Maritime RobotX Challenge
Preliminary Rules and Task Descriptions

www.RobotX.org

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Goals

This competition is designed to foster student interest in autonomous robotic systems operating in the maritime domain, with an emphasis on the science and engineering of autonomy, not on vessel construction. The Office of Naval Research (ONR) will provide a standard surface vessel to each team that will serve as the maritime platform for the various sensor suites and control systems that they determine necessary to complete the mission tasks. These vessels will be provided WITHOUT propulsion units so that the maneuvering control of the vessel must be selected by each team, and integrated fully into their autonomy schema. Each team will be provided with a stipend to defray the costs of designing and building their own propulsion system, motor controller, and electric power source. The vessels will be delivered to the teams in November 2013, giving each team about 11 months to outfit their craft and prepare for the competition.

Points of Contact

Aamir Qaiyumi, NSWC PCD	Technical Director – Rules, Procedures, Specifications
Bill Porter, NSWC PCD	Deputy Technical Director – Rules, Procedures, Specifications
Daryl Davidson, AUVSI Foundation	Competition Coordination
Cheri Koch, AUVSI Foundation	Competition Logistics
Pam Smith, AUVSI Foundation	Sponsorship and Media Requests
Ho Choong Chuin	Competition Site Coordinator

Competition Location Information

The competition will take place at Marina Bay, Republic of Singapore, adjacent to a large floating platform that abuts an amphitheater on the north shore. The platform is 120 meters long and 83 meters wide. There will be an 80 meter square practice area located on the east side of the platform and two competition courses laid out to the west side located inside a 190 meter by 190 meter square area.

All events and Team practice will occur within these three operating areas. Launch and recovery operations will take place near the competition courses. Tasks may be positioned at any location within the larger 190 meter square area and may be moved from day to day during the competition. The venue is large enough to support simultaneous operation of two courses at once. A vehicle will be operating in one arena while a team prepares for a run in the other.

Team Tasks

In addition to the tasks that the vehicle must complete, the teams will need to document their efforts leading up the competition, as well as present their work to the judges on site. This section contains a summary of those requirements. Scoring will be accomplished as described in the scoring section of this document.

Website

Teams must maintain a website documenting their efforts and progress leading up to the competition. The website should include at a minimum the following information:

- Team name
- Team member information

- Media (pictures, video, etc.) taken during development and testing
- Sponsors
- Contact details for more information

Journal Paper

Each team is required to submit a journal paper in English that describes the design of their vehicle and the rationale behind their design choices. Specific requirements for the journal paper are listed below:

- The paper may be no more than 10 pages long (including all figures, reference, and appendices).
- Each journal paper must include an abstract of no more than 250 words, which is not counted towards the 10-page limit.
- The journal paper must use margins of at least 1 inch on all sides, and all text must be 12-point or larger font.
- Each page must contain a footer with the page number and the team name.
- The journal paper must be received in pdf format via email, submitted to info@robotx.org.

On-site Presentation to Judges

Along with the paper and website, each team will also be required to present their project to the judges in the form of an oral presentation with visual aids. This is anticipated to be conducted indoors at the competition venue. The presentation should introduce the team, their craft, and special features and/or strategies for the competition.

Water-based Vehicle Tasks

Starting Point

Craft will be launched from the floating platform and may be directed by remote control to the indicated START point on the assigned course. During the scoring rounds, **teams must start at the beginning of Task 1**. After completing Task 1, the team may continue their run attempt at beginning of any other task with the understanding they will only be allowed to complete that task and any following tasks, but not any preceding tasks. They must have their vehicle navigate autonomously to the task area, and begin the task by proceeding through any entrance gate for that task if present. Once the run commences and the craft maneuvers through the starting gate of Task 1, all operations must be performed autonomously by the craft. The five mission tasks are listed here in no particular order.

Task 1: Demonstrate Navigation and Control (MANDATORY)

All teams must complete this task at the start of each of their runs before continuing to other tasks. In this Task the craft must maneuver autonomously along a marked course, beginning at the START point, traversing a linear course marked by two sets of buoys (“gates”).

Detailed Task Description:

The first gate is the START of the course; the second gate is the END of the course. Both gates consist of a pair of buoys spaced 10 meters apart following the convention of placing a GREEN buoy to starboard and a RED buoy to port in the direction of travel along the course. The length of the course is variable but will not exceed 100m. A NOMINAL course arrangement is shown in Figure 1. Each craft will begin the course at the START gate and maneuver autonomously to follow the course to the END gate. The GPS coordinates for the START and END gate buoys will be published on site.

