1 PoR

2) Task 2 – Infrastructure Survey and Repair: Task 2 requires an underwater vehicle and an aerial vehicle to survey and repair a damaged underwater pipeline. The UUV identifies the pipeline, determines the condition of its segments, reports the survey results, and may perform the required repair operation. At higher capability tiers, the UUV can request a resource from the UAV for delivery. AQUAHOLICS recognizes that the handbook specifies a UUV and UAV as the minimum systems for this task. Therefore, the current USV–UAV configuration does not independently provide the complete platform capability required for Task 2. The team is currently developing the UUV capability. However, implementation of this task will not be claimed until the UUV is fully developed, integrated, and successfully tested for compliance.



Fig. 4: GARUDAN [UUV] Underdev.

3) Task 3 – Coordinated Logistics: Task 3 represents coordinated post-disaster logistics operations involving autonomous docking, firefighting, and resource delivery. DRAKEN Mark 1 will autonomously identify the available docking bay, navigate to the designated bay, and complete the docking operation. At the Core Tier, the USV will identify the active target window and use its water-delivery system to extinguish the simulated fire. At the Advanced Tier, the USV will interpret the resource-delivery requirement and communicate the destination information to REVELATION. The UAV will then locate and deliver the required relief resource to the designated target. At the Disruptive Tier, the USV will interpret both the required resource and its delivery destination and communicate this information to the UAV. REVELATION will locate the required resource, retrieve it, and autonomously deliver it to the specified target, demonstrating coordinated USV–UAV logistics.

4) Task 4 – Dynamic Incident Response: Task 4 evaluates the ability of the System of Systems to respond to changing mission priorities and operating conditions. AQUAHOLICS will design the autonomy architecture so that an active vehicle can interrupt its current mission, respond to a new RoboCommand task, travel to the specified location, report readiness, and subsequently resume normal mission execution. For higher capability tiers, the system will respond to dynamic keep-out areas and moving-object information received through RoboCommand. The affected vehicle will modify its mission behavior while maintaining safe operation and system-level situational awareness. This task directly supports the AQUAHOLICS strategy of maintaining autonomous operation while allowing the mission state to be dynamically modified through communication between RoboCommand, the OCS, and the individual vehicles.

D. Cross-Cutting System Capabilities

AQUAHOLICS has developed the cross-cutting capabilities required to support safe and coordinated autonomous operation across the vehicle systems. These capabilities include RoboCommand integration, obstacle avoidance, inter-vehicle communication, dynamic adaptability, and safety mechanisms.

1) RoboCommand and OCS: The Onboard Control Station (OCS) architecture has been implemented and is currently under testing. The OCS is designed as the communication interface between the AQUAHOLICS System of Systems and the RoboCommand environment. Vehicle status, mission-related information, and required reports are handled through the OCS architecture, while vehicle-level communication remains under team control.

2) Obstacle Avoidance: Obstacle avoidance is implemented as part of the autonomous navigation architecture. The perception system uses camera-based computer vision to identify relevant obstacles in the vehicle's operating area. When an obstacle is detected along the planned trajectory, the autonomy system commands the vehicle to reduce or stop its motion, assess the obstacle, and generate a revised path before continuing operation. This approach is intended to provide safe navigation while maintaining autonomous operation.

3) Inter-Vehicle Communication: The USV and UAV communication architecture uses MAVLink-based telemetry over a SiK radio link. The radio system employs RF communication with frequency-hopping spread spectrum (FHSS), adaptive time-division multiplexing (TDM), and GFSK modulation. The operating RF band is targeted at 900 MHz, subject to the final radio module configuration. The inter-vehicle communication system is being integrated and validated to support information exchange between the DRAKEN Mark 1 USV and REVELATION UAV.

4) Dynamic Adaptability: The autonomy architecture supports dynamic changes during mission execution. If an unexpected obstacle is detected, the vehicle can stop and re-plan its path. If communication with the supervisory or collaborating system is lost, the affected vehicle transitions to a predefined autonomous return-to-home behavior. Autonomous-system failures are handled through a manual-control fallback where appropriate. The architecture also supports interruption of the current mission in response to a higher-priority command and subsequent continuation of the mission after the required condition is resolved.

