Rules and Task Descriptions

Version 2, Updated January 31, 2019

Reed Canal Park

Daytona Beach, Florida, USA

June 17 – 23, 2019

www.roboboat.org

RoboBoat 2019 Rules and Task Descriptions

1 Objective

RoboBoat is an international student competition designed to build and enhance a community of innovators, capable of making substantive contributions to the Autonomous Surface Vehicle (ASV) domain.

Such vision is achieved by providing a venue and mechanism, whereby practitioners of this technology come together at the event to share knowledge, innovate, and collaboratively push the envelope of ASV systems.

2 RoboBoat Support

All questions, comments, and suggestions should be posted on the 2019 RoboBoat Forum. Teams are encouraged to actively participate in the online community and monitor it for latest news and updates regarding all things RoboBoat.

3 Venue Overview

The competition is held at the Reed Canal Park's pond; located at 919 Reed Canal Rd, South Daytona, FL 32119. The pond measures roughly 700ft by 550ft and water depth ranges from 5ft to 30ft.

Reed Canal Park's pond will be divided into four courses; Courses Alpha, Bravo, Charlie and Delta. Course Alpha, Bravo and Charlie are similarly arranged competition courses. Course Delta is designated as the introductory course. A proposed area for testing and practice is located south of course Charlie.

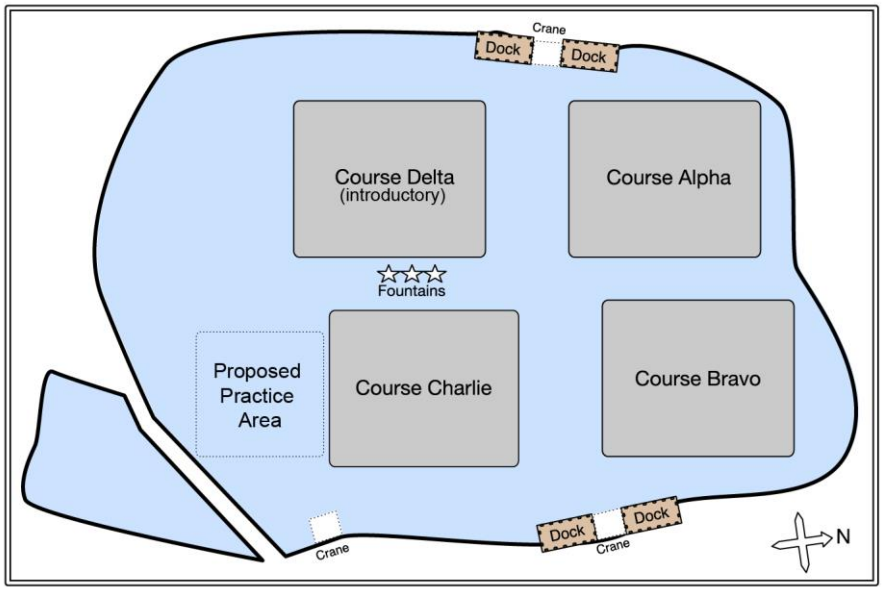

Figure 1: Reed Canal Park pond layout

The pond is generally free from obstacles (seaweed, lily pads, trees, etc.), however, three floating water fountains are located near the center of the pond. The fountains should be treated as a natural obstacle and be avoided at all costs. See satellite image for more details: https://goo.gl/maps/p28kwaZjtKw.

During the competition, each team is provided with a covered 10ft by 10ft workspace. Although the covered workspace is weather resistant, teams are discouraged from leaving humidity-sensitive electronics, or other equipment in their workspace overnight.

Electricity (one outlet) and internet connection (wireless) are available in the workspace. The United States uses a 120V 60Hz 15A electrical outlet plug. Usually 3 pins, two parallel blades (one wider than the other), and an offset semi-round pin. The wider blade is Neutral, the short blade is Hot/Line and the semi-round pin is ground.

Figure 2: Electrical outlet plugs

4 Schedule

The competition is held, rain or shine. The competition's schedule is available on the RoboBoat Website and the RoboBoat Forum. It is subject to changes due to inclement weather, and safety considerations. Teams are responsible to check the website for the most up to date version of the schedule.

5 Participation and Eligibility Requirements

There is no requirement for teams to be associated with a school or university, however, 75% of the participants must be full time students. The student members of a team are expected to make significant contributions to the engineering development cycle of their ASV. Though a minimum number of on-site team members is not prescribed, please consider that at least 3 members are needed for RoboBoat operations. Faculty, industrial and governmental partners may be used.

Only one vehicle per team can be entered in the competition. Each team must designate a student team member as their *team leader*. The team leader is the only person allowed to speak for the team, to request vehicle deployment, run start, run end, or vehicle retrieval. The team leader must be conversationally fluent in English to communicate with RoboBoat staff. Teams who do not have members fluent in English, should contact RoboNation staff as soon as possible.

6 Registration Information

6.1 Fees

To participate in the competition, all teams must register via the official competition website and submit the registration fee.

7 Team Deliverables

In addition to the mission tasks, each team must document their efforts leading up to the competition by authoring a Technical Design Report (TDR), building a website, creating a video, and preparing a Technical Design Presentation (TDP). All elements of the competition will be conducted in English.

Once your team is officially registered for the competition, the team leader will receive an invitation to create an account in an online portal called Submittable. Submittable will streamline the teams' submissions process. Only the team leader and RoboNation staff will have access to the teams' submissions. Detailed instructions on how to submit team deliverables will be provided in Submittable. Each team leader is responsible for adhering to the instructions and deadlines listed on the RoboBoat website.

7.1 Website

Teams must maintain a website documenting their development. Layout and contents of the website are left for the teams to develop; however, the website should include at a minimum the following information:

- Team information (name and team contact information).
- Team member information (name, picture, contact information).
- Media (pictures, video, etc.) taken during development and testing.
- List of sponsors with logos.
- Teams are encouraged to build an archive of previous vehicles and design reports.

7.2 Team Introduction Video

Each team is required to submit a 2-3 minute video introducing their team. This video will be scored, and will be used online and onsite, as necessary. The video is not intended to present teams' vehicle design and it may not be used as part of the design presentation.

7.3 Technical Design Report (TDR)

Each team is required to submit a TDR that describes the design of their vehicle, as well as strategies for their approach to the tasks. The TDR should also include rationale for design choices. Teams must follow the TDR instructions provided in Submittable.

7.4 Technical Design Presentation (TDP)

The TDP is an opportunity for teams to introduce themselves, their vehicle, and special features and/or strategies for the competition. It is also an opportunity for judges to inspect the vehicle, and interview team members about the presentation and their contribution to the engineering development cycle. Due to the lack of electricity in the presentation area, slide-based presentations, or those utilizing audio-visuals will not be accepted.

