2016 Maritime RobotX Challenge Task Descriptions

Version 1.0, Updated 18 November 2016

www.RobotX.org

Honolulu, Hawaii, USA

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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 cooperative autonomy. In addition, the competition should facilitate the building of international relationships between students, academic institutions, and industry partners.

RobotX Challenge Competition Structure

The Maritime RobotX Challenge is a capstone robotics competition which builds upon the successful implementation of other student robotics competitions such as RoboBoat and RoboSub. We encourage student teams to participate and learn from other competitions, and then apply those skills to the advanced challenges presented in the RobotX Challenge. RoboBoat and RoboSub are annual events that may serve as test beds for future RobotX Challenges.

The purpose of the RobotX Challenge is to enhance the community of innovators capable of substantive contributions to the domain of autonomous, unmanned, multi-domain vehicles. This enhancement is achieved by providing a venue and mechanism whereby the practitioners of the autonomous vehicle community may form new connections and collaborations, increase their proficiency and inventiveness, and foster their passion for robotics and the maritime domain. The inaugural RobotX Challenge was an autonomous surface vessel competition, however there will be a continually increasing emphasis on multi-domain and collaborative autonomy going forward.

The term **ASV** will be used through this document to mean the Autonomous Surface Vessel (ASV) and any ancillary subsystems used to accomplish the tasks.

Many of the past RoboBoat and RoboSub challenges have been executed serially or independently. One of the big challenges for autonomous systems continues to be development and integration of higher level autonomy. With higher level autonomy, these systems can accurately identify and classify objects, adapt to a dynamic environment, make smart decisions, and require the ability to prioritize tasking based on mission time and vehicle health to accomplish the overall mission.

With this in mind, RobotX offers a significant departure from previous competitions in that the Semi-final and Final courses are not here pre-defined. Teams will have access to several in-water practice/qualifying areas for each task, clustered as Challenge Courses designed permit Teams greater access to the competition course tasks. Teams may qualify for the semi-finals by completing individual tasks during the initial practice/qualifying days of the competition.

For the Semi-final and Final rounds we will combine some or all of the individual tasks into a full Competition Course. This course will require execution of multiple individual tasks, in certain combination, to complete the overall mission. In other words, Teams can qualify and practice with the individual tasks leading up to the Semi-final and Final rounds, but to win, they have to bring it all together. During the Semi-final and Final rounds all Teams will compete on the same course layout.

To add even more challenge to this event, we anticipate a need for Teams to construct a System of Systems (SoS) consisting of craft operating in multiple domains. For 2016 all Teams must use the WAM-V surface vessel, but will also need the ability to sense and act underwater. This may be accomplished by incorporating an underwater vehicle into the system to act as an off-board sensor.

Competition Location Information

The 2016 competition will take place at Sand Island in Honolulu, Hawaii, in the United States of America. In-water areas will have beach access on the southern side of Sand Island. The general RobotX Challenge event layout is shown in Figure 1, with the competition and practice areas identified. **Due to our proximity to the Honolulu airport, air vehicles will not be permitted during the competition.**

All events and Team practice will occur within these operating areas. Launch and recovery operations will take place either near the practice/qualifying areas or near the Competitor's Village. Competition task elements may be positioned at any location within the larger competition area. The task elements may be moved or reconfigured from day-to-day during the competition.

NOTE: The beach access area where Teams will be able to operate their ASVs has a shallow gradient and is subject to tidal variations of water depth. It will be relatively easy to pull the ASV up on the beach so that Teams may conduct minor hardware changes and repairs, as well as software updates. This shallow gradient means that there is also a risk of getting the ASV's propulsion systems fouled in the sand. It is recommended that Teams consider ways to retract or raise their motors to account for this risk.

Competitor's Village

Each Team will be provided with a covered working area near the Marine Education Training Center (METC). This work area will have power and an internet connection.

2016 Maritime RobotX Challenge Venue

The 2016 Maritime RobotX Challenge will be set up along the shore and in-water near the primary public boat ramp on Sand Island in Hawaii, as represented in Figure 1. The venue will include elements of each of the competition tasks which Teams may use to train and tune their unmanned systems. For example, **at least** one acoustic pinger, one docking setup, one light buoy, and a representative obstacle course will be set up in the practice area.

Figure 1. Overall 2016 Maritime RobotX Challenge Venue

Practice/Qualifying Area

The Practice/Qualifying Area will be set up along the shore and in-water, structured as groups of the seven tasks arranged in Challenge Courses. The practice/qualifying area will be arranged such that multiple Teams may practice or qualify at the same time.

Competition Area

The venue is large enough to support installation of multiple instances of each task in which Teams may practice and qualify for spaces in the Semi-final round. An example competition venue and Challenge Course venue is shown in Figure 2 and Figure 3 with the following caveats:

- Sizes and bearings shown are preliminary.
- Final size and layouts are subject to change.
- Dotted lines shown are only for the purpose of identifying tasks and courses on the drawing. They do not represent anything physical that will be present on or under the water.

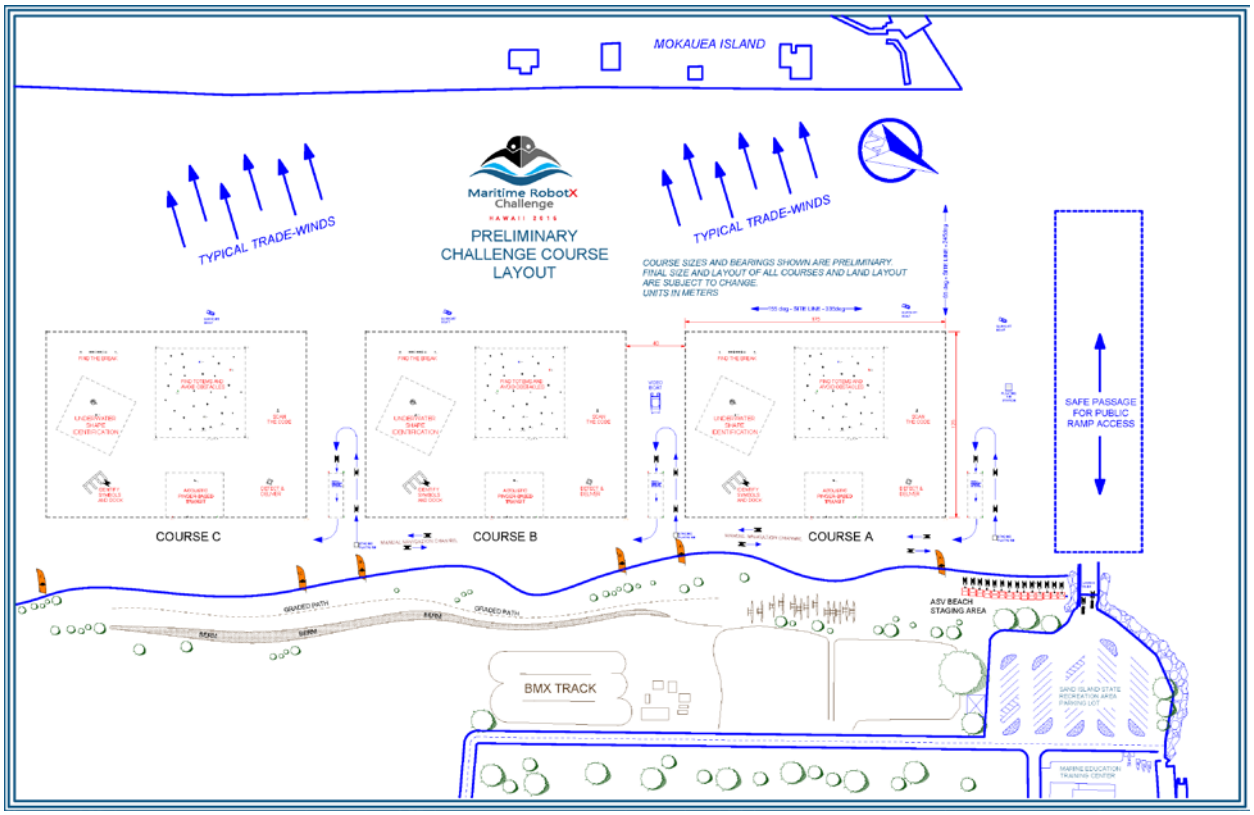

Figure 2. Planned 2016 Maritime RobotX Competition Layout

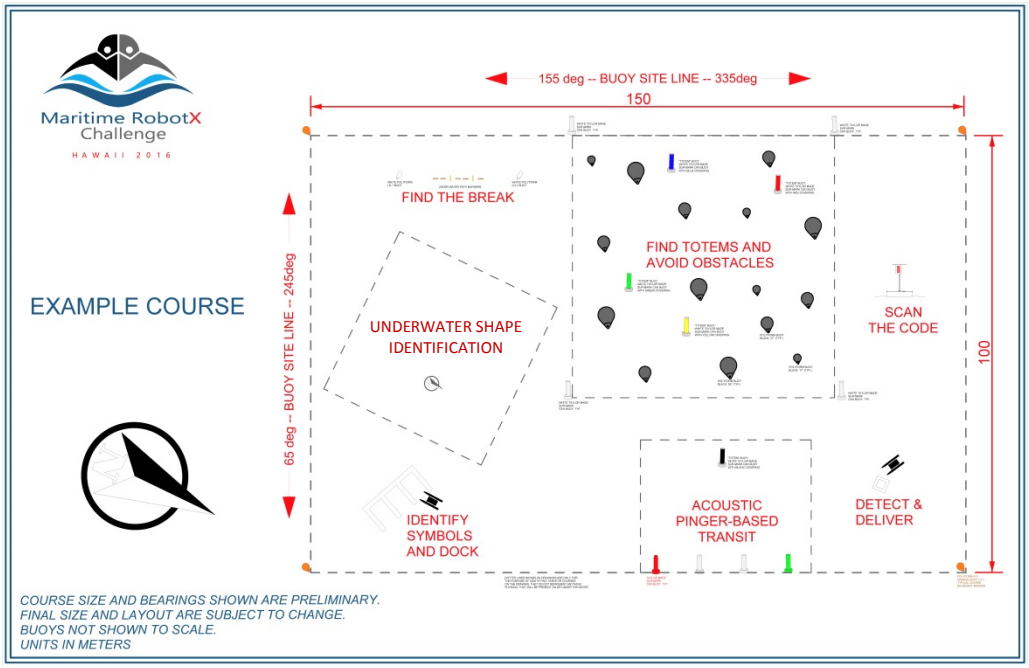

Figure 3. Example Challenge Course Layout

Course and Task Area Boundaries

The Challenge Course and Competition Course boundaries will be clearly identified. During the scoring rounds, collision with the boundary markers constitutes an end to that run attempt. Leaving the assigned course or task area, whether intentionally or otherwise, will also constitute an end to that run. The Team may be permitted to restart their run if they have sufficient time remaining in their scheduled time slot.