5) Safety and Fail-Safe Operation: Safety is supported through a physical kill switch that disconnects the actuator system, together with software-based geofencing and low-battery return-to-home functionality. These mechanisms provide independent layers of protection during autonomous operation. The system retains manual control capability as an additional fallback during autonomous-system failures.

E. Risk Management and Fallback Strategy

AQUAHOLICS follows a layered risk-management approach in which autonomous operation is supported by predefined fallback behaviors for communication, perception, navigation, power, and system failures. The objective is to maintain safe vehicle behavior while allowing the mission

to continue whenever the affected subsystem can be safely isolated.

1) Communication Failure: If communication between the USV and UAV is temporarily lost, each vehicle is designed to continue its individual autonomous operation using its predefined mission state and safety behavior rather than remaining indefinitely dependent on the other vehicle. If the communication link cannot be recovered, the affected vehicle transitions to its predefined safe-return behavior.

2) Obstacle and Perception Failure: Unexpected obstacles detected during autonomous navigation cause the vehicle to reduce or stop its motion, reassess the environment, and replan a safe path before continuing. If reliable perception is unavailable, the system transitions to a conservative operating state rather than continuing at normal autonomous speed.

3) Autonomy Failure: If the autonomous navigation or mission-control system becomes unreliable, manual control is retained as a fallback for the USV. This allows the operator to recover the vehicle while preventing continued operation based on an unreliable autonomy state.

4) Vehicle Failure: The USV and UAV incorporate return-to-home behavior as a predefined recovery mechanism. A detected vehicle-level failure or loss of the required operating condition initiates the appropriate safe-return procedure where vehicle state and mission conditions permit.

5) Power and Battery Risk: Low battery conditions are monitored by the vehicle system. When the predefined low-battery threshold is reached, the vehicle initiates Return-to-Home (RTH) rather than continuing the mission until the available energy is exhausted.

6) GPS Loss: GPS loss is handled as a degraded-navigation condition. The vehicle first reduces or stops autonomous movement and attempts to recover reliable positioning information. If GPS cannot be recovered within the defined timeout, the vehicle transitions to a predefined safe fallback, such as Return-to-Home where reliable recovery is possible or manual intervention when required.

7) Geofence and Emergency Protection: Software geofencing is implemented to constrain autonomous operation within the permitted operating area. In addition, a physical emergency kill switch provides an independent safety mechanism capable of disconnecting the actuator system. Manual intervention remains available as a recovery mechanism when autonomous operation cannot safely continue.

8) Mission-Level Failure Handling: The autonomy system is designed to prioritize safety over uninterrupted mission execution. A higher-priority command can interrupt the current mission, execute the required response, and resume the previous mission when appropriate. This approach allows the System of Systems to adapt to changing mission conditions while maintaining predefined safe states.

Overall, the fallback strategy is based on the principle of detect, transition to a safe state, recover where possible, and resume autonomous operation when the required conditions are restored. This provides a structured response to foreseeable failures while supporting the autonomous and multi-domain operating requirements of RobotX 2026.

III. Design Strategy

A. System Architecture

The AQUAHOLICS RobotX 2026 system is designed as a modular multi-domain System of Systems (SoS) integrating the DRAKEN Mark 1 Uncrewed Surface Vessel (USV) and REVELATION Uncrewed Aerial Vehicle (UAV). The architecture separates high-level autonomy and perception from low-level vehicle control, allowing each vehicle to operate independently while supporting coordinated mission execution.

The DRAKEN Mark 1 USV follows a layered architecture in which onboard sensors and camera data are processed by a Raspberry Pi 5 for perception, autonomous decision-making, and mission-level functions. Navigation information from the GPS and 9-axis IMU supports vehicle-state estimation and navigation. High-level commands are passed to the Pixhawk flight controller, which performs vehicle control and interfaces with the propulsion system. The REVELATION UAV follows a similar architecture. Camera and GPS information are processed through the Raspberry Pi 5 companion computer, while the Pixhawk 2.4.8 provides flight-control functions. This separation allows the companion computer to handle higher-level autonomy and perception while the flight controller manages real-time vehicle control.