Planned Presentation Breakdown:

- 20-minute oral presentation with visual aids (for example: a poster board).
- 5-minute question and answer session.
- 5-minute judges' inspection of the vehicle.

After the design presentation, teams should make themselves available for a team photo, and optional video interview for archival purposes. This video interview will not be judged.

8 Public Display

The Daytona Beach and Volusia County community is proud to host the 2019 RoboBoat Competition and plans to organize a number of public events during the competition. These events will include organizations interested in STEM (Science, Technology, Engineering, and Mathematics), autonomous systems, and public education. Media are likely to be present. These events will showcase your team and your vehicle; you may wish to have material prepared for public display. RoboBoat judges and industry partners will be on the lookout for specific examples of outstanding public displays amongst the teams entering the competition.

9 Competition Rules

The following is a list of minimal requirements for a vehicle to be permitted access to a course. **Teams that arrive at the competition failing to meet these requirements will not be permitted on the course, until they modify their vehicle to meet all the requirements.**

9.1 Vehicle Requirements

- **Autonomy**: Vehicle shall be fully autonomous and shall have all autonomy decisions made onboard the ASV.
- **Buoyancy**: The vehicle shall be positively buoyant.
- **Communication**: The vehicle cannot send or receive any **control** information while in autonomous mode (to and from Operators Control Station). Communication is allowed between the vehicle and subsystems (Unmanned Aerial Vehicle – UAV).
- **Deployable**: The vehicle must have its own 3 or 4 point harness for crane deployment and recovery. Underslung harnesses will NOT be permitted.
- **Energy source**: The vehicle must be battery powered. All batteries must be sealed to reduce the hazard from acid or caustic electrolytes. The open circuit voltage of any battery (or battery system) may not exceed 60Vdc.

- **Kill Switch**: The vehicle must have at least one 1.5 inch diameter red button located on the vehicle that, when actuated, must instantaneously disconnect power from all motors and actuators.
- **e-Kill Switch**: In addition to the physical kill-switch, the vehicle must have at least one remote kill switch that, when actuated, must instantaneously disconnect power from all motors and actuators. If the remote kill switch system is powered off, vehicle must default to a state in which power is disconnected from all motors and actuators.
- **Propulsion**: Any propulsion system may be used (thruster, paddle, etc.). However, all moving parts must have protection. For instance, a propeller must be shrouded.
- **Remote-controllable**: The vehicle must be remote-controllable (tele-operated) to be brought back to the dock. If the remote controller is turned off (or power is interrupted), vehicle must default to a state in which power is disconnected from all motors and actuators. Controlling vehicle through a laptop is discouraged.
- **Safety**: All sharp, pointy, moving or sensitive parts must be covered and marked.
- **Size**: The vehicle must fit within a six feet, by three feet, by three feet "box".
- **Surface**: The vehicle must float or use ground effect of the water. Mostly submerged/flying vehicles are forbidden for use as primary autonomous platform.
- **Towable**: The vehicle must have a tow harness installed at all times.
- **Visual Feedback**: Teams are required to implement a visual feedback system, indicating status of their ASV. Additional information on this is available in Appendix 16.4 Visual Feedback.
- **Weight**: The entire maritime system (including UAV) shall weigh less than 140 lbs.
- **Payload**: The vehicle must have a place to mount a GoPro (or similar) camera with an unobstructed view from the front of the vehicle.

9.2 Interference

- Interference with course elements will result in a run termination.
- Any vehicle entangled in, dragging, pushing or damaging competition elements or the landscape is interfering.
- Any vehicle leaving its assigned course is interfering.

9.3 Judges' Decisions

- Judges' decisions are final.

9.4 Vehicle Recovery

No team member is allowed in the pond at any time. 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, host and sponsors can take no responsibility for such damage or loss.

10 Weight and Thrust Measurements

Vehicles are weighed during crane deployments (see section 16.2 for more information). Teams planning to attempt the Unmanned Aerial Vehicle (UAV) challenge (Raise the Flag), must have the UAV present on the vehicle during weight and thrust measurements. The weight used is the stable scale reading.

Thrust is measured after the vehicle is deployed in the water either in manual or autonomous mode. The thrust value used is the highest scale reading that is stable for at least two seconds. Vehicles are weighed each time they are deployed. Teams may opt to repeat their thrust measurement at each deployment.

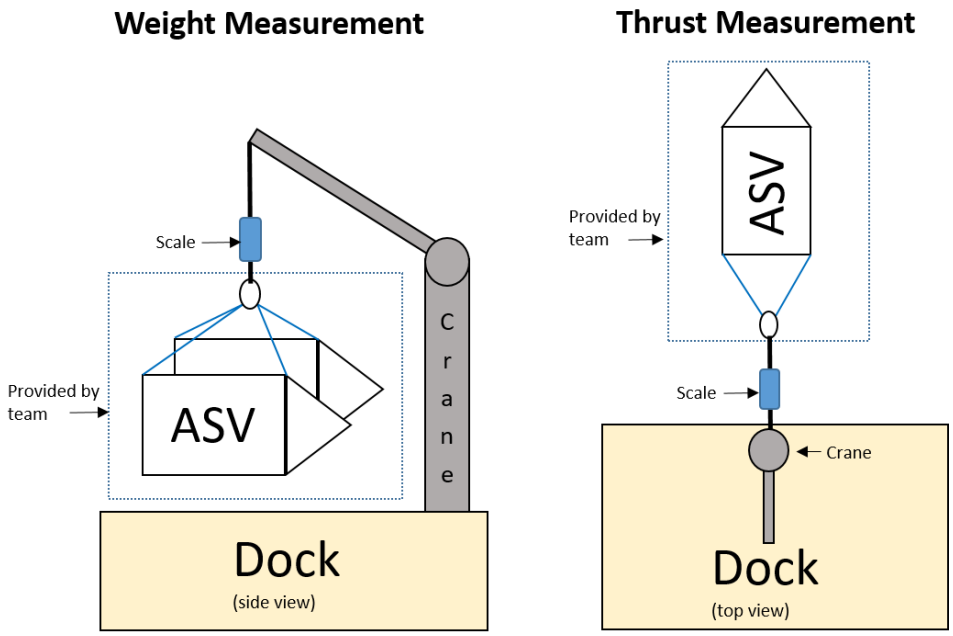

Figure 3: Weight and Thrust Measurement setup

10.1 Task scoresheet

Table 1: Weight and thrust scoresheet

Parameters	Points
ASV + UAV weight > 140 lbs.	**Disqualified!!!**
140 lbs > ASV + weight > 110	-250 - 5*(w - 110)
110 lbs > ASV + weight > 70	2*(110 – w)
ASV weight ≤ 70 lbs	80 + (70 - w)
Dimensions greater than: - three feet of width or - three feet of height - six feet of length	**Disqualified!!!**
Thrust (t) vs weight (w)	*100*(t / w)*

11 Introductory Course Tasks

This course is designed to allow new teams, or returning teams with new members, the opportunity to learn fundamentals of maritime autonomy. Hands-on learning is encouraged through introduction of the following challenges.