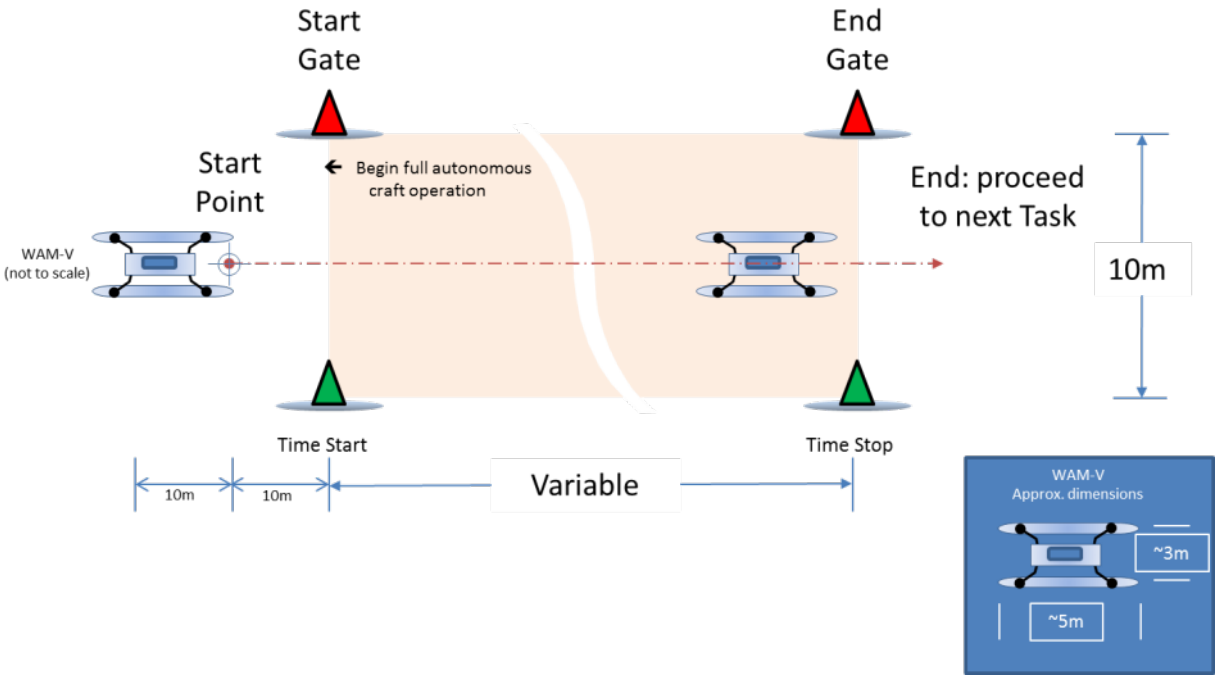

Figure 1. Task 1 Nominal Layout

Judging:

Passage through each gate will be determined by judges; contact with buoys will result in a scoring penalty. The total elapsed time to perform this task will be recorded beginning when the bow of the craft crosses the START gate line and ending when the bow crosses the END gate line.

Task 2: Detect and Avoid Obstacles

In this Task, the craft must navigate to the pre-designated START gate (1, 2, or 3), travel autonomously through an arrangement (or field) of various floating, stationary obstacles, and complete the course by passing through the pre-designated END gate (X, Y, or Z). The objective is to traverse the course in the shortest time, avoiding completely all obstacles and gates (no contact allowed).

Detailed Task Description:

There are three START gates and three END gates at opposite ends of a moored obstacle field. There are nine possible combinations of entry and exit gates, but the same pair will be designated for all craft for each day's competition. The Technical Director will select an obstacle path of the day citing the entry gate (1, 2, or 3) and exit gate (X, Y, or Z). For each run, the Team craft will maneuver through the assigned START gate (1, 2, or 3) and through the assigned END gate (X, Y, or Z) without touching any intervening obstacle.