At the System-of-Systems level, the USV and UAV exchange mission and telemetry information through a MAVLink-based wireless communication link. The Operator Control Station (OCS) provides the interface between the team system and the RoboCommand environment, while vehicle-to-vehicle communication remains under the team's control. This architecture enables the two platforms to combine information from different domains and support coordinated mission execution. The overall autonomy flow follows a Perception $\rightarrow$ Decision $\rightarrow$ Navigation/Control $\rightarrow$ Vehicle Action structure. This modular architecture allows individual subsystems to be developed and tested independently before integration into the complete multi-vehicle system, supporting the team's strategy of progressively increasing autonomous and coordinated capabilities.

B. USV Design and Engineering Decisions

The DRAKEN Mark 1 was designed as a compact custom-built USV with emphasis on maneuverability, stability, propulsion efficiency, and integration of autonomous systems. The design decisions were guided by the team's priority of establishing a reliable autonomous platform for the RobotX 2026.

1) Hull and Hydrodynamic Design: A V-shaped hull was selected to provide a streamlined profile through the water and reduce resistance during forward motion. The geometry allows the vessel to cut through the water more effectively,

with the intended benefit of reducing propulsion effort and energy consumption during transit. The hull is custom fabricated using fiberglass and resin over a lightweight structural base, providing a practical balance between structural strength, weight, and ease of fabrication.



Fig. 5: CAD Model of Hull

2) Stability and Ballast: A custom ballast-tank system was incorporated to improve vessel stability under different water conditions. The ballast system allows the vehicle's water displacement and balance to be managed according to operating conditions, supporting stable camera perception, navigation, and propulsion during autonomous operation.

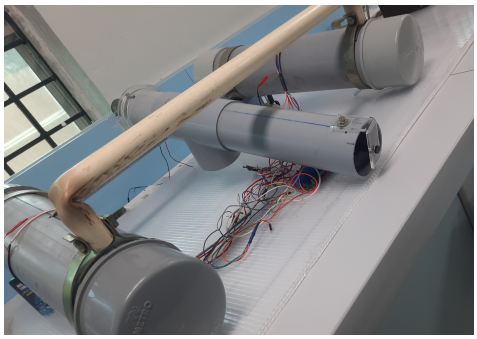


Fig. 6: Ballast Tanks

3) Propulsion: Underwater thrusters were selected as the primary propulsion mechanism because they provide a compact and direct method of generating thrust while remaining suitable for the compact hull configuration. The propulsion arrangement is intended to provide sufficient thrust for maneuvering and forward motion while simplifying mechanical integration compared with an exposed shaft-and-propeller arrangement.

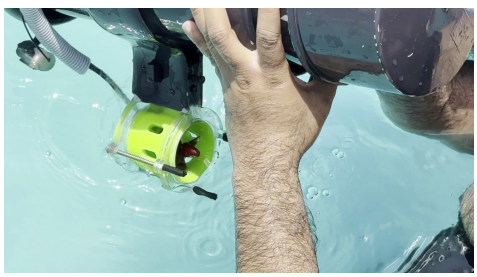


Fig. 7: Propulsion System

4) Computing and Vehicle Control: The USV uses a Raspberry Pi 5 as the high-level computing platform for perception, AI processing, autonomy, and mission-level decision-making. A Pixhawk flight controller is used for low-level vehicle control and provides the interface between high-level commands and the propulsion system. Separating high-level computing from real-time vehicle control reduces the dependency of the control loop on the AI-processing workload and provides a modular architecture for future autonomy development.

5) Navigation and Perception: GPS and a 9-axis IMU provide navigation and vehicle-state information, while camera-based computer vision provides environmental perception. The design intentionally emphasizes vision-based perception for obstacle and mission-object detection, allowing the team to perform autonomous perception without adding the mechanical and computational complexity of a dedicated LiDAR system.

Overall, the DRAKEN Mark 1 design reflects a trade-off between capability, energy consumption, system complexity, and reliability. The architecture allows the mechanical, control, computing, and perception subsystems to be developed independently and progressively integrated as autonomous navigation capabilities mature.

C. UAV Design and Engineering Decisions

The REVELATION UAV was designed as a compact aerial platform capable of providing an additional sensing and information-gathering domain for the AQUAHOLICS System of Systems. Its design emphasizes stable flight, onboard perception, autonomous capability, and compatibility with the team's existing vehicle-control and communication architecture.