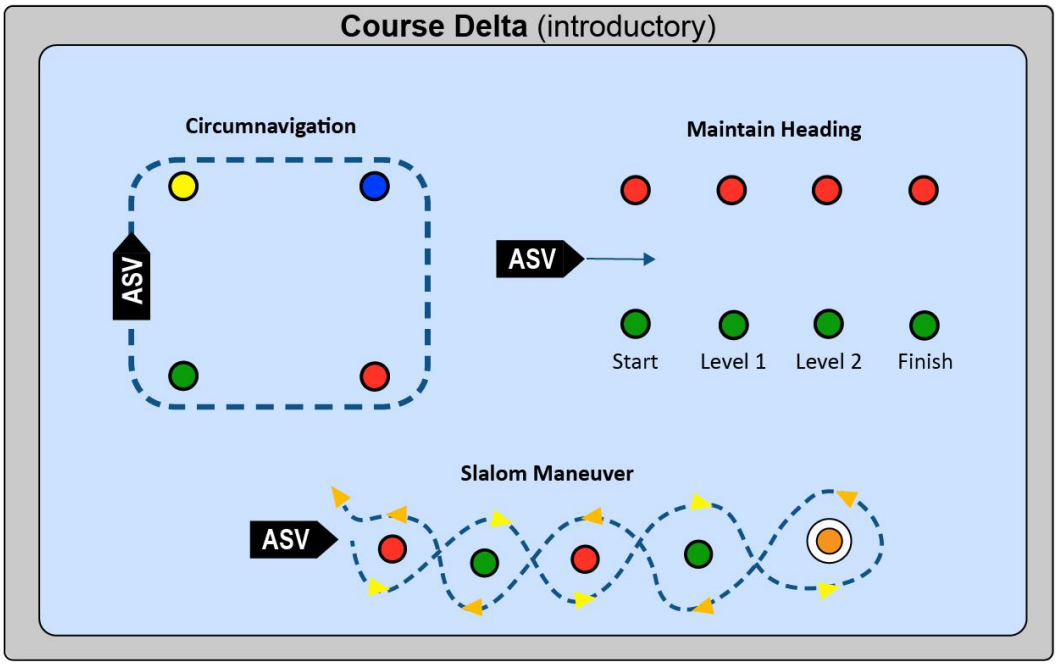

Figure 4: Sample introductory course layout

11.1 Circumnavigation

Using their vehicle, teams must collect Global Positioning System (GPS) data at each of the buoys. This portion of the task may be accomplished by tele-operating the vehicle.

After collecting the GPS data points, teams must circumnavigate the buoys in a prescribed sequence. Teams will be notified of the sequence each day. Figure 5 depicts a subset of potential sequences. These sequences are subject to change, and could be altered based on the level of task success. This aspect of the task must be accomplished autonomously.

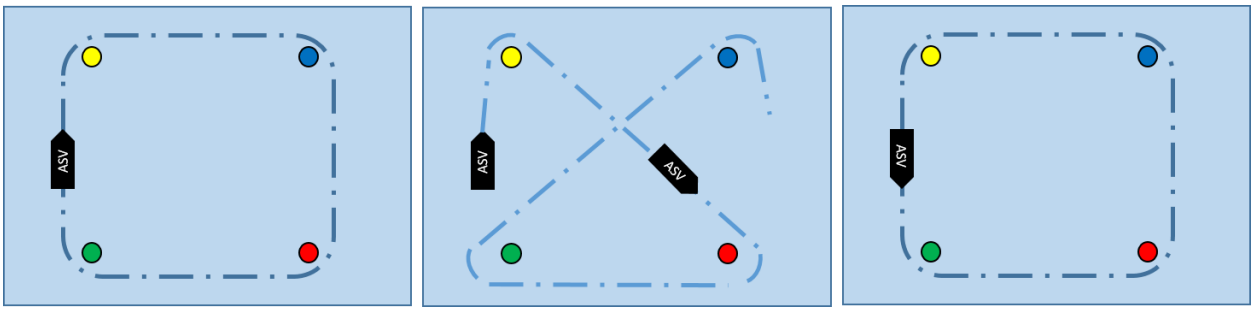

Figure 5: Potential configurations of Circumnavigation

11.1.1 Task Elements

Table 2: Circumnavigation task elements

Task Element	Description	Model No.
Buoy	Polyform A-0 (Green)	A-0
Buoy	Polyform A-0 (Red)	A-0
Buoy	Polyform A-0 (Yellow)	A-0
Buoy	Polyform A-0 (Blue)	A-0

11.2 Maintain Heading

Vehicle shall navigate through a set of buoys, from Start to Finish, using any set of autonomous behaviors (vision, path planning, obstacle detection and avoidance, heading hold or a combination of these).

Figure 6 is an illustration only and not indicative of the final layout. Buoy color, size and shape, and orientation is subject to change. Distance between a set of buoys could change (for example – wide to narrow, from start to finish).

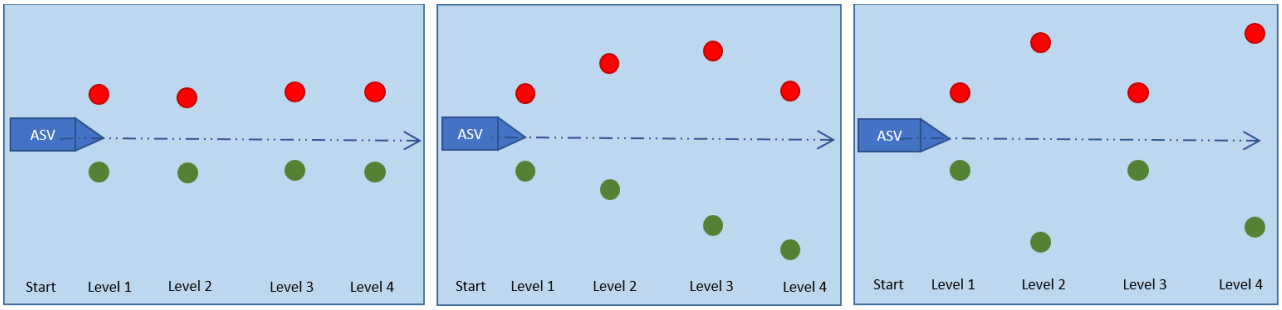

Figure 6: Potential configurations of Maintain Heading

11.2.1 Task Elements

Table 3: Potential buoy elements for Maintain Heading

Task Element	Description	Model No.
Buoy	Polyform A-0 (Green)	A-0
Buoy	Polyform A-0 (Red)	A-0

11.3 Slalom Maneuver

Teams must use a combination of sensors and algorithms (vision, object detection and classification, and others) to navigate this challenge. The objective of this task is to maneuver between the buoys, while avoiding contact with any buoy.