The six gates are each 10m wide and marked as follows: START Gate #1, RED buoy to port, WHITE buoy to starboard; START Gate#2, WHITE buoys to both port and starboard; START Gate#3, WHITE buoy to port and GREEN buoy to starboard; X, Y, and Z are marked similarly to the START gates as shown in the diagram below. The various floating obstacles in the field will be placed at random positions and moored, but the arrangement for all competitors, for each day of competition, will be the same. The obstacle field may be different between the two courses. Each obstacle course will be approximately 40m wide and not more than 100m long. Moored obstacles will be floating on the surface, visible, and of various shapes and colors. A NOMINAL course arrangement is shown in Figure 2. GPS coordinates for the START and END gate buoys will be published on site. The craft must navigate the course through the field autonomously.

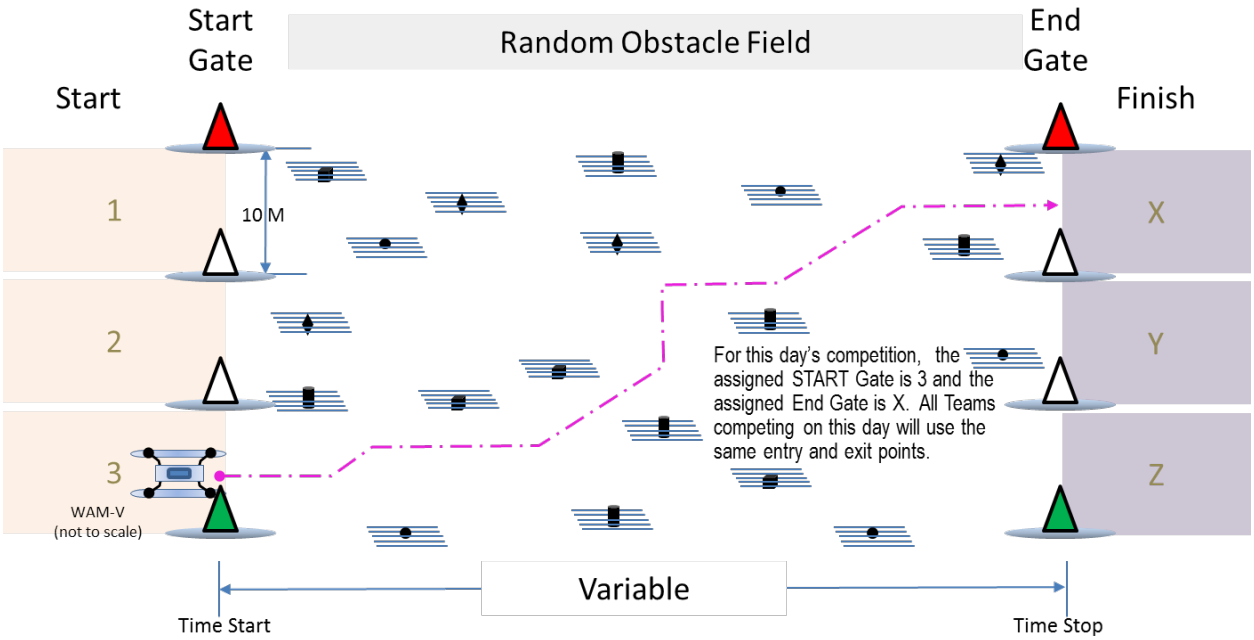

Figure 2. Task 2 Nominal Layout

Judging:

Successful passage through both gates will be determined by judges; no contact with buoys or obstacles is permitted. In the case of contact with gates or obstacles, judges may assess a penalty. The total elapsed time to perform this task will be recorded beginning when the bow of the craft crosses the START gate line and stopping when the bow crosses the END gate line. Should the craft become ensnared with any part of the course, the run will be ended by a safety judge and penalties assessed.

Task 3: Underwater Search

In this Task, the craft must successfully identify and locate a specific underwater device that is emitting an acoustic signal.

Detailed Task Description:

The craft will enter a search area at least 40m wide and not more than 100m long in which there are multiple randomly placed underwater acoustic devices each attached to an anchored floating buoy. GPS coordinates for the search areas of each course will be published on site. The craft may enter the area

from any location. For each competitive run, one of the devices will be designated at random to emit an acoustic signal; the others will remain silent. The craft must autonomously search the area to detect the device emitting the acoustic signal and maneuver to place itself adjacent to its buoy.