The Team Captain may request that the run be ended or the emergency stop (kill switch) be initiated for any reason. If a Judge determines that there is an unsafe condition present or imminent the Judge may activate the kill switch. The Judge is not required, nor will the Judge have time to advise the Team prior to the Judge's decision to terminate the run attempt. In this and all other matters of safety, the Judges' decisions are final.

Transporting the ASVs at the Competition Venue

The RobotX organizers will provide trailers for the ASVs at the competition venue. These trailers may be used to move the ASVs between locations on site using ground vehicles provided and operated by the organizers. Additional information regarding these trailers will be provided via the RobotX.org website at a later date.

Competition Tasks

Listed below are descriptions of the tasks to be performed by Teams' ASVs during the 2016 Maritime RobotX Challenge. There is no guarantee that the tasks will remain exactly as written below.

Demonstrate Navigation and Control

It is **MANDATORY** that Teams demonstrate that their control system has positive control of the platforms and that they can detect the channel markers. This will be a minimum requirement to course/field entry during practice and semi-final days.

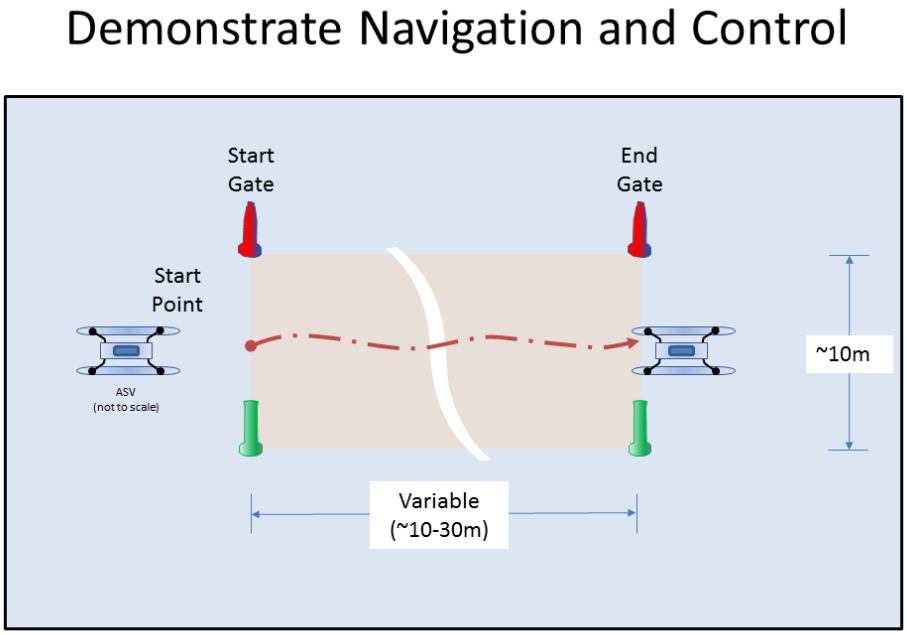

Figure 4. Demonstrate Navigation and Control

Detailed Task Description

The ASV must successfully navigate through two pairs of red and green buoys in a fully autonomous manner, demonstrating effective control of the system. After demonstrating this capability, the ASV will be allowed to proceed to the Team's assigned area.

Task Elements

Table 1. Navigation and Control Task Elements

Task Element	Description	Model No.	Ht. Above Waterline	Tower Diam.	Base Diam.
Start Gate Port Marker	Taylor Made Products Sur-Mark Can Buoy (Red)	950410	39in.	10in.	18in.
Start Gate Starboard Marker	Taylor Made Products Sur-Mark Can Buoy (Green)	950400	39in.	10in.	18in.
End Gate Port Marker	Taylor Made Products Sur-Mark Can Buoy (Red)	950410	39in.	10in.	18in.
End Gate Starboard Marker	Taylor Made Products Sur-Mark Can Buoy (Green)	950400	39in.	10in.	18in.

Find Totems and Avoid Obstacles

This is a classic perception/navigation task. The ASV must detect and avoid a range of obstacles. For the 2016 event, however, we will require Teams to do more than just avoid obstacle buoys. Teams will be tasked to find and completely circle three distinct objects, representing traditional Hawaiian Tiki totems. Teams will demonstrate they have identified the object of interest by circling the correct totems in the correct direction. On practice and qualifying days the Technical Director (TD) will post the order and color totems for that day.

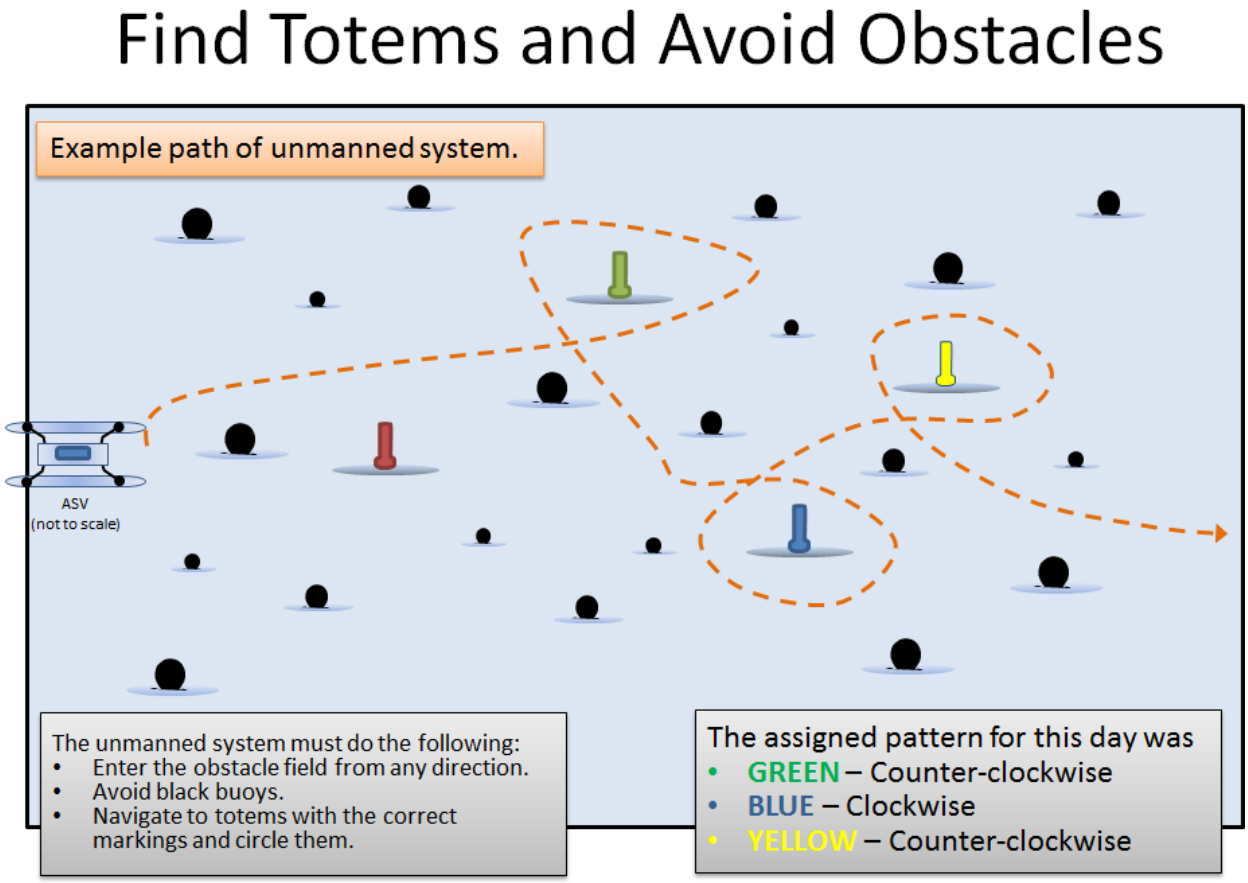

Figure 5. Example of Find Totems and Avoid Obstacles

Detailed Task Description

The obstacle area may be marked by four white buoys (listed in Table 3) around an area approximately 60m x 60m. The obstacles and totems will be placed inside the area. Entering the obstacle avoidance field and avoiding at least one obstacle or circling any totem will be considered as an attempt at completing this task.

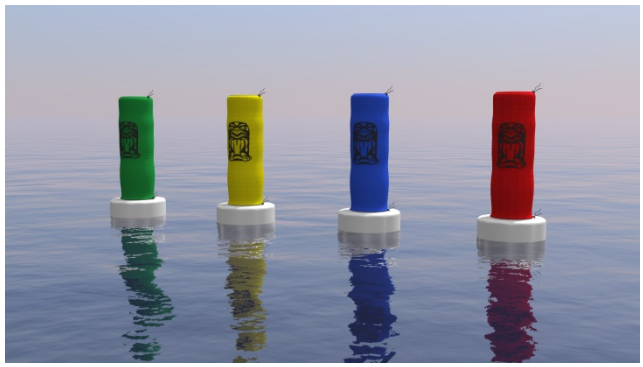

Figure 6. Totem Concept Image

The "Tiki totems" will rise 1-2 meters high above the water's surface, based on the Taylor Made White Sur-Mark Buoys. There will be red, green, yellow, and blue totems present in the field. The

various floating obstacles in the field will be placed at random positions and moored. These moored obstacles will be floating on the surface, visible, and of various sizes as described in Table 3.