The vehicle must traverse the course, circumnavigate the can buoy (top half orange, bottom half blue), and return to the start point. Traversing the buoys must be accomplished such that ASV must remain to the Starboard (right) side of the red buoy, and to the Port (left) side of the green buoy.

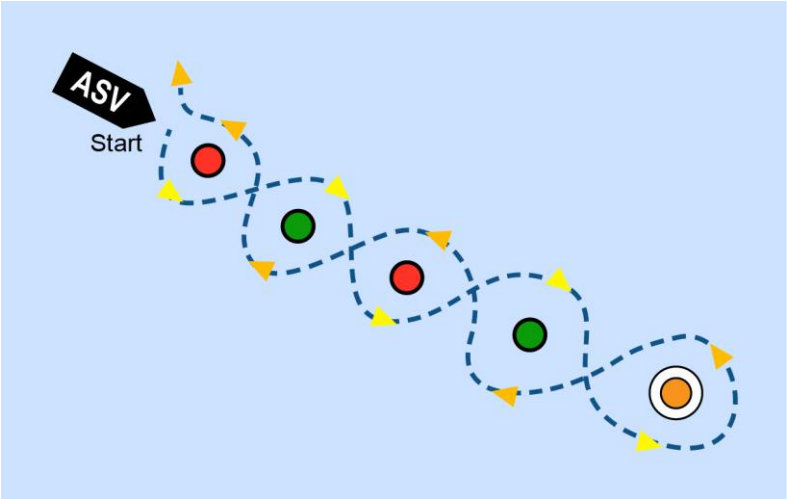

Figure 7: Slalom Maneuver

From the vehicle's perspective, this means it must always pass a red buoy to the vehicle's port side, and must always pass a green buoy to the vehicle's starboard side. This is illustrated in Figure 7 above.

11.3.1 Task Elements

Table 4: Slalom Maneuver

Task Element	Description	Model No.
Can buoy	Taylor Made Sur-Mark Marker Buoy (Covered in half orange and half blue, cloth sleeve)	46104
Obstacle buoy	Polyform A-0 (Green)	A-0
Obstacle buoy	Polyform A-0 (Red)	A-0

12 Autonomous Navigation (mandatory)

The purpose of this mandatory task is to demonstrate basic autonomous control and sensing abilities. This mandatory task is required for all teams operating in the advanced courses.

This water-based task must be completed before mission tasks are attempted. Task must be completed once per competition day, or at the start of new competition phase (ex: finals). Teams planning to attempt the Unmanned Aerial Vehicle (UAV) challenge (Raise the Flag), must have the UAV present on the USV when attempting this, or any other challenge on a course. The UAV can only be launched during the Raise the Flag task.

The vehicle passes through two sets of gates. To be successful, the entire vehicle must pass through both sets of the gates in fully autonomous mode, without touching the buoys. The vehicle must start its autonomous navigation a minimum of 6 ft. before the first set of gates. Successfully passing through both gates is a requirement to attempt any mission tasks.

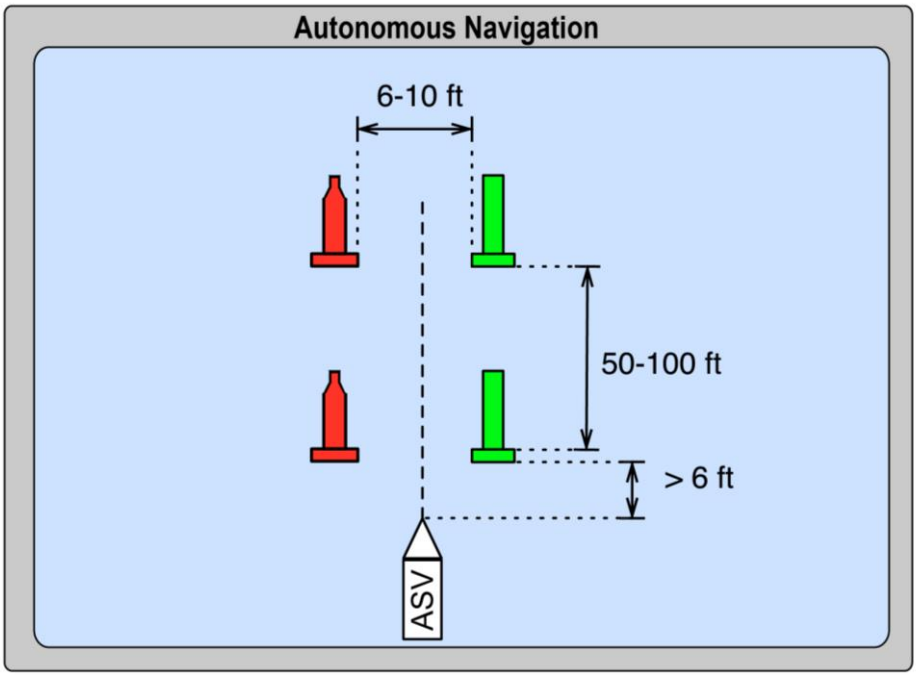

Figure 8: Autonomous Navigation overview

12.1 Task Elements

Table 5: Autonomous Navigation task elements

Task Element	Description	Model No.
Port buoy	Taylor Made Sur-Mark Can Buoy (Red)	950410
Starboard buoy	Taylor Made Sur-Mark Can Buoy (Green)	950400

13 Mission Tasks

The purpose of the mission tasks is to evaluate advanced autonomous behavior of the maritime system, in different scenarios. Mission tasks may be attempted in any order. A single GPS position, representing the center of the task's 'entrance' will be provided at the competition (in decimal degree format).