Upon arriving within one craft length of the buoy supporting the active acoustic transmitter, the craft will send an alerting signal to the judge's station indicating which emitting object has been located using the required message format, as specified in the RobotX Communications Protocol document. Once this is done, the craft may continue to the next task. If multiple messages are received, only the last message received at the judge's station will be counted. An example search area, track, and sequential run execution is shown in Figure 3.

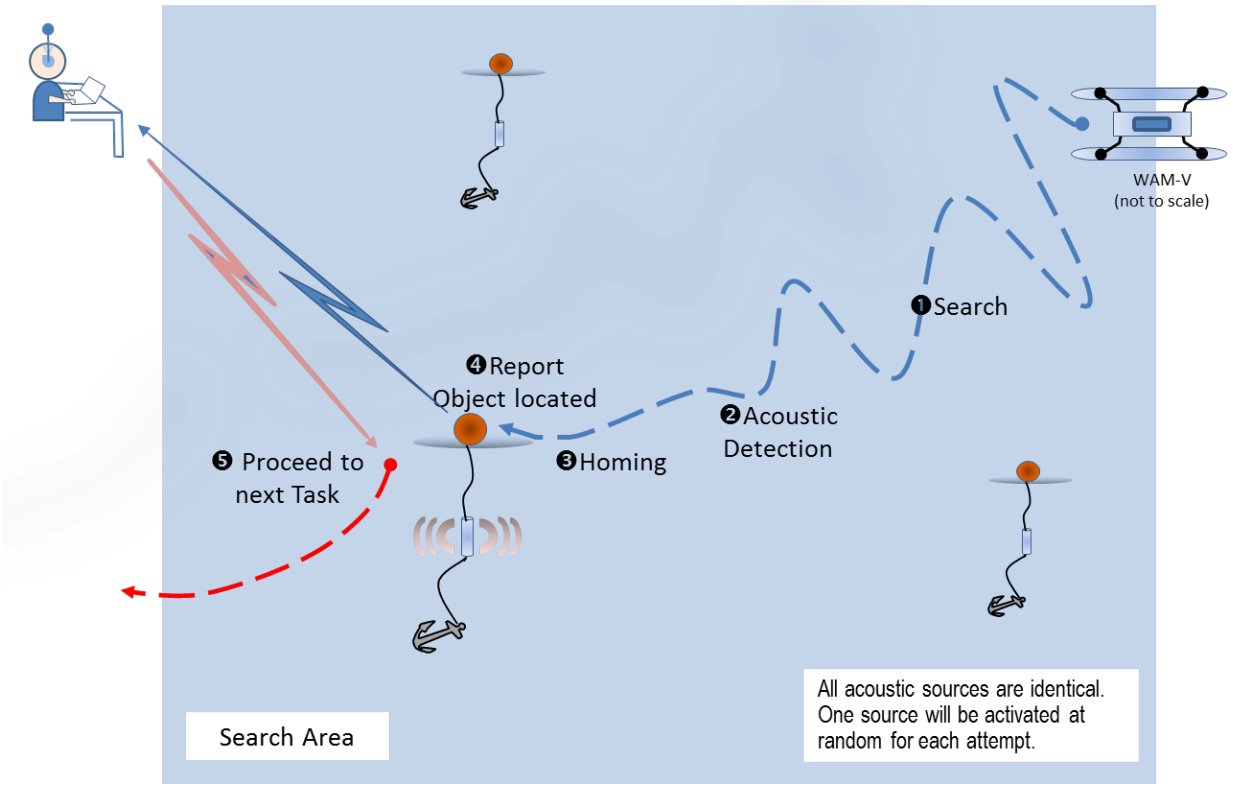

Figure 3. Task 4 Example

All the acoustic transmitters are identical. Their signal characteristics will be posted to the RobotX website. For each team attempt, a single transmitter will be randomly activated.

Optional Task for Bonus Points

The normal water depth in the area is 4-6 meters. Each emitter will be tethered to its buoy at a random depth from the lagoon bottom to very near the surface buoy. If teams choose to attempt to estimate the depth of the acoustic emitter from the surface in meters, and transmit it in the "Object located" message, additional points will be added to the team score based on the accuracy of the estimate.

Task 4: Observation

In this Task, the craft will conduct observation of an object buoy to determine the light pattern of a series of lights mounted a marker buoy. The craft will autonomously report the sequence of the buoy lights, then continue to the next task. The lights for this task will not be activated until the vehicle has started its autonomous mission run.