The craft must avoid the obstacle buoys while circumnavigating the totems in the correct order and in the correct direction, as listed in Table 2. During the practice and qualifying days, the required order will be posted.

Table 2. Totem Colors and Directions

Color	Direction
Red	Clockwise
Green	Counter-clockwise
Blue	Clockwise
Yellow	Counter-clockwise

Task Elements

The task elements used for this task are listed below.

Table 3. Find Totems and Avoid Obstacles Task Elements

Task Element	Description	Model No.	Ht. Above Waterline	Tower Diam.	Base Diam.
Totem Marker	Taylor Made Products Sur-Mark Can Buoy (White)	46104	39in.	10in.	18in.
Obstacle Field Boundary Marker	Taylor Made Products Sur-Mark Can Buoy (White)	46104	39in.	10in.	18in.
Obstacle – Small	PolyForm A-3 Black Buoy (17")	A-3 Black			
Obstacle – Medium	PolyForm A-5 Black Buoy (27")	A-5 Black			
Obstacle – Large	PolyForm A-7 Black Buoy (39")	A-7 Black			

Potential Links to Other Tasks

For the semi-final and final rounds, this task will be combined with other tasks to form the competition course. Potential linkages include the following:

- SCAN THE CODE – The order in which the light pattern flashes will indicate the order in which the vessel must approach and circle the totems.

Identify Symbols and Dock

The ASV must autonomously locate the dock, identify the correct symbols and their associated docking bays, and proceed into the correct bays in the correct order. Contact with the dock is permitted, as long as the vessel does not damage course equipment. If necessary to maintain position inside the dock, minimum ASV headway into the dock is permitted.

Detailed Task Description

The ASV must demonstrate the ability to successfully dock in bays identified by a color and shape. The ASV must dock in the bays in the correct sequence. The TD will specify sequences of 2 colored symbols marking each bay. (e.g. "blue cruciform" then "red circle").

The dock will consist of three similar docking bays, distinguishable by a large geometric shape located at its closed end. The shapes may be red, green, or blue in color on a white background. The dock will be anchored in a fixed location, with the shapes affixed at the closed end. Each bay consists of floats positioned to form a cul-de-sac with sufficient clearance on both port and starboard sides as represented in Figure 8.

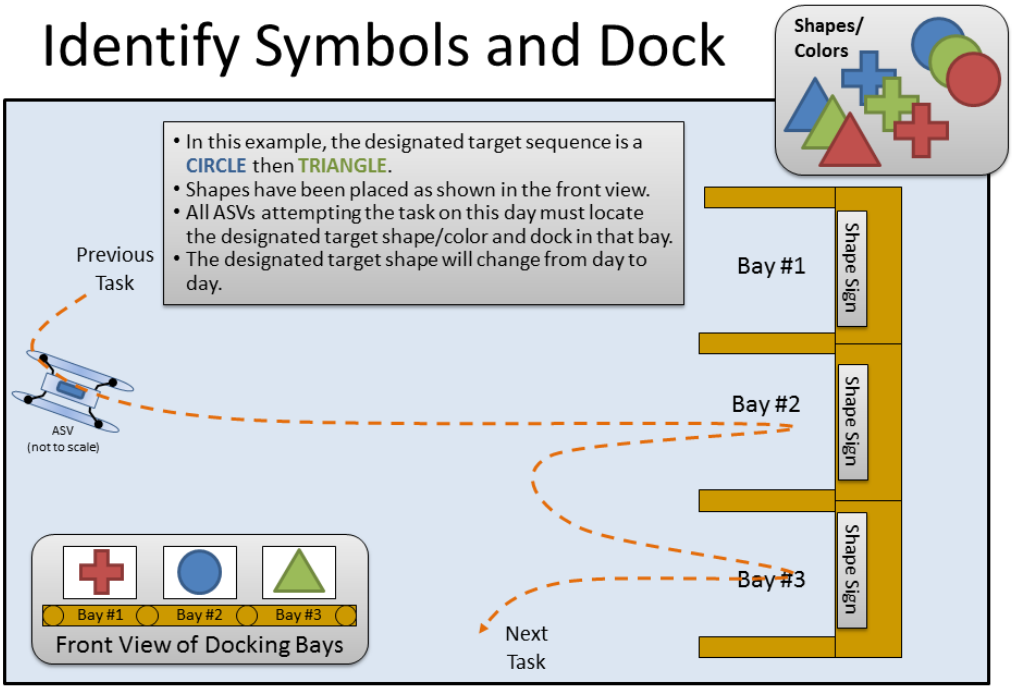

Figure 7. Identify Symbols and Dock

A large WHITE placard will be affixed to each docking bay. This placard will have either a cruciform (Bay #1, above), a circle (Bay #2, above), or a triangle (Bay #3, above) to provide a visual reference mark for each respective bay. The shapes will be at least 1m across on the white background, and may not be precisely centered in the docking bay. The shapes will be presented in one of three colors: red, green, or blue. During the Practice and Qualifying days two of the three colored symbols (the circle, the triangle, or the cruciform) will be designated as “Color/Symbol of the Day”.

Each ASV approaching the dock must identify the correctly colored symbols for that day, and enter the bays that display those colors/shapes in the specified order. The symbol placards may be randomly moved from one docking bay to another at any time during each day of the competition. There may be multiple placards with the same color but a different shape. There may be multiple placards with the same shape but a different color. Once a Team begins their time slot, the position of the symbols will remain fixed throughout that time slot.

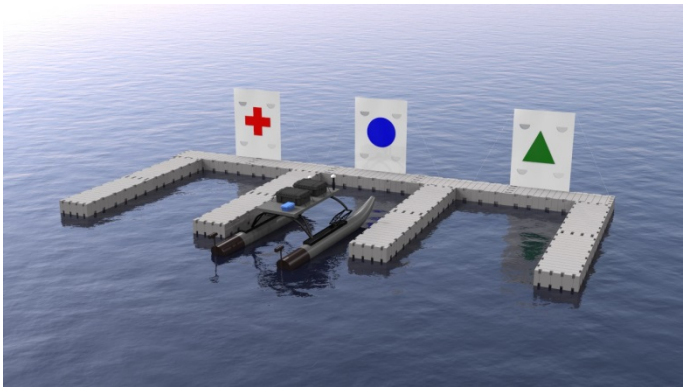

Figure 8. Concept image of docking area. (not necessarily to scale)

Task Elements

The docks for this task will be constructed from Jet Dock assembly cubes (size large). The Jet Dock System is made from Ultra High Molecular Weight High Density Polyethylene Plastic. Jet Dock Large Cubes are 20" X 20" square by 16" tall. Jet Dock Large Cubes weigh 14 pounds each, and have 3.7 cubic feet of volume.

Table 4. Identify Symbols and Dock Task Elements

Task Element	Description	Manufacturer	Example Image
Dock Material	CUBE - LARGE (BEIGE) Item code: C000000008	Jet Dock www.jetdock.com	

Potential Links to Other Tasks

For the practice and qualifying days the shape/color order will be posted daily as a primary and secondary shape/color. For the semi-final and final rounds the ASV will determine the shape and color by completing other tasks. Possible links to other tasks are listed below:

- The shape detected during execution of the UNDERWATER SHAPE IDENTIFICATION task may be considered the shape for the correct docking bay. While the ASV is docking in the bay identified by the correct shape the system will need to **record the color of the shape** to be used in the DETECT AND DELIVER task.
- Alternatively, the first color of the sequence from the SCAN THE CODE task may indicate the color of the correct shape in the docking bay. In this case, the system must **record the shape** in that bay to be used for completion of another task, such as DETECT AND DELIVER.

Scan the Code

The craft will observe a light sequence on an RGB buoy and report the color pattern. This is similar to the 2014 RobotX light buoy task. The added twist will be that we may require the craft to use information from this task to complete another competition task.