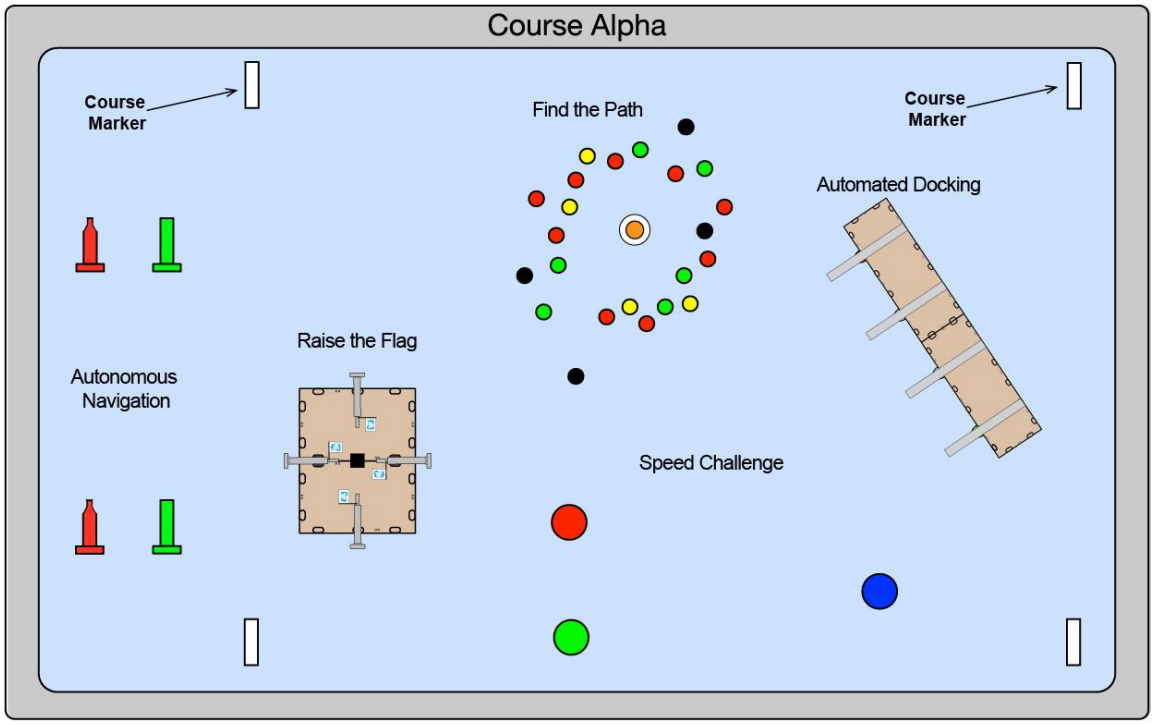

Figure 9: Sample advanced course layout

13.1 Speed Challenge

The purpose of this task is to demonstrate efficiency of a vehicles hull form and propulsion system, and the resulting maneuverability.

The vehicle should enter through the gate buoys, circle the Mark buoy (counterclockwise or clockwise), and exit through the same gate buoys, as quickly as possible. The gate buoys are moored 6-10 ft apart, and the Mark buoy is placed 60 to 80 ft, from the gate buoys. This is a timed challenge. Time starts when the bow (front) of the vehicle crosses the Gate buoys (entry), and stops when the stern (back) of the vehicle crosses the Gate buoys (exit).

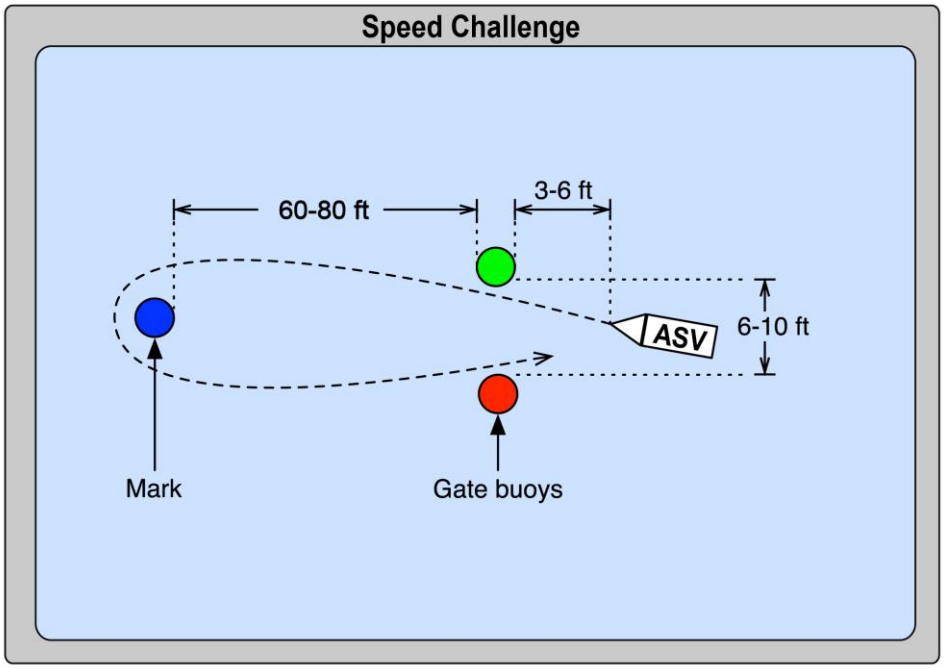

Figure 10: Speed Challenge

13.1.1 Task Elements

Table 6: Speed Challenge task elements

Task Element	Description	Model No.
Gate buoy	Polyform A-2 (Red)	A-2
Gate buoy	Polyform A-2 (Green)	A-2
Mark buoy	Polyform A-2 (Blue)	A-2

13.2 Automated Docking

The purpose of this task is to demonstrate the ability to detect an underwater acoustic signal and localize to the source, in autonomous mode.

The vehicle executes a sequence of docking and undocking maneuvers based on which beacon is active. Each bay is fitted with an acoustic beacon, only one of which will be active during a run.

To execute the docking maneuver, the vehicle identifies the location of the active beacon and enters the bay corresponding to the active signal. The vehicle then exits the bay.