Detailed Task Description

A white object buoy with a light bar on a mast will be located randomly within the search area, which is approximately 40 X 60 meters. The light atop the buoy will be no more than 3 meters above the water's surface. The light assembly on the buoy will successively turn on the colors one at a time to generate a pattern of three colors. Each color will remain on for 500 milliseconds, after which the lights will remain off for 2 seconds before repeating the pattern.

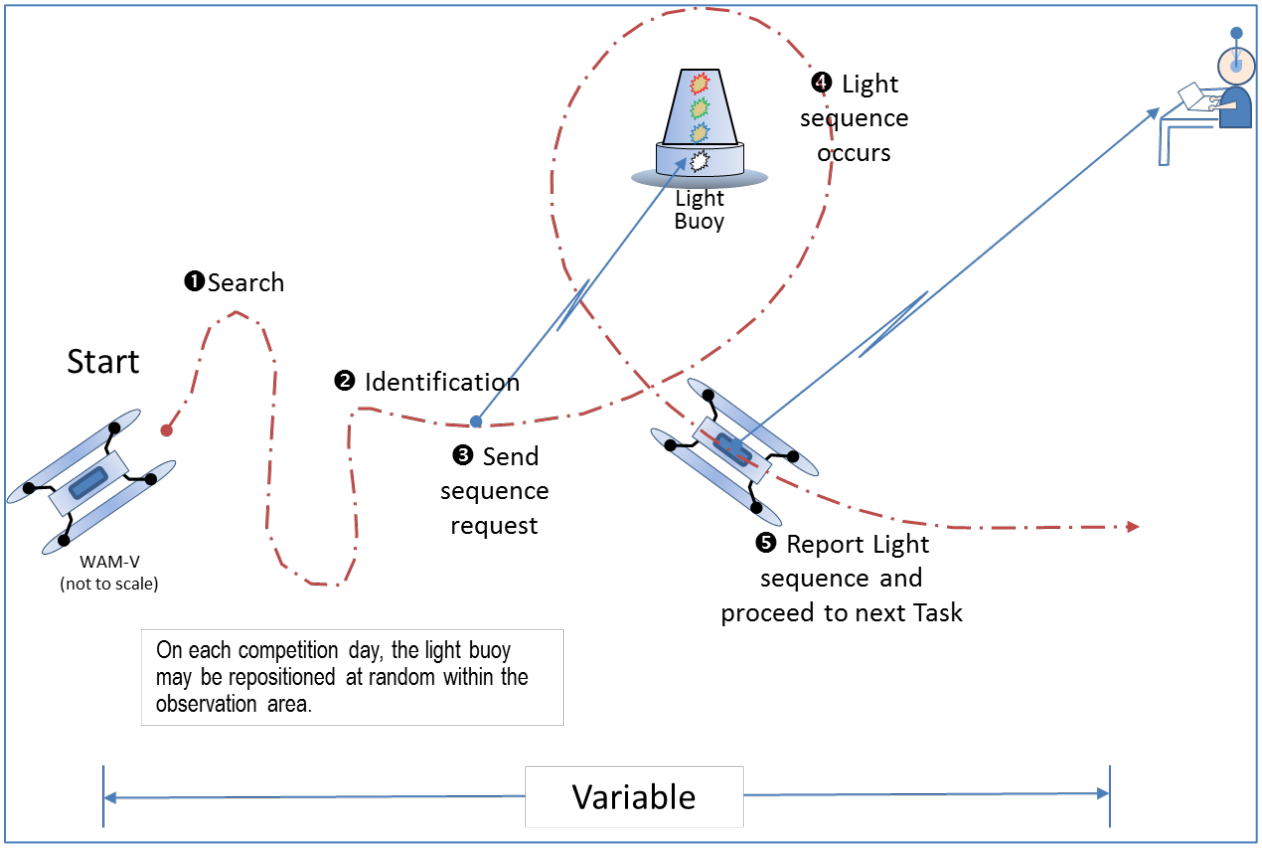

Figure 4. Task 4 Notional Example

The craft must transmit the detected light sequence in accordance with the message format detailed in the RobotX Communications Protocol document prior to attempting its next task or ending its run to receive points. Receipt of the message will be verified by a judge. A NOMINAL search area is shown in Figure 4.

Upon passing into the search area at any point, the craft is free to maneuver as necessary to conduct observation in the vicinity of the object buoy to determine the sequence of the lights.