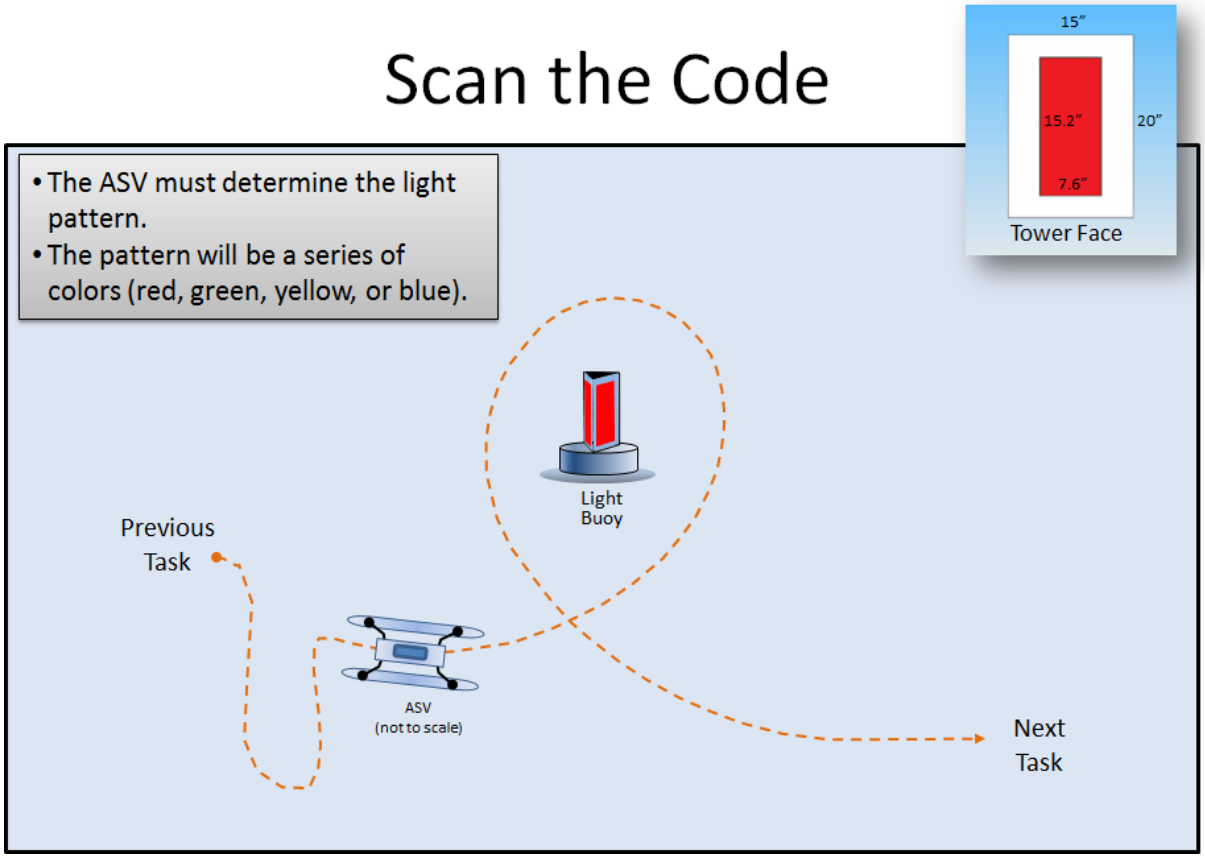

Figure 9. Scan the Code

Detailed Task Description

In this Task, the USV will be required to observe a "light buoy" to determine the sequential light pattern it flashes. The USV must autonomously report the color sequence of the buoy's flashing light per the Task Reporting section of this document. The light buoy will not be activated until the USV has started its autonomous mission run on the competition course.

A floating platform with a vertical light bar (similar to Figure 10) will be located randomly within the search area, which is approximately 40 X 40 meters.

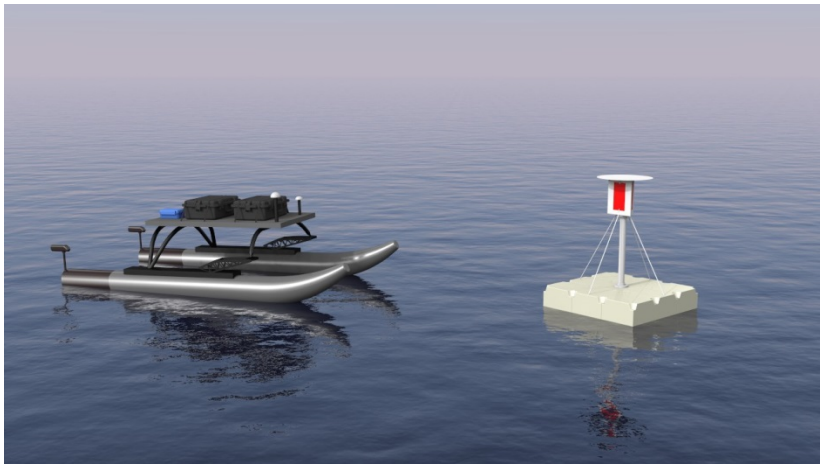

Figure 10. Concept Rendering of Scan the Code Task

The light bar atop the buoy will be no more than 3 meters above the water's surface and will display any three of the four colors: red, green, yellow, or blue. The light bar will appear black when it is off. The light assembly on the buoy will successively display colors one at a time to generate a sequential pattern of three colors (e.g., red-green-red). Each individual color will appear for 1 second, after which the lights will remain off (black) for 2 seconds before repeating the same pattern. A color may be repeated in the pattern, but the same color will not appear twice in a row.

The ASV must detect and record the sequential light sequence. During qualifying days the ASV must report the correct light sequence to earn points in accordance with the descriptions in the Task Reporting section of this document. A nominal search area and light buoy configuration is shown in Figure 9.

No contact with the light buoy is permitted. Striking the buoy will result in termination of the run with no points scored. This is to encourage Teams not to create situations that may be hazardous to personnel, other craft, or competition elements.

Task Elements

Further details of the light buoy are available in the RobotX Light Buoy Preliminary Specifications document**.**

Potential Links to Other Tasks

Possible links to other tasks are listed below:

- The color sequence from this task may indicate the order in which the ASV must find and circle the totems in the FIND TOTEMS AND AVOID OBSTACLES task.
- The first color in the sequence may be designated as the color to be used in completion of the DETECT AND DELIVER or IDENTIFY SYMBOLS AND DOCK task.

Underwater Shape Identification

The ASV must locate objects on the seafloor given an assigned quadrant relative to a reference buoy. This task requires an underwater sensing capability. The underwater objects will be white shapes on black backgrounds. There will be a white border around the edge of the black background. This task approximates a real-world challenge in which scientists are interested in mapping areas of bleaching coral.

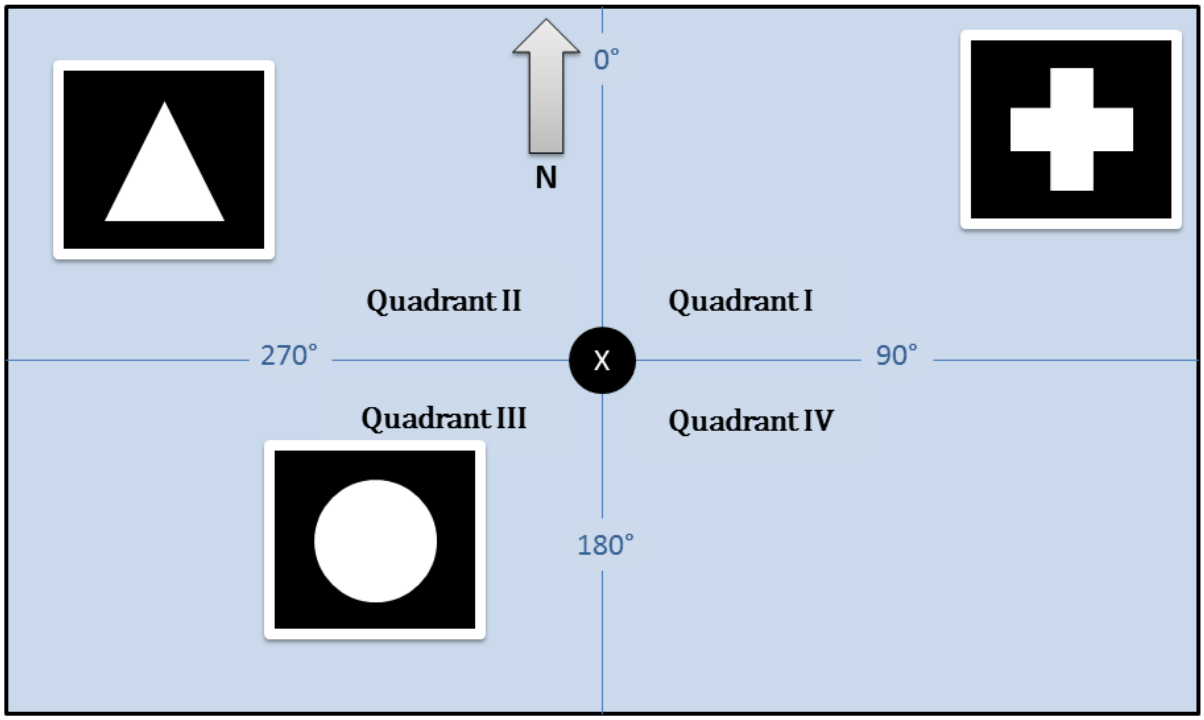

Figure 11. Underwater Shape Identification Task Diagram

Detailed Task Description

The task area will be approximately 40m x 40m in size. There will be a reference buoy in the field for this task. The black circle with the X in Figure 11 represents the Reference Buoy listed in Table 5. During the practice and qualifying days the TD will post the "Quadrants of the Day" relative to the reference buoy. There will be a sign structure elevated above the seafloor within the posted quadrants. The ASV must determine the shapes present in the assigned quadrants. There may be shapes at other locations in the field. The shapes will be a triangle, a cruciform, or a circle. Shapes will be at least 1m across on a black background.

During the qualifying days Teams must report the detected shapes in accordance with the method detailed in the Task Reporting section of this document. During the semi-final and final rounds the shapes detected will be required to complete other tasks.

Task Elements

- This section contains details of the task elements associated with the Underwater Shape Identification task.

Table 5. Underwater Shape Identification Task Elements

Task Element	Description	Model No.	Ht. Above Waterline	Tower Diam.	Base Diam.
Reference Buoy	Taylor Made Products Sur-Mark Can Buoy (White)	46104	39in.	10in.	18in.

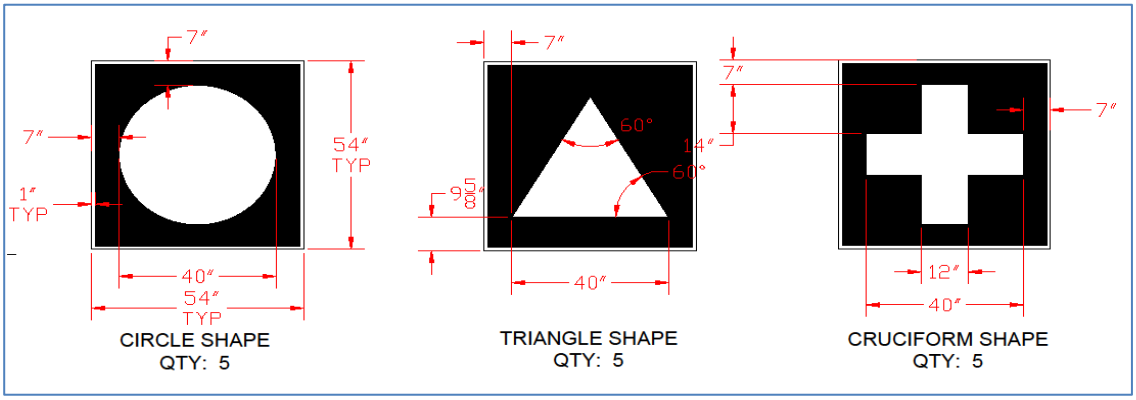

Figure 12. Underwater Shape Identification Sign Specifications

Potential Links to Other Tasks

Possible links to other tasks are listed below:

- The shape sequence from this task may indicate the order in which the ASV must dock in the bays for the IDENTIFY SYMBOL AND DOCK task.
- A pinger from the ACOUSTIC PINGER-BASED TRANSIT task could be used in the semi-final or final rounds to indicate which targets to locate. The detected shapes could then be used for other tasks.