Fig. 8: REVELATION

1) Navigation and Perception: The S500 frame was selected as the UAV platform because its configuration provides a practical balance between structural space, payload capability, flight stability, and ease of integration. The available frame area supports the installation of the flight controller,

companion computer, camera, GPS, telemetry equipment, and battery while retaining sufficient capacity for mission-related payloads. This makes the platform suitable for progressively integrating autonomous functions without requiring a highly specialized airframe.

2) Flight Control and Computing: The UAV uses a Pixhawk 2.4.8 flight controller together with a Raspberry Pi 5 companion computer. The Pixhawk is responsible for real-time flight-control functions, while the Raspberry Pi 5 performs higher-level computing, perception, AI processing, and mission-level decision-making. This separation prevents computationally intensive perception and autonomy workloads from being directly coupled to the low-level flight-control loop. It also provides a modular architecture in which autonomy software can be developed and updated independently of the flight-control system.

3) Vision and Perception: An Arducam IMX296 camera is integrated as the primary visual sensing device. The camera provides image data for computer-vision-based perception and supports the identification of mission-relevant objects and environmental information. The camera was selected as part of the onboard perception architecture to enable the UAV to provide information that can complement the surface vehicle's perception during cross-domain operations.

4) Navigation and Communication: A RadioLink SE100 GPS provides position information for aerial navigation, while MAVLink-based telemetry supports communication with the flight-control and supervisory systems. The communication architecture is designed to allow the UAV to exchange relevant mission and vehicle information with the wider System of Systems.

Overall, the REVELATION design follows the same high-level principle as the DRAKEN Mark 1: separate high-level autonomy and perception from real-time vehicle control. This modular approach simplifies subsystem integration and allows the UAV to progressively transition from semi-autonomous operation toward the higher levels of autonomous and coordinated operation required by the competition.

D. Autonomy, Perception and Navigation

The AQUAHOLICS autonomy architecture combines onboard computer vision, navigation data, and vehicle control to enable autonomous operation of the DRAKEN Mark 1 USV and REVELATION UAV. The design emphasizes onboard processing so that perception and decision-making can be performed without continuous dependence on an external operator.

1) Perception and AI: YOLOv5n is used as the primary vision-based detection model. The model is trained using a custom dataset and is intended to identify buoys, light states, obstacles, and other mission-relevant objects. Camera data are processed by the Raspberry Pi 5, allowing detected environmental information to be incorporated into the vehicle's autonomy decisions.

2) Navigation: The navigation architecture combines GPS and 9-axis IMU information to provide vehicle position and motion-state information. Mission-level navigation uses waypoint-based autonomous operation, with high-level navigation decisions generated by the onboard computing system and vehicle-control commands passed to the Pixhawk controller. This separation allows the Raspberry Pi 5 to handle computationally intensive perception and mission logic while the Pixhawk maintains real-time vehicle control.

3) Obstacle Avoidance and Path Replanning: Obstacle avoidance is integrated with the perception and navigation pipeline. When the vision system identifies an obstacle that may interfere with the planned trajectory, the vehicle reduces or stops its motion, evaluates the detected obstacle, and generates a revised local path before continuing. This perception–decision–action loop enables the vehicle to respond to changes in the operating environment rather than following a fixed trajectory regardless of detected obstacles.

4) Mission-Level Autonomy: The overall autonomy process follows a continuous Perception → State Estimation → Decision → Navigation → Control → Action cycle. This architecture supports autonomous waypoint navigation, mission-object detection, obstacle handling, and dynamic path adjustment while retaining manual and safety fallback modes. The same modular principle is extended to the UAV, where the Raspberry Pi 5 performs higher-level perception and mission functions and the Pixhawk 2.4.8 maintains flight-control responsibilities.

The architecture is designed to progressively support the competition's Core capabilities and provide a foundation for Advanced and Disruptive capabilities requiring greater autonomy and cross-domain coordination.

E. Communication, Integration and Safety

The communication and integration architecture is designed to allow the DRAKEN Mark 1 USV and REVELATION UAV to operate as coordinated but independently controllable systems. The architecture separates vehicle-level control, inter-vehicle communication, and competition-level communication to reduce coupling between subsystems and improve system reliability. For vehicle communication, the system uses MAVLink over a SiK-based RF telemetry link. The radio architecture incorporates frequency-hopping spread spectrum (FHSS), time-division multiplexing (TDM), and GFSK modulation. The RF operating band is targeted at 900 MHz, subject to the final radio-module configuration. This communication layer provides the mechanism for exchanging telemetry, commands, and relevant mission information between the vehicle systems.