No contact with the object buoy is permitted and the accuracy of the craft report will be a scoring factor. Striking the buoy will result in point penalties. This is to encourage teams not to create situations that may be hazardous to personnel, other craft, or competition components.

Judging

Successful completion of this task will be evaluated based on a review of the message received from the vehicle. The report generated by the craft need only indicate the light sequence on the buoy via the transmission form described in the RobotX Communications Protocol document.

Task 5: Craft Docking and Target Identification

In this Task, the craft must successfully identify one of three marked docking bays designated for that day, locate it, maneuver to enter the correct dock, stop, and then leave the dock before moving on to the finish gate.

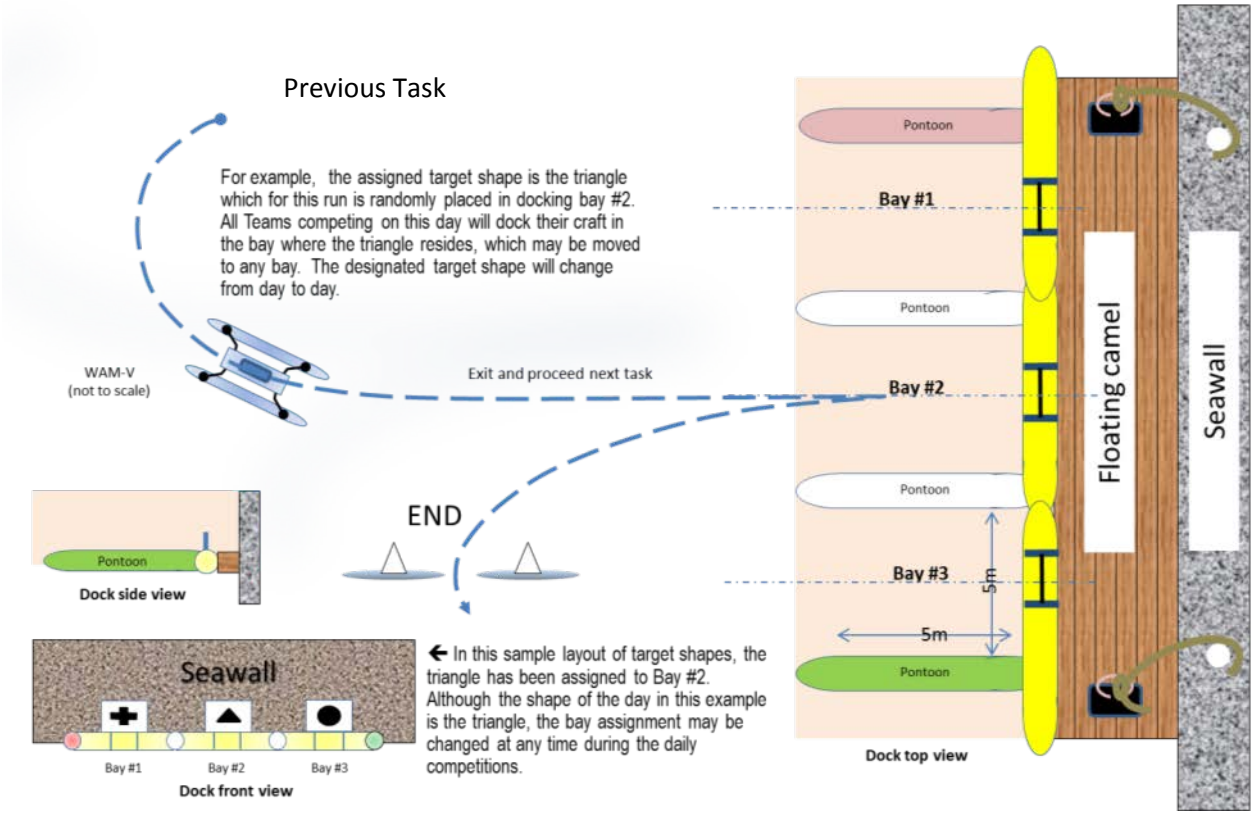

Figure 5. Task 5 Example

Detailed Task Description:

The dock will consist of three similar docking bays, each the same size, but distinguishable by a large geometric shape located at its closed end. The dock will be permanently attached to a fixed location, closed end toward the platform, with open ends of its three bays facing seaward. Each bay consists of floats positioned to form a cul-de-sac. Bay #1 will have a RED pontoon to port, a WHITE pontoon to starboard and a YELLOW pontoon connecting them at the closed end. Bay #2 will have a White pontoon to port, a WHITE pontoon to starboard and a YELLOW pontoon connecting them at the closed end. Bay #3 will have a WHITE pontoon to port, a GREEN pontoon to starboard and a YELLOW pontoon connecting them at the closed end. Each bay will accommodate a WAM-V craft with sufficient clearance on both port and starboard sides. The YELLOW connecting pontoons at the closed end of each bay will be positioned a minimum of 5 meters from the entrance to the bay.