Find the Break

Teams must scan markers placed on or near the seafloor (similar to the orange path markers used in RoboSub) and count the segments between a "gap" indicated by other underwater markers.

This task relates to an aspect of Hawaiian culture, known as a Loko Kuapa. In this case the Loko Kuapa (http://hawaiihistory.org/index.cfm?fuseaction=ig.page&PageID=516) has been damaged and the fish are escaping.

The unmanned system must search an area and indicate the location of the break. This can be done by reporting the number of wall markers before and after the break in accordance with the descriptions in the Task Reporting section of this document.

Detailed Task Description

This task consists of line segments constructed of approximately 6 inch (15 cm) wide by 4 feet (1.2 m) long sections of aluminum sheet. The "wall" will be covered with Blaze Orange Duck tape as described in Table 6. The "wall" will be raised off the seafloor 1-2 feet (0.3-0.6 m). The "breaks" will be of similar dimension to the path markers, covered in Yellow Duck Tape. The wall marker specifications are shown in Figure 14.

The unmanned system is required to determine the number of "path" markers between the two yellow "breaks" and report this to the judges using the Team-provided method detailed in the Task Reporting section of this document.

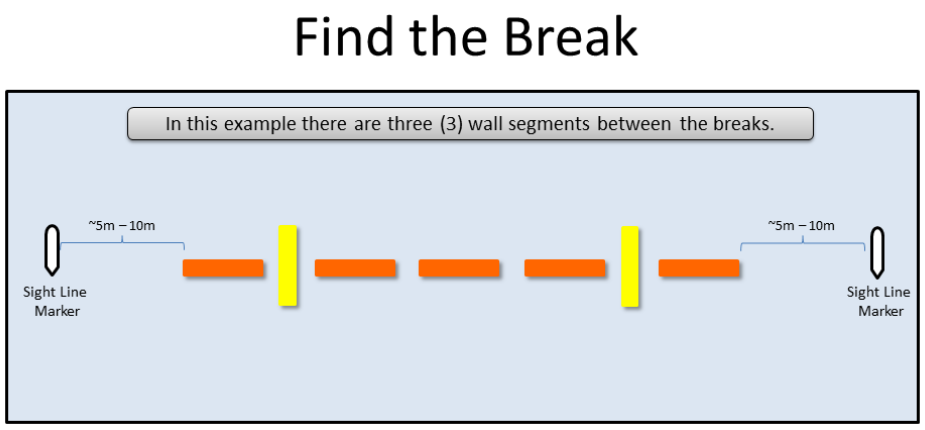

Figure 13. Find the Break

During the practice and qualifying days, the FIND THE BREAK task will be placed in a pre-defined area identified to Teams by a pair of sight line markers. During the semi-finals and finals days, FIND THE BREAK may be included as part of another task, identified with a reference buoy, or by a reference GPS position.

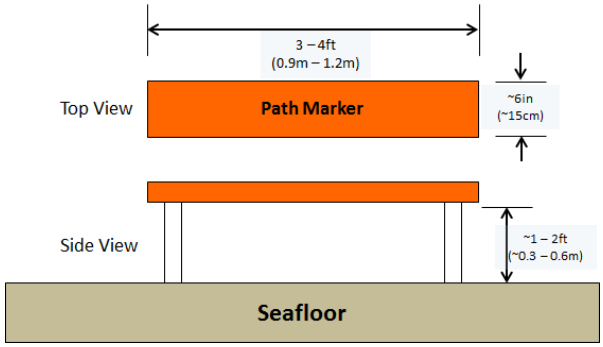

Figure 14. Wall Marker Specifications

Task Elements

The task elements to be used in the Find the Break task are listed in Table 6 below.

Table 6. Find the Break Task Elements

Task Element	Description	Model No.
Wall Segment Tape	Duck Brand 1265019 Color Duct Tape, Neon Orange	Neon Orange
Break Segment Tape	Duck Brand 1304966 Color Duct Tape, Yellow	Yellow
Sight Line Marker	Polyform LD-1 White Buoy	LD-1, White

Potential Links to Other Tasks

- The line segments may be used to indicate the path between tasks during the semi-final and final rounds. In this situation the segments will be situated in such a way that if the ASV follows a heading along the line segment it will meet with the next task. The next path segment will be located on the "far side" of this task approximately 1 to 3 ft (0.3m to 0.9 m) from the task exit area. Distances between segments will vary depending on the positioning of the tasks.
- The number of orange segments between the yellow indicators may be used to indicate which quadrant to search in for the UNDERWATER SHAPE IDENTIFICATION task.

Detect and Deliver

A four-sided floating platform will be tethered in an open area. Each side of the platform will have a face rising up with a colored shape and a pair of square holes. The ASV must propel or insert objects through the target holes on the face. This task may tie into semi-finals or finals tasks where information from this task is necessary to complete other tasks or information from other tasks is required to complete the Detect and Deliver task.

Detailed Task Description

For each run, Teams will be provided with four (4) balls described in Table 7. The ASV must detect the assigned shape on the target face. The target shape will be at least 1m across. Once detected, the system must place or launch the balls into one of the two target holes on the upper part of the floating platform. There will be two holes, one larger than the other, each outlined in black on a white background. The larger hole will be a square 0.5m on a side, and the smaller hole will be a square 0.25m on a side. A concept drawing of the DETECT AND DELIVER target is shown in Figure 15.

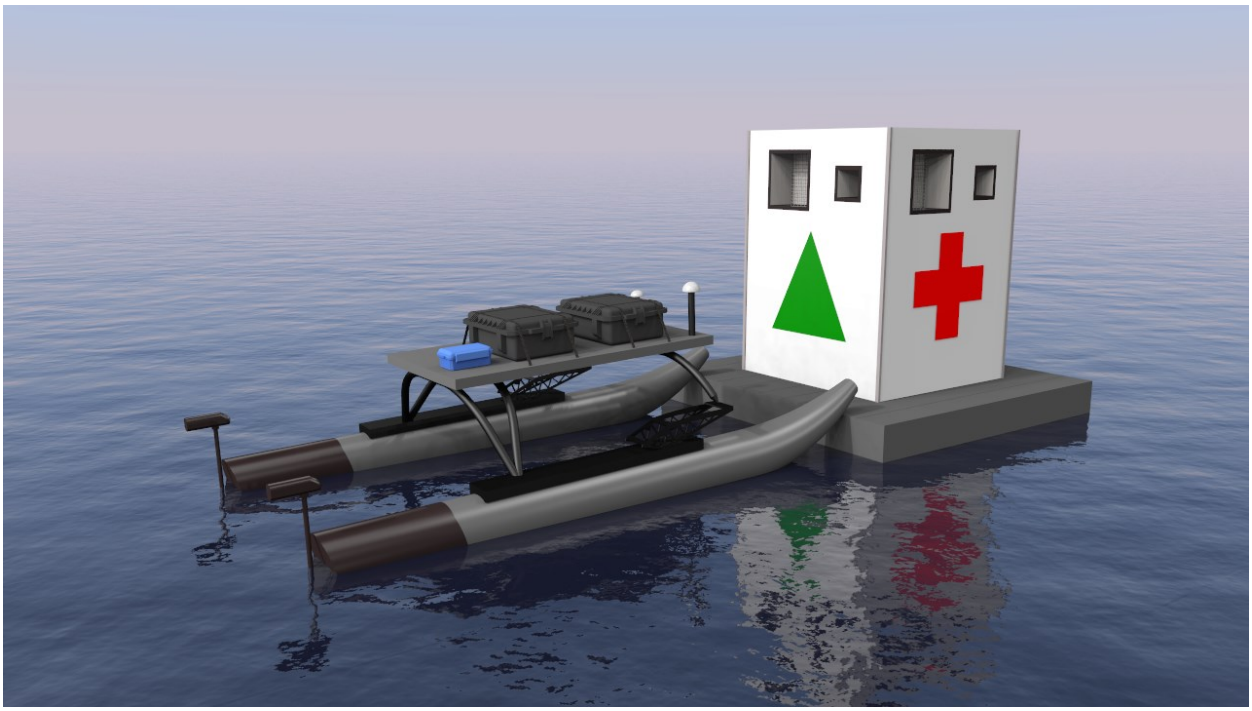

Figure 15. Concept drawing for Detect and Deliver task. (not necessarily to scale)

Getting the balls through the smaller hole will earn more points than getting them in the larger hole. For the qualifying days the shape/color of the day for this task will be posted at the Technical Director's station. For semi-final and final rounds other tasks will provide the information needed to determine the correct color/shape to target.

Task Elements

Table 7. Detect and Deliver Task Elements

Task Element	Description
Blue Projectile	Penn Ultra-Blue Racquetball

Potential Links to Other Tasks

This task has several potential links to other tasks:

- The color/shape combination detected during the IDENTIFY SYMBOL AND DOCK task may indicate the color/shape combination that must be targeted for this task.
- The correct target shape and color may be determined by combining information from two other tasks:
    - The shape from the UNDERWATER SHAPE IDENTIFICATION task may be designated as the target shape for the DETECT AND DELIVER task in the semi-final and final rounds.
    - The first color from the SCAN THE CODE task may be designated as the target color for the DETECT AND DELIVER task in the semi-final and final rounds.

Acoustic Pinger-Based Transit

A set of three gates will be located in the practice/qualifying area. There will be a pinger in the middle of each gate. Vehicles must pass through the course and go through the assigned ENTRY and EXIT GATES which will be marked by an underwater acoustic pinger active at the frequencies posted daily. The gate with the active pinger may change between runs.