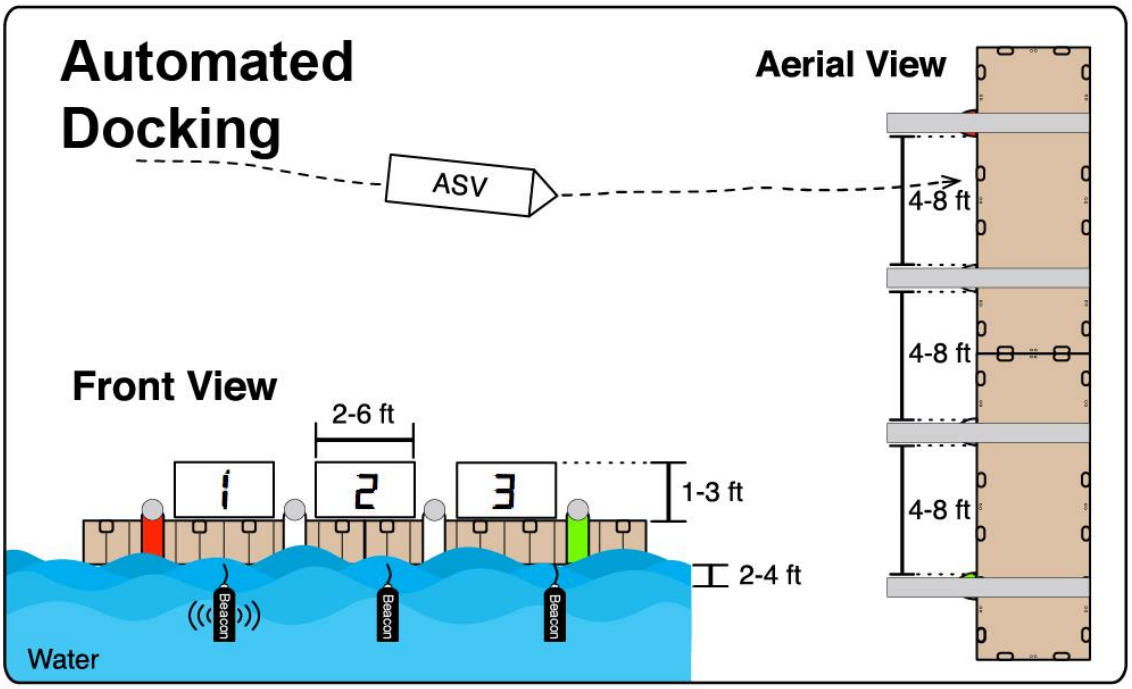

Figure 11: Automated Docking (illustration only)

13.2.1 Task Elements

Table 7: Automated Docking task elements

Task Element	Description
Dock Sections (x2)	40” Dock (EZ Dock)
Acoustic Signal Generator	ALP-365 Beacon

13.3 Raise the Flag

This task requires collaboration between two systems, an ASV and an Unmanned Aerial Vehicle (UAV), to successfully complete the challenge; raising the flag in this case. The UAV can only be launched when attempting this task.

A 7-segment module is located on top of the dock. The ASV must deploy a UAV to identify the number being displayed on the 7-segment module. Note: the 7-segment module is built such that the number is not legible unless, viewed directly from above. Once this number is identified and transmitted to the ASV, the ASV must then locate a sign (located around the dock) with the same number, and push the button in front of it. A flag will be raised to indicate the vehicle has successfully pushed the button.

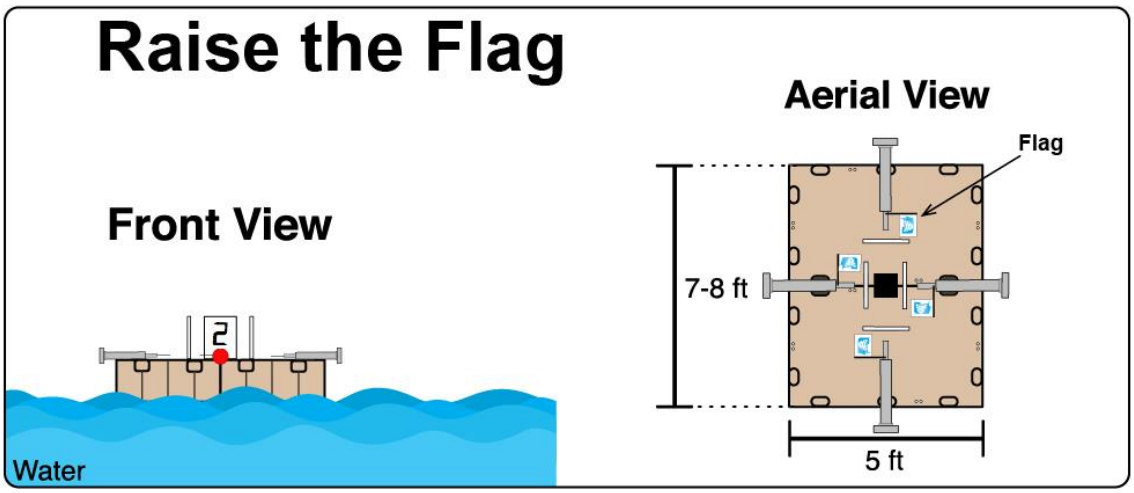

Figure 12: Raise the Flag (illustration only)

Note: A separate document on RoboBoat Unmanned Aerial Vehicle (UAV) guidelines will be published along with these rules. Teams must read and comply with these guidelines, in addition to all FAA regulations in order to fly a UAV at RoboBoat 2019.

13.3.1 Task Elements

Table 8: Raise the Flag task elements

Task Element	Description
Dock Sections (x2)	40” “Baby” Dock (EZ Dock)

13.4 Find the Path

The purpose of this task is to demonstrate complex path planning.

The vehicle finds an opening in a field of obstacles to reach the can buoy in the middle. Upon reaching the can buoy (top half orange, bottom half blue), the vehicle circumnavigates it, and finds an opening (either a different one or the same) to exit the obstacle field. As illustrated in Figure 13, the USV must transit around the can buoy until it has crossed its approach path, transiting at least 360 degrees, before exiting. There is at least one point in the obstacle field where the two closest buoys are four to six feet apart.

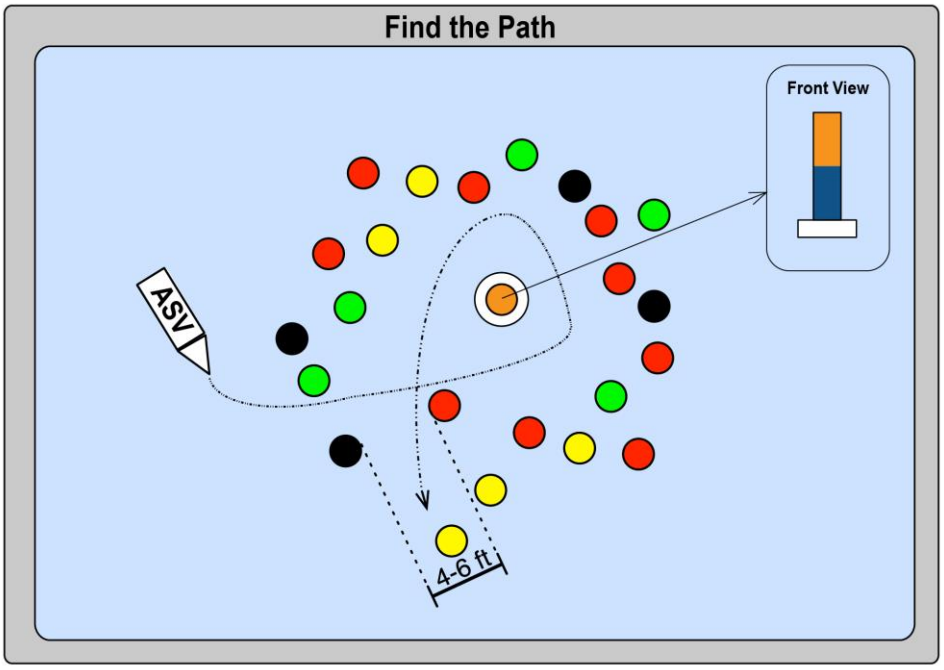

Figure 13: Find the path (illustration only)