At the competition interface, the Operator Control Station (OCS) acts as the team's interface to RoboCommand. The vehicle systems do not directly connect to RoboCommand; instead, required system-level information is handled through the OCS architecture. This maintains a clear separation between the RobotX communication interface and the internal vehicle-control architecture. System integration follows a modular

approach in which the Raspberry Pi 5 performs high-level perception, AI, autonomy, and mission functions, while the Pixhawk controllers perform real-time vehicle control. Communication interfaces connect these layers without directly coupling high-level AI processing to the actuator-control loop. The USV and UAV are therefore capable of maintaining their own vehicle-level operation while exchanging information when cross-domain coordination is required.

Safety is integrated into the communication and control architecture through multiple fallback mechanisms. These include geofencing, low-battery Return-to-Home, communication-loss recovery, GPS-loss handling, manual-control fallback, and a physical kill switch for actuator disconnection. If inter-vehicle communication cannot be established, each vehicle can continue its individual autonomous mission using its predefined safe behavior rather than remaining indefinitely dependent on the other vehicle. This architecture provides a balance between autonomy, coordination, modularity, and safety, supporting the team's objective of progressively integrating the USV and UAV into a cohesive multi-domain System of Systems.

IV. Testing Strategy

A. Testing Approach

AQUAHOLICS follows a progressive testing strategy to evaluate individual components, validate vehicle-level functionality, and integrate the DRAKEN Mark 1 USV and REVELATION UAV into a coordinated System of Systems. Testing is organized into four levels: virtual and algorithm testing, component and laboratory testing, relevant-environment testing, and full-system integration testing. This approach is intended to identify failures early, validate subsystem behavior, and progressively improve autonomous operation and cross-domain coordination.

1) Level 1 – Virtual and Algorithm Testing: This level focuses on validating perception and autonomy algorithms before their deployment on the vehicles. AI-based object detection and mission-related visual perception are evaluated as part of the autonomy development process. Navigation, decision-making, and obstacle-handling algorithms require continued validation as autonomous capabilities are developed.

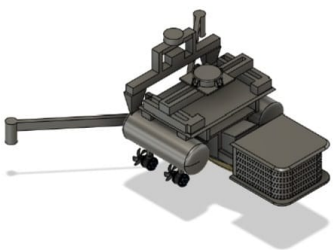


Fig. 9: REVELATION

2) Level 2 – Component and Laboratory Testing: Individual hardware and software components are evaluated before and during system integration. These include the Raspberry Pi 5 computing platforms, Pixhawk controllers, camera-based perception systems, navigation sensors, propulsion interfaces, and telemetry communication. Component-level testing helps identify interface and functionality issues before integrated operation.



Fig. 10: Component Testing

3) Level 3 – Relevant-Environment Testing: The DRAKEN Mark 1 has undergone manual water testing, and the REVELATION UAV has undergone flight testing. USV autonomous navigation and UAV autonomous flight are partially validated and remain under development. USV obstacle detection has been tested, while communication between the USV and UAV is undergoing integration and validation.

4) Level 4 – Full-System and Pseudo-Competition Testing: Integrated testing of the USV and UAV is underway. This stage focuses on validating vehicle-level autonomy, communication, mission coordination, and the interaction between perception, navigation, and control systems. The OCS/RoboCommand interface is partially implemented and remains under testing. Further testing will evaluate coordinated mission execution and the behavior of the system under communication loss, unexpected obstacles, and other predefined failure conditions.

Testing follows an iterative cycle of test execution, observation, failure identification, design or software modification, and retesting. The results are used to guide further development and prioritize unresolved integration issues. The principal current priorities are completing autonomous navigation, improving autonomous flight capability, validating the USV–UAV communication link, and progressing toward integrated multi-vehicle mission testing.

B. Test Plan and Validation Matrix

The AQUAHOLICS test plan is organized around progressive validation of perception, vehicle control, autonomy, communication, and System-of-Systems integration. Each test is intended to verify a specific functional requirement before the corresponding capability is incorporated into higher-level mission testing.