Detailed Task Description

Buoys will be configured as a single set of gates (RED-WHITE-WHITE-GREEN). The gates will each be approximately 10m wide in the following combination: RED-WHITE, WHITE-WHITE, WHITE-GREEN. Each gate will have an acoustic pinger in the water between the marker buoys. At the start of each run a pinger programmed to the ENTRY/EXIT GATE frequency will be activated in one of the three gates. This pinger will remain active for the duration of that run. In order to successfully complete this task the ASV must be able to detect the active buoy, enter through the ENTRY gate, and exit through the correct EXIT GATE. The differences between the Practice/Qualifying and Semi-final/Final versions of this task are detailed below.

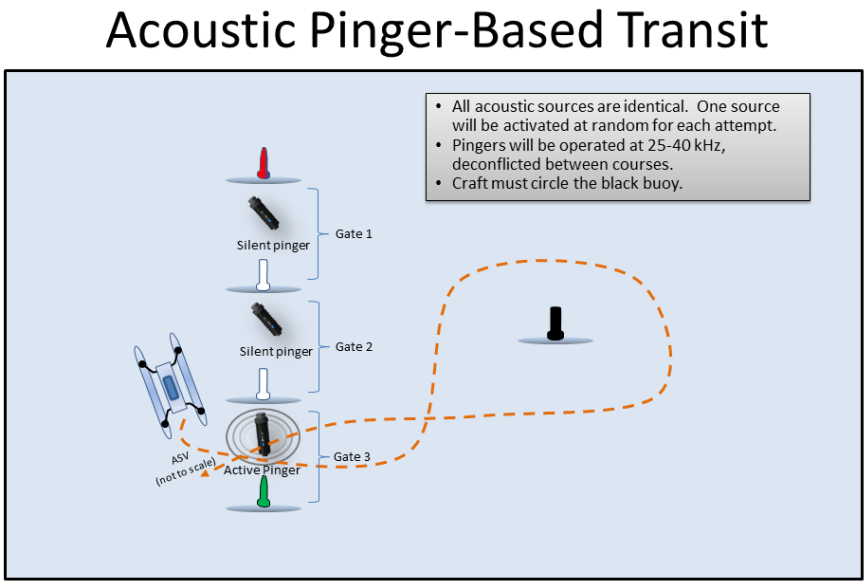

Figure 16. Acoustic Pinger-Based Transit

Practice/Qualifying

For the Practice and Qualifying days there will be up to four (4) instances of the Acoustic Pinger-Based Transit task. A vertical black buoy (based on the white Taylor Made Can Buoy) will be placed approximately 30 meters beyond the gate as depicted in Figure 16. In order to successfully complete this task the ASV must enter through the ENTRY gate, circle the black buoy, then transit back through the correct EXIT GATE.

During this challenge, one pinger will be active in each instance of the task. The frequencies of the instances will be separated by at least 2kHz. The ASV must detect the active pinger and successfully transit between the gates with the active pinger. Pinger frequencies for each instance will be posted daily during the competition. The pings will be staggered in time as well as frequency.

Semi-Finals/Finals

For the Semi-final and Final rounds, the gates will serve as entry and exit points for the Competition Courses. The vertical black buoy will not be present. A single pinger will be activated at the start of each run to indicate the correct ENTRY GATE and EXIT GATE. The ASV should **record the correct gate number** for use in combination with other tasks.

Task Elements

Planned task elements for this task are detailed in Table 8.

Table 8. Acoustic Pinger-Based Task Elements

Task Element	Description	Model No.	Ht. Above Waterline	Tower Diam.	Base Diam.
Entry Gate Port Marker	Taylor Made Products Sur-Mark Can Buoy (Red)	950410	39in.	10in.	18in.
Entry Gate Middle Marker	Taylor Made Products Sur-Mark Can Buoy (White)	46104	39in.	10in.	18in.
Entry Gate Starboard Marker	Taylor Made Products Sur-Mark Can Buoy (Green)	950400	39in.	10in.	18in.
Exit Gate Port Marker	Taylor Made Products Sur-Mark Can Buoy (Green)	950410	39in.	10in.	18in.
Exit Gate Middle Marker	Taylor Made Products Sur-Mark Can Buoy (White)	46104	39in.	10in.	18in.
Exit Gate Starboard Marker	Taylor Made Products Sur-Mark Can Buoy (Red)	950400	39in.	10in.	18in.
Buoy to Circle Around	Taylor Made Products Sur-Mark Can Buoy (White) with black cover	46104	39in.	10in.	18in.

Potential Links to Other Tasks

This task has several potential links to other tasks:

- The gates will be used to indicate the ENTRY and EXIT points for the Semi-finals or Finals courses. When the ASV crosses through a gate the judges will start or stop the timer measuring time to complete the course.
- This challenge may be combined with the FIND TOTEMS AND AVOID OBSTACLES task so that the active pinger must be located to navigate through the correct ENTRY and EXIT GATES to navigate the obstacle course while locating the correct totems.
- The DETECT AND DELIVER TASK may be placed in between the ENTRY and EXIT GATES so that the ASV must enter the correct ENTRY GATE deliver the balls, then depart through the correct EXIT GATE.
- The ENTRY GATE number (as shown in Figure 16) may represent the quadrant number to search for in the UNDERWATER SHAPE IDENTIFICATION task.

Competition Structure

Overall Approach

There will be time early in the competition week for Teams to practice on the individual tasks and earn points towards qualifying for the Semi-final round. Teams must demonstrate the ability to autonomously complete the NAVIGATION AND CONTROL task daily. Once a Team has successfully earned points on five (5) of the seven (7) individual tasks, they will be able to sign up for time slots on the full competition courses.

The practice/qualifying areas will be available throughout the competition on an assignment basis to be presented to Teams during the orientation. At least part of the Team must remain on site at the competition venue at all times during the challenge days to remain eligible for daily and final prizes.

A representative example of a possible semi-final or final course is shown in Figure 17. The ASV starts by detecting and entering through the correct ENTRY gate based on the active pinger. From there, the system attempts the other tasks as appropriate to complete the course. A point in or near each task of the course may be provided by the Technical Director (TD). This example does not necessarily indicate the order in which the tasks must be completed. The information from some tasks will be needed to complete other tasks.

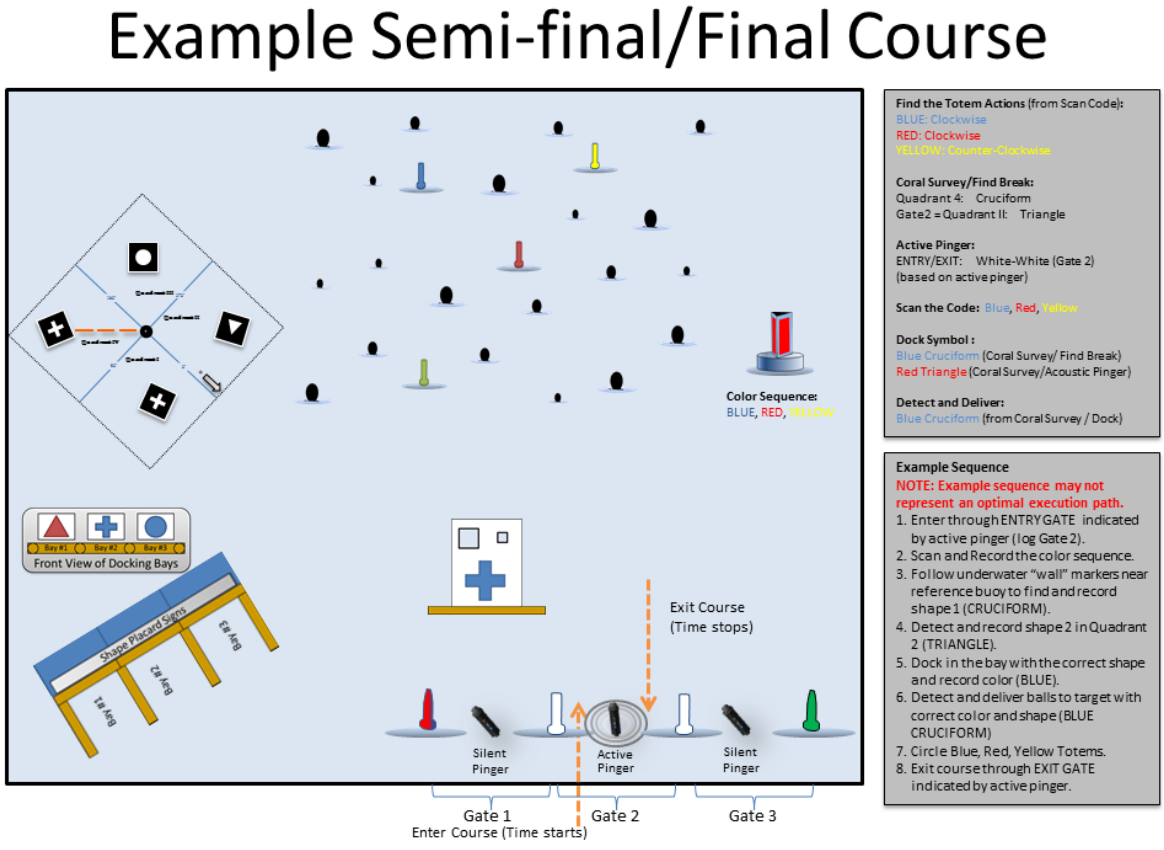

Figure 17. Example Semi-final/Final Course

Judging and Scoring Guidance

Detailed task scoring breakdowns are in development. They will be provided in a separate document, *2016 Maritime RobotX Preliminary Scoring Guidance*, which will be updated independently of this document. Scores will be calculated by the Judges, and all decisions of the Judges are final.

Planned Sequence of Events

This section summarizes the main events of each day of the 2016 Maritime RobotX Challenge. A more detailed schedule will be provided later.