Each YELLOW connecting pontoon will have a large WHITE placard affixed to it, upright, with either a black cruciform (Bay #1), a black triangle (Bay #2), or a black circle (Bay #3) to provide a visual reference mark for the centerline of each respective bay. The shapes will be at least 1m across on the white background. Daily, the circle, the triangle, or the cruciform will be designated as that day's docking bay symbol for all Teams. Each craft approaching the dock will sense (visually) the correct form for that day,

and enter the bay that displays that shape. The shapes may be randomly moved from one docking bay to another at any time during the day's competition.

A NOMINAL dock and course arrangement are shown in Figure 5. A GPS point approximately 10 meters seaward of the dock assembly will be posted on site.

At the completion of the previous task, the craft will autonomously locate the dock and the designated bay, approach it, alter its course to enter, and proceed into the bay. Once fully inside the bay, the craft may exit the bay and proceed to the next task or the finish gate. Light contact with the pontoons is permitted, as long as the pontoons are not damaged in any way. If necessary to maintain position inside the dock, minimum craft headway into the YELLOW connecting pontoon is permitted.

Judging

Docking is considered successful when the USV maintains station completely within the dock boundaries. Successful docking and departure will be judged according to judging criteria to be provided on the competition website.

Ending Point

A run attempt comes to an end when one of the following occurs:

1. The vehicle passes through the finish line buoys at the end of the course
2. The team signals an early termination without the loss of points due to penalties
3. A safety judge activates the kill switch to maintain craft and/or course safety, resulting in loss of points due to penalties.

Once beyond the FINISH buoys, the Team will maneuver the craft by remote control to the recovery point.

Early Termination

There are two means by which a run attempt can be terminated early. The first is a voluntary termination and involves a team notifying the judge to stop their vehicle, ending their run attempt. This method does not incur any additional penalties and allows the team to keep any points earned during that run attempt. If still within the teams' course assignment time window, the team may choose to start a new run attempt. The highest point score earned by a team will be used as their score.

The second method of early termination involves a vehicle stop due to safety reasons. If the vehicle has struck a course boundary or has become a safety concern, a safety judge will signal a safety stop and the run will be ended. If this occurs the team will lose all points earned during that run attempt. If still within the teams' course assignment time window and the safety judge feels the safety issue has been resolved, the team may start a new run attempt.

Platform Requirements

System Requirements

Each team's WAM-V system must include an Operator Control Station (OCS) capable of remote tele-operated control of the WAM-V and monitoring of the autonomous mode operation. The OCS must have the ability to start/stop autonomous missions so that after driving the vehicle to the start point, the team can release control for the vehicle to autonomously execute the mission. The OCS must be

able to be operated safely aboard the safety judge's support boat, which may or may not have power available.

Communications Requirements

Each team's vehicle must transmit a heartbeat message at a rate of 1Hz, as specified in the RobotX Communications Protocol document. This will be verified to be functional at each launch of the vehicle.

Safety Requirements

1. The vehicle must have two methods to stop vehicle operation.
    a. A physical kill switch easily accessible from a nearby support vessel.
    b. A remote (software/hardware) kill switch integrated onto the vehicle that is compatible with the system detailed in the RobotX Kill Switch document on the RobotX website. This switch must be demonstrated to disable vehicle thrusters within 1 second of activation in all vehicle modes. Judges will record successful function of this this function prior to each mission run.
2. All considerations to maintain operator and surrounding safety must be made. This includes mitigating hazards due to props, sensors, sharp objects, man portability, etc.
3. All RF equipment must be operated within the rules and regulations of the host country for such RF equipment. This includes frequency, transmitting power, antenna height, etc.
4. Vehicle power systems (batteries, fuel, etc.) must follow the safety rules and regulations of the host country as well as the teams' home country.