TABLE I: Testing and Validation Status

Test	Objective	Validation	Status
AI Detection	YOLOv5n object detection	Reliable mission-object detection	Completed
USV Manual	Propulsion and manual control	Stable water operation	Completed
USV Autonomous	GPS/IMU waypoint navigation	Stable waypoint following	Partial
UAV Flight	Flight and control systems	Stable outdoor flight	Completed
UAV Autonomous	Autonomous navigation	Successful mission behavior	Partial
USV Obstacle	Camera-based detection	Detection and avoidance	Completed
USV–UAV Communication	MAVLink data exchange	Reliable telemetry	Undergoing
OCS/Rx	Command and reporting	Required communication	Testing
USV–UAV Integration	Coordinated operation	Information exchange and coordination	Undergoing

Testing is performed progressively so that failures at one level can be isolated before they propagate into the integrated system. Results from each test are used to identify software, hardware, communication, or integration issues and determine the next development iteration. The final validation stage will combine the tested subsystems into representative mission scenarios. These tests will include autonomous navigation, obstacle response, inter-vehicle communication, mission coordination, communication-loss recovery, Return-to-Home behavior, and other predefined safety responses.

C. Testing Results and Design Improvements

Testing has been used as an iterative engineering process in which individual subsystem results are used to guide subsequent integration and development. The completed AI detection, USV manual water, UAV flight, and USV obstacle-detection tests established the initial functional baseline for the respective subsystems. The results from these tests have been incorporated into the ongoing autonomous-system development. The USV has progressed from manual water operation toward autonomous navigation, with autonomous navigation currently partially validated. This has directed further development toward reliable waypoint execution, vehicle-state estimation, obstacle response, and integration with the Pixhawk control system.

The UAV has completed basic flight testing and has progressed toward autonomous flight, which remains partially validated. Continued testing is focused on autonomous mission behavior and integration of the Raspberry Pi 5 companion computer with the Pixhawk flight controller. Obstacle detection on the USV has been tested successfully at the subsystem level and is being incorporated into the autonomous navigation loop. The resulting architecture uses camera-based perception to identify obstacles and initiate the predefined stop, assessment, and path-replanning behavior.

The primary remaining integration challenge is coordinated operation between the USV and UAV. MAVLink-based communication is undergoing testing, while the OCS/RoboCommand interface is partially implemented and under validation. Integrated USV–UAV testing is therefore being performed progressively rather than treating the two vehicles as a single system before their individual capabilities are sufficiently validated. Based on the current testing status, the team's development priorities are to complete autonomous navigation validation, improve autonomous UAV operation, validate reliable USV–UAV communication, complete OCS/RoboCommand integration, and conduct representative multi-vehicle mission tests. This iterative approach allows identified integration limitations to be addressed before full-system and pseudo-competition testing.

V. Conclusion

AQUAHOLICS has developed a modular multi-domain System of Systems centered on the DRAKEN Mark 1 USV and REVELATION UAV for the RobotX 2026 Maritime RobotX Challenge. The system combines autonomous perception, navigation, vehicle control, communication, and safety mechanisms to support coordinated operation across surface and aerial domains. The team's competition strategy prioritizes reliable execution of Core capabilities while progressively pursuing Advanced and Disruptive capabilities where technically feasible. The design strategy separates high-level autonomy and AI processing from real-time vehicle control, enabling independent subsystem development and progressive system integration. Testing has established functional baselines for key subsystems, while autonomous navigation, UAV autonomy, inter-vehicle communication, OCS/RoboCommand integration, and full USV–UAV coordination remain under continued validation. The ongoing iterative development and testing process will be used to improve system reliability and prepare the integrated platform for representative RobotX mission scenarios.

References

[1] G. Kolev, S. N. Tayarani Bathaie, V. Rybin, M. Kulagin, and T. Karimov, "Design of Small Unmanned Surface Vehicle with Autonomous Navigation System," *Inventions*, vol. 6, no. 4, p. 91, 2021. doi: 10.3390/inventions6040091.

[2] H. Ma, X. Mu, and B. He, "Adaptive Navigation Algorithm with Deep Learning for Autonomous Underwater Vehicle," *Sensors*, vol. 21, no. 19, p. 6406, 2021. doi: 10.3390/s21196406.