Competition Phases

There are three (3) phases to the 2016 Maritime RobotX Challenge:

- During Practice and Qualifying, Teams will be given time to assemble and test their unmanned systems, participate in initial safety inspections, practice, and earn points in the water against the individual tasks.
- During the Semi-final Round, Teams will have the opportunity to earn points towards the Final Round by completing runs on the Competition Courses. During this time, the Competition Courses will be reserved for Teams who have qualified by successfully completing five of the seven System Performance Tasks. Points earned during this round will be used to determine which Teams will compete in the Final Round of the 2016 Maritime RobotX Challenge.
- The Final Round will be held on Sunday, 18 December 2016. Teams that qualify for the Final Round will compete for the grand prize. All Teams will have opportunities to earn other awards during this time.

Daily Events

Each day will start and end with a MANDATORY TEAM MEETING with the Technical Directors at the TD tent. At a minimum, TEAM CAPTAINS are required to attend. All participants are strongly encouraged to attend.

During the morning meetings, the plan of the day will be presented; Teams will have an opportunity to provide feedback and ask questions.

During the evening meetings, the TD will summarize the day's events and Teams will be encouraged to provide feedback. It is likely that at the evening meetings Teams can sign up for or trade time slots for the next day's in-water events. Daily course changes will be described at the evening meeting.

There will be multiple instances of each task element organized as sets of tasks (seven tasks per group) to be referred to as **Challenge Courses**. Teams will have time slots during which they may earn points towards qualifying for the Semi-final Round. Teams will rotate through the tasks on the Challeng Course in a set order to attempt the tasks.

Once a team has qualified for the Semi-final Round they will be permitted to start using a full **Competition Course**. For the Semi-finals at least one of the Challenge Courses will be converted to a Competition Course. On the Competition Courses the unmanned systems must demonstrate the ability to collect and use data from previous individual tasks to complete other tasks.

Daily Plan

Introduction, Practice, and Qualifying

Saturday 10 December 2016	• MANDATORY Introduction and Orientation session for ALL PARTICIPANTS o Introduce Competition Staff o Review rules and regulations o Assign times for team presentations to judges • Evening Social Event
Sunday 11 December 2016	• MANDATORY on-site tour for ALL PARTICIPANTS • Teams will be given access to the Competitor's Village to assemble and test their systems (after the site tour). • Begin Safety Inspections • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).
Monday 12 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. o Course Elements will be active. o Teams may earn points on individual tasks in Challenge Courses. o Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. o Judges will record performance and scores for each run • Begin On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).
Tuesday 13 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. o Course Elements will be active. o Teams may earn points on individual tasks in Challenge Courses. o Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. o Judges will record performance and scores for each run • Continue On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).
Wednesday 14 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. o Course Elements will be active. o Teams may earn points on individual tasks in Challenge Courses. o Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. o Judges will record performance and scores for each run • Continue On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).

Introduction, Practice, and Qualifying (continued)

Thursday 15 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. o Course Elements will be active. o Teams may earn points on individual tasks in Challenge Courses.

	○ Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. ○ Judges will record performance and scores for each run • Begin On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).
Friday 16 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. ○ Course Elements will be active. ○ Teams may earn points on individual tasks in Challenge Courses. ○ Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. ○ Judges will record performance and scores for each run • Begin On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND).
Saturday 17 December 2016	• Morning TD Meeting with all Team Captains and representatives. • On-water Challenge Course and Competition Courses open. ○ Course Elements will be active. ○ Teams may earn points on individual tasks in Challenge Courses. ○ Competition Courses available only to Teams that have qualified for the opportunity to earn Semi-final points. ○ Judges will record performance and scores for each run • Begin On-site Design Presentations and Interviews • Evening TD Meeting (At a minimum, ALL TEAM CAPTAINS MUST ATTEND). ○ Standings and Finals Teams will be announced.

Finals Round

Sunday 18 December 2016	• Teams that qualified for the Final Round will begin runs for points in the Competition Course areas. • Teams that choose to participate in the Bonus Challenge will be able to work on the tasks for this event. • Once the final competition round begins all other in-water events will be stopped. • The final awards ceremony and dinner will be held Sunday night.

Pack-up and Depart

Monday 19 December 2016	• Teams must pack up and prepare their equipment for return shipping. The Freight Handler will pick up and deliver all equipment to the shippers.

RobotX Project Deliverables and Presentations

As in the previous competition, we require Teams to post a Website, create a Team Introduction Video, write a Journal Paper, present an oral presentation to the judges, participate in an interview session with the judges, and present their System for inspection by the judges. The Website, Team Introduction Video, Journal Paper (as well as the **optional** Appendix Special Topic) will be due **BEFORE** the start of the in-water events in Hawaii. A summary of the delivery due dates is provided in Table 9. The methods of delivery will be sent to team points of contact via e-mail.

Team Technical Submission Package

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

The exact layout and contents of the website are left for the Teams to develop. The Technical Directors may visit this site prior to the competition to follow the Teams' progress. The website development must be complete and ready for judging by **1200 UTC on 20 November 2016**. However, Teams are expected to continually update their website up to the start of the competition.

Team Introduction Video

Each Team must submit a 2-3 minute video introducing their Team. This video will be scored, and will be used online and onsite during the webcast. The video is not intended to present Teams' vehicle design and it may not be used as part of the design presentation. The Team video is due by **1200 UTC on 20 November 2016**.

Journal Paper

Each Team is required to submit a journal paper in English that describes the design of their USV autonomy system, propulsion system, and control systems, as well as strategies for their approach to the tasks. They should include the rationale for their design choices. Specific requirements for the journal paper are provided in the *2016 RobotX Journal Paper document* on the RobotX.org website. Team Journal Papers will be published on the RobotX.org website after the competition. The Journal Paper is due by **1200 UTC on 20 November 2016**.

On-site Design Presentation and Interview

Each Team is required to present their sensing, integration, power, propulsion, and autonomy scheme to the Judges in the form of an oral presentation (conducted in English) with visual aids.

This component of the Challenge will include a presentation to the Judges, as well as an opportunity for the Judges to interview the Team members with a specific set of standard questions. The presentation should introduce the Team, their ASV, and special features and/or strategies for the competition.

The **ENTIRE TEAM** must be present for the design presentation.

Planned Presentation Breakdown:

- Team Video will be played first.
- Teams will conduct a 20-minute oral presentation with visual aids
- Ten (10) minutes will be allotted for questions
- Ten (10) minutes will be allotted for the Judges to interview the Team.

Judges will inspect the ASVs at a later time during the Documentation Judging days.

The Documentation Tasks comprise a critical element of the competition. Scores from this element will be used as a tie-breaker, if needed.

System Inspection

Judges will inspect the Team's unmanned system, assessing technical design, craftsmanship, technical innovation, and visual impact of the design. Team members should be present to answer technical questions posed by the judges during this inspection. The System Inspection schedule will be provided at the competition site.

At least one team representative must be present for the System Inspection.

Team Information Package

Teams are required to submit the following items using the Team registration information provided by the RoboNation organizers by **01 October 2016**:

Team Biography

Your Team bio should be 250 words or less using either Microsoft Word or PDF format.

Team Logo

The Team Logo will be displayed in an App designed for mobile devices. Therefore, a school or Team logo is more appropriate than a Team photo. Please submit your Team logo in the format below:

- 200 pixels X 200 pixels
- JPEG/JPG/PNG/GIF
- 72dpi image

Team Roster

Please confirm all registration information, including Official Team Name and School or Organization Name. All t-shirt sizes must be confirmed on the official Team roster. Additionally, please confirm Web URL, Facebook and Twitter information (if this information was provided at time of registration). If this information was not provided, or has changed, please provide and/or correct.

Waiver and Release of Liability Forms

In order to participate in the 2016 RobotX Challenge, **each Team member** must submit a Release of Liability Form. Failure to submit these forms will result in non-participation. Forms must be submitted electronically as part of the Team Information Package. Each Team member must complete and submit his or her own form. These forms will be provided from the RobotX.org website. You will first need to download the forms in order to complete and then upload the completed and signed forms back to your Team Dropbox.

Individual Student Resumes

Each Team member should submit an individual resume. Because the AUVSI Foundation offers students the opportunity to connect with industry professionals, student resumes will be distributed to AUVSI Foundation sponsors. Please upload all individual resumes to your Team Dropbox.

Shipping Plan

As stated in the RobotX Rules Document, Teams will be required to submit a shipping plan to RobotX organizers no later than **1200 UTC on 01 October 2016**. This is to allow time for organizers to work with Teams to ensure that their systems and support equipment can be received, worked through U.S. Customs, and staged for use during the competition. A shipping plan form, shipping address, and point of contact for the RobotX freight forwarder will be provided on the RobotX.org website.

Table 9. Summary of Deliverables

Deliverable	Due Date
Registration Deadline	01 September 2016
Team Information Package	01 October 2016
Shipping Plan	01 October 2016
Team Technical Submission Package: Website, Video and Journal Paper	20 November 2016

Task Reporting

This section details the high-level requirements for Teams to provide a display to allow judges to evaluate the performance of the ASVs against the three 2016 RobotX tasks that require reporting of results during the Practice/Qualifying days.