13.4.1 Task Elements

Table 9: Find the Path task elements

Task Element	Description	Model No.
Can buoy	Taylor Made Products Sur-Mark Marker Buoy (Covered in half orange, half blue cloth sleeve)	46104
Obstacle buoy	Polyform A-0 (Green)	A-0
Obstacle buoy	Polyform A-0 (Red)	A-0
Obstacle buoy	Polyform A-0 (Yellow)	A-0
Obstacle buoy	Polyform A-0 (Black)	A-0

13.5 Return to Dock

The purpose of this task is to demonstrate the ability to navigate back to the launch point while avoiding interaction with any obstacles.

After having earned points on mission tasks, the vehicle returns to the dock in autonomous mode. The vehicle avoids all obstacles and mission task equipment (buoys, floating docks, etc.) on its way back. The vehicle then comes to a full stop within six feet of the dock from which the vehicle was launched.

If a vehicle crosses through a different course on its way back, the run will be immediately terminated (refer to 9.2 Interference).

Teams returning to dock without attempting all tasks, will be awarded points for returning to the dock. Teams attempting all tasks and returning to dock, before the end of their mission task time, will be awarded points for returning to the dock, as well as bonus points for their remaining mission task time.

14 Network

14.1 Software Security

Our intent is for students to develop skills in systems engineering by accomplishing realistic missions with autonomous vehicle. We have a zero-tolerance policy for any deliberate attempts at sabotaging other teams, or the competition network. Any attempts (successful or not) to hack any of the software systems or other teams' vehicles will result in disqualification of the team.

14.2 Team Deployed Network

Each team is responsible for deploying their own 'network' solution for communication with their vehicle. There is no restriction on the actual communication mechanism (e.g., underwater modems, cellphone, 802.11xx wireless, etc.). Each team must provide a base station that can bridge the communication between their vehicle and a wired RJ-45/cat5 Ethernet network. If you opt for a wireless technology, you must use a public frequency or acquire a license from the FCC.

15 Communication (Please pay particular attention to this section)

15.1 Communication with Competition Mission Task Server

To earn points **on the advanced competition course, teams must be able to communicate with the competition mission task server.** All competitor OCU (Operator Control Stations) will be required to have the ability to connect to a wired Ethernet network (provided), and request an IP address from a DHCP server. Once connected, they should establish a TCP connection to a server, with an address and port number, for the course they will compete on. These addresses and port numbers are unique to each of the courses and will be listed on the competition information board during the event. A different NMEA sentence will be defined for each challenge requiring communication between the vehicle and a judge.

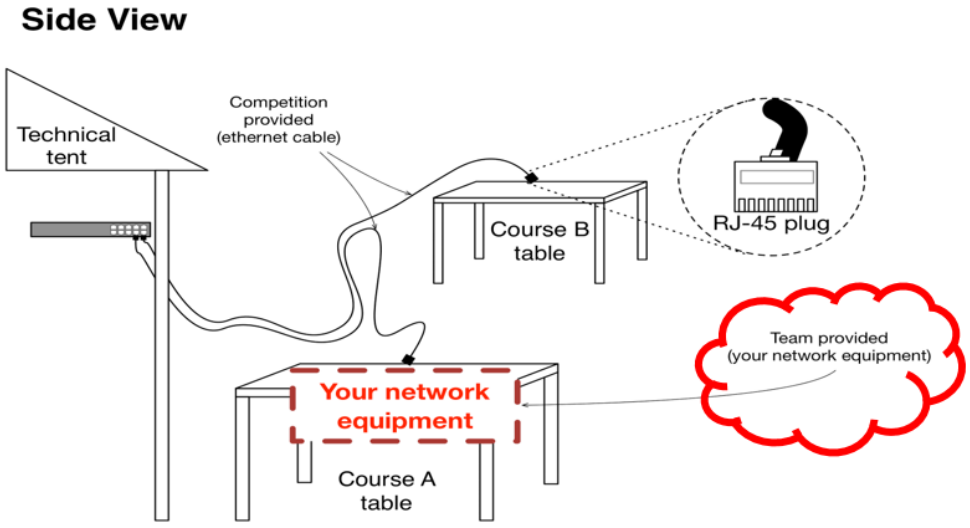

Figure 14: Physical network setup

The router is DHCP enabled and provides a dynamic IP address in one of the following subnets: 192.168.65.0, 192.168.66.0, 192.168.67.0, or 192.168.68.0.

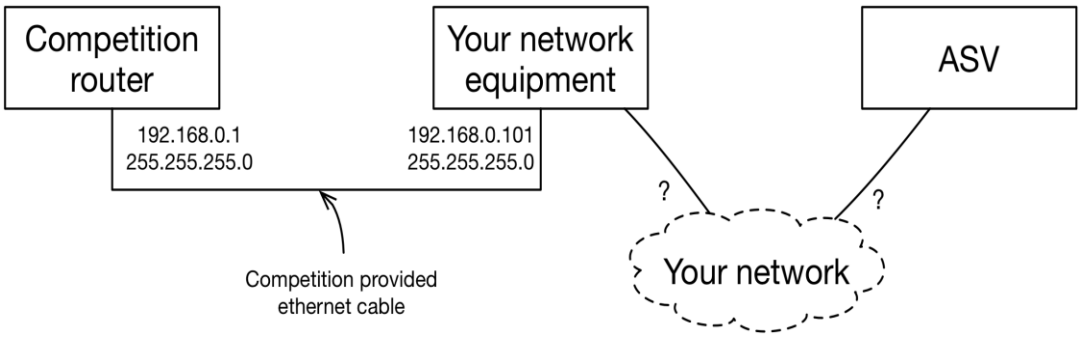

Figure 15: Virtual network connectivity overview

All communication will be formatted as a NMEA-like sentence, characterized by the following guidelines:

- Each message's starting character is a dollar sign.
- The next five characters identify the competition (two characters) and the type of message (three characters).
- All data fields that follow are comma-delimited.
- Where data is unavailable, the corresponding field remains blank (it contains no character before the next delimiter)
- The first character that immediately follows the last data field character is an asterisk.
- The asterisk is immediately followed by a checksum represented as a two-digit hexadecimal number. The checksum is the bitwise exclusive OR of ASCII codes of all characters between the $ and *.
- <CR><LF> ends the message.