[3] F. Maurelli, S. Krupiński, X. Xiang, and Y. Petillot, "AUV localisation: A review of passive and active techniques," *International Journal of Intelligent Robotics and Applications*, vol. 6, pp. 246–269, 2022. doi: 10.1007/s41315-021-00215-x.

[4] J. Qin, M. Li, D. Li, J. Zhong, and K. Yang, "A Survey on Visual Navigation and Positioning for Autonomous UUVs," *Remote Sensing*, vol. 14, no. 15, p. 3794, 2022. doi: 10.3390/rs14153794.

[5] A. Author et al., "Collaboration of Heterogeneous Marine Robots Toward Multidomain Sensing and Situational Awareness on Partially Submerged Targets," *IEEE Journal of Oceanic Engineering*, vol. 47, no. 4, pp. 880–894, 2022. doi: 10.1109/JOE.2022.3156631.

[6] T. Matsuda, K. Fujita, Y. Hamamatsu, T. Sakamaki, and T. Maki, "Parent–child-based navigation method of multiple autonomous underwater vehicles for an underwater self-completed survey," *Journal of Field Robotics*, vol. 39, pp. 89–106, 2022. doi: 10.1002/rob.22038.

[7] B. Zhang, D. Ji, S. Liu, X. Zhu, and W. Xu, "Autonomous Underwater Vehicle navigation: A review," *Ocean Engineering*, vol. 273, p. 113861, 2023. doi: 10.1016/j.oceaneng.2023.113861.

[8] P. Chaysri, C. Spatharis, K. Blekas, and K. Vlachos, "Unmanned surface vehicle navigation through generative adversarial imitation learning," *Ocean Engineering*, vol. 282, p. 114989, 2023. doi: 10.1016/j.oceaneng.2023.114989.

[9] S. Cheng, Y. Zhu, and S. Wu, "Deep learning based efficient ship detection from drone-captured images for maritime surveillance," *Ocean Engineering*, vol. 285, p. 115440, 2023. doi: 10.1016/j.oceaneng.2023.115440.

[10] Y. Wang, W. Liu, J. Liu, and C. Sun, "Cooperative USV–UAV marine search and rescue with visual navigation and reinforcement learning-based control," *ISA Transactions*, vol. 137, pp. 222–235, 2023. doi: 10.1016/j.isatra.2023.01.007.

[11] J. Wu, R. Li, J. Li, M. Zou, and Z. Huang, "Cooperative unmanned surface vehicles and unmanned aerial vehicles platform as a tool for coastal monitoring activities," *Ocean & Coastal Management*, vol. 232, p. 106421, 2023. doi: 10.1016/j.ocecoaman.2022.106421.

[12] D. F. Carlson, S. Akbulut, J. F. Rasmussen, C. S. Hestbech, M. H. Andersen, and C. Melvad, "Compact and modular autonomous surface vehicle for water research: The Naval Operating Research Drone Assessing Climate Change (NORDACC)," *HardwareX*, vol. 15, p. e00453, 2023. doi: 10.1016/j.ohx.2023.e00453.

[13] D. Fenucci, F. Fanelli, A. Consensi, G. Salavasidis, M. Pebody, and A. B. Phillips, "A multi-platform Guidance, Navigation and Control system for the autosub family of Autonomous Underwater Vehicles," *Control Engineering Practice*, vol. 146, p. 105902, 2024. doi: 10.1016/j.conengprac.2024.105902.

[14] M. C. Santos, B. Bartlett, V. E. Schneider, F. O. Brádaigh, B. Blanck, P. C. Santos, P. Trslic, J. Riordan, and G. Dooly, "Cooperative Unmanned Aerial and Surface Vehicles for Extended Coverage in Maritime Environments," *IEEE Access*, vol. 12, pp. 9206–9219, 2024. doi: 10.1109/ACCESS.2024.3353046.

[15] H. Zhang, J. Fan, X. Zhang, H. Xu, and C. Guedes Soares, "Unmanned Surface Vessel–Unmanned Aerial Vehicle Cooperative Path Following Based on a Predictive Line of Sight Guidance Law," *Journal of Marine Science and Engineering*, vol. 12, no. 10, p. 1818, 2024. doi: 10.3390/jmse12101818.