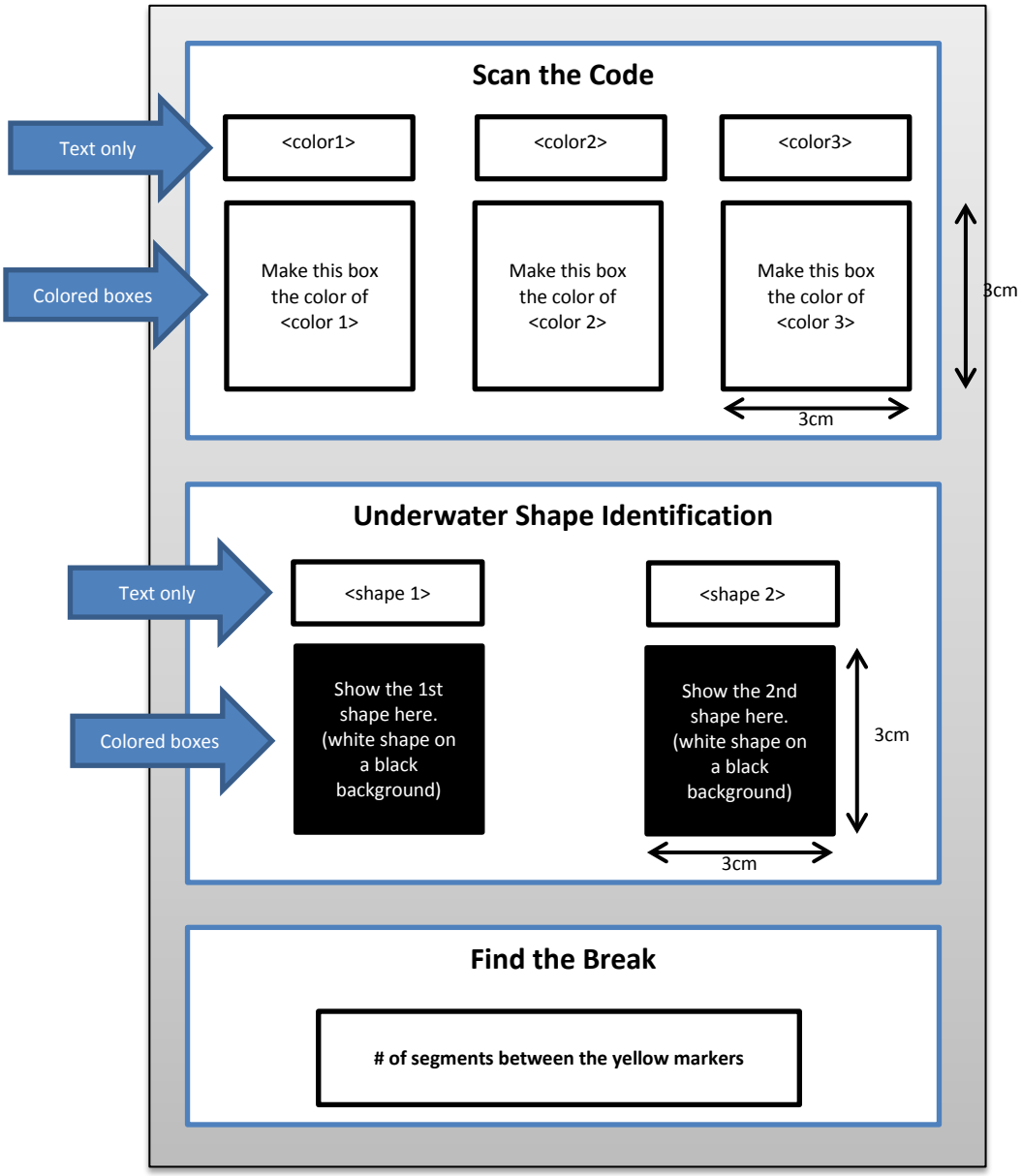

Figure 18. Judge's Display Specifications

There are three tasks in the 2016 Maritime RobotX Challenge that require the Teams' ASVs to report results: SCAN THE CODE, UNDERWATER SHAPE IDENTIFICATION, and FIND THE BREAK. To facilitate judging of these challenges, Teams are required to implement a display that can be monitored by judges during the points run to show what the ASV has detected. The specifications for this display are shown in Figure 18. Teams are required to provide their own communications solutions and a display that the

judges can monitor to evaluate their performance. Teams are encouraged to maintain a log of results as well.

All fonts in the Team-provided Judge's Display shall be Arial, 18 point. The colored square boxes displaying SCAN THE CODE and UNDERWATER SHAPE IDENTIFICATION results shall be 3cm on a side. An example of the Judge's Display is shown in Figure 19. In this example, the following conditions apply:

- SCAN THE CODE task is flashing RED, YELLOW, BLUE.
- The shapes at the two locations specified for the UNDERWATER SHAPE IDENTIFICATION task are the CRUCIFORM and TRIANGLE.
- There are 3 path markers in between the yellow indicators.

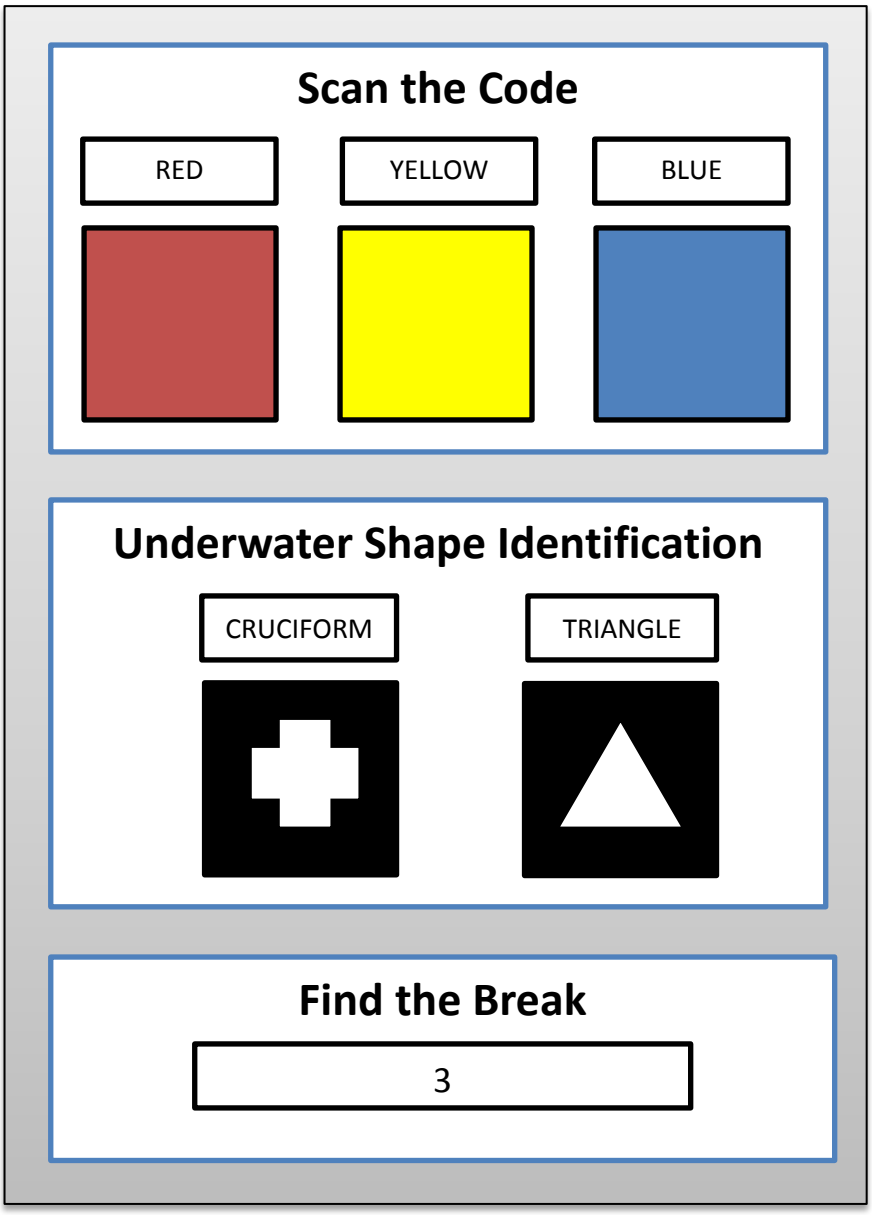

Figure 19. Example Judge's Display.

Important Terms

Term	Definition
ASV	Autonomous Surface Vehicle
Challenge Course	Group of RobotX task elements organized as a set of seven tasks which Teams can attempt individually to earn points towards qualifying for the Semi-finals Round of the competition.
Competition Course	A set of RobotX tasks organized as an integrated course which Teams may attempt for points towards qualifying for the Finals Round. When using the Competition Course, Teams must attempt multiple tasks in which the information required to complete some tasks are dependent on information gathered attempting another task.

Change Log

This change log lists many of the most significant changes made in this revision of the Rules. It may not be all-inclusive, as minor corrections and changes may not be listed. Teams should review and understand the entire document.

Version	Changes	Date
v0.4	First release of Preliminary Task Descriptions, based on "Initial Task Ideas" document from 01 October 2015.	21 January 2016
v0.5	• Added statement in Competition Location Information section clarifying that air vehicles will not be permitted for this competition. • Updated FIND THE BREAK task to explain how the task area will be indicated. • Clarified DETECT AND DELIVER task wording. • Added note to Teams in the 2016 Maritime RobotX Challenge Venue • The 2016 Maritime RobotX Challenge will be set up along the shore and in-water near the primary public boat ramp on Sand Island in Hawaii, as represented in Figure 1. The venue will include elements of each of the competition tasks which Teams may use to train and tune their unmanned systems. For example, **at least** one acoustic pinger, one docking setup, one light buoy, and a representative obstacle course will be set up in the practice area. • Practice/Qualifying Area section.	08 April 2016
v0.6	• Updated Figure 17 to show more representative semi-finals/finals course layout. • Updated Identify Symbols and Dock Task • Updated Detect and Deliver Task • Updated Underwater Shape Identification Task • Updated Acoustic Pinger-Based Transit Task • Added Judging and Scoring Guidance section • Updated • RobotX Project Deliverables and Presentations section • Added Task Reporting section	14 June 2016
v0.7	Minor updates to wording to clarify based on questions from teams.	13 July 2016
v0.8	• Updated all task descriptions and figures. • Changed Dock Material information in Table 4. • Updated Competition Structure to clarify competition structure and daily plan. • Added Important Terms section.	
v0.9	• Renamed CORAL SURVEY to UNDERWATER SHAPE IDENTIFICATION	01 November 2016
v0.91	• Corrected Underwater Shape Identification Image (Figure 11) to match new task name.	03 November 2016
V1.0	• Updated Figure 2 to more accurately reflect the planned layout for the 2016 RobotX Challenge. • Changed to final release.	28 November 2016