Weight and Size Constraints

The baseline WAM-V craft will be provided by the AUVSI Foundation without propulsion or control systems. The student teams are responsible for building and integrating these features. Basic craft specifications are available on the Maritime RobotX Challenge website. These specifications include maximum craft weight.

Official Rules and Team Guidelines

1 . During the competition, the vehicle must operate autonomously, with no control or guidance from a person or any off-board device.
2. Teams may comprise a combination of students, faculty, industrial partners, or government partners. Students may be high school, undergraduate and/or graduate students. Interdisciplinary teams are encouraged. Multiple educational institutions may join together to form single teams. Members from industry, government agencies, or universities (in the case of faculty) may participate; however, full-time students must compose at least 75% of each team. Participants must be enrolled at their schools as a full time student per quarter/semester during winter and spring to be considered "students." The student members of a joint team must make significant contributions to the development of their vehicle.
3. One student member of the team must be designated as the "team captain". The team captain, and only the team captain, will speak for the team during the competition run.
4. Only the student component of each team is eligible for the cash awards.
5. No team member is allowed to enter the arena at any time (this includes wading, swimming, and diving as well as floats, boats, etc.). Competition officials will be responsible for recovering lost vehicles. Officials will make all reasonable efforts to recover a lost vehicle but cannot guarantee that they will be able to do so. All teams recognize that by entering the competition,

they risk damage to or the loss of their vehicle. The judges, officials, hosts, and sponsors can take no responsibility for such damage or loss.

6. The officials will suspend the competition at any time they deem that it is required by safety or security considerations.
7. Teams are responsible for following rules and regulations of their own nation as well as the host nation with respect to radio frequencies, power, vessel markings, etc.
8. Teams are responsible for shipping to and from the competition site.
9. Teams are responsible for providing local transportation to and from the test facility from their on-site residence.

Competition Structure

Overall Approach

There will be time early in the competition week for teams to practice on the competition courses and practice areas. After the practice days, there will be a Qualifying Round in which teams can demonstrate the ability to complete Task 1 autonomously. Successful completion of Task 1 qualifies the team for entry into the next round.

There will be a dedicated practice area separate from the competition areas that can be used by all teams on a sign-up basis throughout the competition dates.

Scoring

Team Judging and Scoring

Teams will be scored based on their submitted paper, the team website, a presentation given to the judges on site, and the team interview on site with the teams. The judges will evaluate based on technical merit, safety, and craftsmanship. Specific scoring breakdowns are still under development and will be provided at a later date on the competition website. Detailed task scoring breakdowns are still in development. They will be posted to the competition website when they are complete.

Water-based Task Scoring

Task scoring breakdowns are still under development and will be provided at a later date on the competition website.

Possible Penalties

Point penalties per task will be outlined in the scoring section. The following rules and penalties apply during the entire run of the vehicle during the attempts of any task.

1. Safety Termination

If the vehicle has struck a course boundary or has become a safety concern, a safety judge will signal a safety stop and the run will be ended. If this occurs the team will lose all points earned during that run attempt. If still within the teams' course assignment time window and the safety judge feels the safety issue has been resolved, the team may start a new run attempt and begin earning points again.

2. Course Boundary

Each course will be bounded on two sides with marker buoys at regular intervals. One side is bounded by a seawall behind the docking task. Collision with course boundaries or the seawall constitutes a safety termination of the run attempt and forfeiture of any points earned in task during the run. It is suggested that the team members monitor their vehicle and exercise a voluntary early run termination if they feel there is a risk of collision with a course boundary. Leaving the course via the open side, whether intentionally or otherwise, constitutes an end of run without forfeiting any points.

3. Interference with Competition Elements

Vehicles that interfere with competition elements may be disqualified at the judges' discretion. "Interference" does not include cases where, in the opinion of the judges, a vehicle is attempting to complete one of the tasks and becomes entangled in an objective. This includes failure to operate within the team's scheduled time slot, affecting the competition schedule.

4. Entanglement

If a vehicle becomes entangled with a course objective, the team may choose to signal a voluntary early termination without losing the points earned during the run. They also retain the option to forfeit any points earned so far and repeat the run if there is time left to do so. However, if they choose to wait to see if the vehicle clears the entanglement on its own they risk an early termination by the safety judge and forfeiture of any earned points during that run.