A different NMEA sentence will be defined for each challenge requiring communication between the vehicle and a judge. Additional information on NMEA specific sentences for each of the tasks will be provided at a later date.

16 Appendices

16.1 Breakdown of a TIMESLOT

TIMESLOT selection varies at different phases of the competition (practice, qualification and final rounds). A timeslot is comprised of a “Pre-Start Time”, “Dock Time”, and “Mission Task Time”.

Pre-Start Time: To maximize in-water time for each team, teams should be physically present with their vehicle, in a ready state, at least five minutes before the start time. Organizers will utilize this time to conduct a safety check of your system.

Dock Time: The first five minutes of a TIMESLOT are allocated to dock time. Dock time begins when the team's vehicle is attached to the crane, for deployment. Dock time can be used for weight and thrust measurement, troubleshooting, and preparation for the runs. Any remaining dock time is waived as soon as the vehicle leaves the dock, or at the request of the team leader. If the vehicle is still at the dock when the dock time runs out, in-water time will automatically start.

Mission Task Time: A 20 minute time follows the designated dock time. During mission task time, teams may attempt as many 'runs' as desired. Only points accrued in the last run of a TIMESLOT will be scored (starting a new run waives all points previously accrued in the same TIMESLOT). The mission task time keeps running, even when vehicles are being brought back to the dock (towed or under their own power). **The last run of a TIMESLOT will automatically end as soon as one of the following occurs:**

- The mission task time runs out.
- The team leader requests that the run be ended.
- The technical director or a judge orders the end of the run.*
- Others, as provided in section 9.2.

**Note: TDs and Judges rarely order the end of a run, but they can do so at their discretion for safety or competition rule violations.*

At the end of a run or TIMESLOT, vehicles must be brought back to the dock, under their own power. In case of systems failure, RoboBoat staff may manually tow the vehicle back.

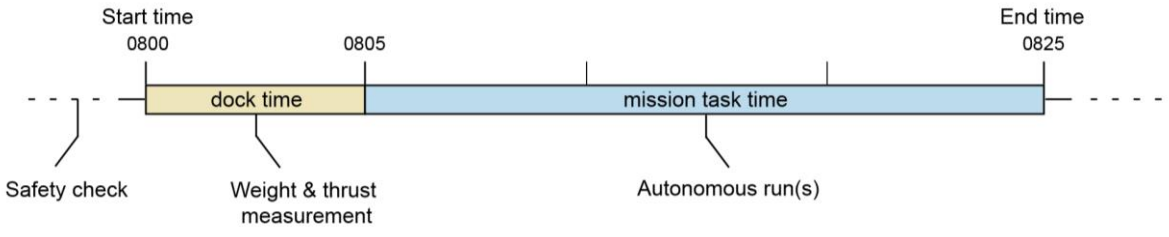

Figure 16: Breakdown of TIMESLOT

16.2 Vehicle Deployment and Recovery

Vehicles are deployed and recovered using a crane and a team-provided 3 or 4-point harness. Each end of the harness must be securely attached to a fixed point on the vehicle (cannot be slung under the vehicle). The ideal methodology is to incorporate three or four eyebolts in the main vehicle structure. These eyes bolts, when paired with a set of spring loaded carabiners and harness will allow for quick connect/disconnect from the vehicle during launch/recovery. A single fixed point (could be a separate carabiner that the 3 or 4 harnesses attach to) must be provided to attach the teams harness to the crane. ***(Note: when selecting lifting components, ensure they are rated for lift, and can lift more weight than your vehicle)***.

Figure 17: Examples of 3 and 4 point lifting harness

16.3 Vehicle Transit

To move your vehicle around the competition venue (when outside of the water), teams must provide a cart for their vehicle. (Suggestions: garden cart, dump cart, etc.). The cart is manually propelled on site (ie: no motorized carts). In order to be maneuvered on the tight launch pad, the cart's handle must be solid (no rope/chain). The cart's width must be less than thirty-six inches to fit on the ramp as well as providing ingress and egress from a residential door frame *(Note: standard residential door frame width is 36" but only 35" is available – accounting for ½ loss on each side)*. Carts with six inch (or more) diameter rubberized wheels are recommended to navigate the gravel, mud and grass terrain during competition.

Figure 18: Examples of vehicle trailer (cart)

16.4 Visual Feedback

This section describes a lighting system that will serve as a visual status indicator for the team's vehicle.

With unmanned systems being integrated into everyday use, it is safety critical for these systems to indicate their operational status. Resources and general guidelines will be outlined in this document to permit teams to acquire, integrate, and test a system that meets the safety requirement set forth for RoboBoat operations.

The lighting system shall consist of, at minimum, three lights: Red, Amber/Yellow, and Green/Blue. Lights shall be arranged in a vertical configuration and mounted such that they provide a **360 degree daylight visibility**, when viewed from shore or nearby vessel.

Lighting system colors shall correspond with the applicable mode of the team's autonomous system as indicated in Table 10, below. The lights may be flashing or steady on/off according to the state of the system.

Table 10: Light color and correlating modes

Color	Mode
Red	E-Stop active (propulsion disabled)
Amber/Yellow	Tele-Operation / Manual Operation
Green/Blue	Autonomous operation

Visual indication system can be purchased commercially, or can be a custom array of RGB LEDs. Keeping the below specifications in mind, design and selection of the final system is the team's decision.

Figure 19: Visual Feedback Indicators (Left – Commercial; Right – Custom)

To provide visibility in sunlight, teams should use lighting systems that have clear enclosures for the light to shine through; rather than colored enclosures with standard light bulbs.

16.5 Acoustic Beacon Specifications

Each team will need to build a localization system compatible with the competition beacon system if they are attempting underwater beacon localization tasks. The beacon type and configuration are described in this appendix so teams may acquire a comparable unit to test, if they so choose.

The beacon selected for competition use is the Benthos ALP-365. This model has a selectable frequency between 25 and 40kHz with a 0.5kHz increment.

A link to the specifications: ALP-365 Beacon

The frequency and pulse rate of the beacons in each field may change daily; this information will be available to teams during the competition. The full range of frequencies (25 – 40 kHz) and pulse rate (0.5 Hz to 2 Hz) will be used throughout the competition. During the competition there may be multiple units active at any time, with at least one (1) in each course.

Figure 20. Benthos ALP-365 Beacon