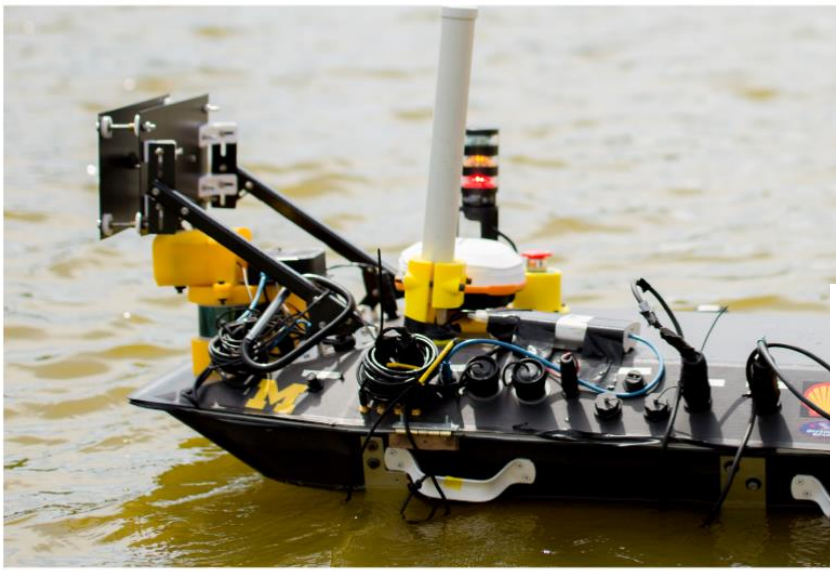
roboboat

A DAY AT THE CARNIVAL

# 2022

# TEAM HANDBOOK

Version 1 (January 2022)

# Introduction



**Welcome to the frontlines of innovation at the 2022 RoboBoat Competition!**
This Team Handbook contains information that teams need to compete at the 2022 RoboBoat Competition. It includes task descriptions, rules, and requirements, and other guidance and specifications. Teams are encouraged to read this document for a thorough understanding of what is necessary to compete effectively.

**What is RoboBoat?** RoboBoat is an international student program established to generate, cultivate, and enhance a community of innovators capable of making substantive contributions to the Autonomous Surface Vehicle (ASV) domain. The vision is achieved by providing a venue and mechanism, whereby practitioners of robotics and maritime autonomy come together at RoboBoat to share knowledge, innovate, and collaboratively advance the technology of ASV systems. Teams must also document their designs as described in this Team Handbook.

**Why RoboBoat?** The objective of RoboBoat is to build an international community of innovators – ranging from high school to higher education, capable of making substantive contributions to the maritime field and pushing development of small-scale (X-Class) Autonomous Surface Vehicle (ASV).

**Why compete in RoboBoat?** Participants of RoboBoat may expect to:

- Increase technical proficiency;
- Establish valuable professional connections; and
- Enjoy the satisfaction of learning and collaborating while advancing the technology of ASV systems.

The nominal winners are those teams that have scored the most points. The real winners are all those participants who have learned something lasting about working together to create an autonomous system that accomplished a challenging mission in a complex environment.

*Maritime autonomous technology is critical to monitoring and healing our oceans. Developing the human resource to expand this effort is even more essential.*

**2022 ROBOBOAT ORGANIZERS**

The 2022 RoboBoat Competition is hosted by RoboNation, in collaboration with the United States Office of Naval Research (ONR).

# Table of Contents

# Version Updates



| Version | Changes | Date |
|---|---|---|
| V1 | First release of RoboBoat 2022 Team Handbook. | 24 January 2022 |

Table 1. Document Version Log

# SECTION 1: RoboBoat Overview

*RoboBoat 2022* *www.roboboat.org*

## 1.1 Dates & Venue

The 2022 RoboBoat Competition (RoboBoat 2022) will be conducted 20-25 June 2022 at the Nathan Benderson Park in Sarasota, Florida. Multiple courses will be used for the competition (Figure 1).


Figure 1: Preliminary Venue Layout

**Health and Safety**

Due to the evolving nature of COVID-19 related travel and tourism guidance, teams are encouraged to stay apprised of updated rules and regulations for entering the United States and Florida. For more information, see Section 5: How to Compete.

## 1.2 Competition Structure

RoboBoat 2022 includes the Autonomy Challenge and Design Documentation with the option for teams to compete in-person (travel to Florida, USA) or online (from home/school location). The competition includes:

- Autonomy Challenge demonstrates safety and performance; and
- Design Documentation presents each team's work and vehicle design.

## 1.3 Eligibility

Student teams from anywhere in the world are eligible to participate. All teams must build an ASV to compete and only enter one vehicle in the competition.

### 1.3.1 Eligibility Details & Team Composition

- Teams must be comprised of 75% or more full-time students. Student members are expected to make significant contributions to the engineering development cycle of their ASV.
- The majority of team members must be college or high school students. Teams may also include middle school students. Interdisciplinary teams are encouraged.
- Teams may be comprised of 25% or less alumni, industry, academic or government partners.
- Three (3) team members are required for safe operations on-site at RoboBoat.

## 1.4 Point of Contacts

| RoboBoat Questions: | Registration Questions: | Technical Questions: | On-Site Logistics/Safety: |
|---|---|---|---|
| autonomy@robonation.org | support@robonation.org | roboboat.org/forum | events@robonation.org<br>850.642.0536 |

# SECTION 2: Competition



This section includes general competition information for the 2022 RoboBoat Competition (RoboBoat 2022) including competition schedule, Design Documentation, and Autonomy Challenge.

## 2.1 Competition Schedule

RoboBoat 2022 includes:

- **Design Documentation:** Teams provide a variety of design documentation prior to and during the competition.
- **Autonomy Challenge:**
  - **Qualifying Round:** Teams assemble and test their ASV, participate in initial safety inspections, practice, and qualify for Semi-Finals in the water on the Practice Courses.
  - **Semi-Finals Round:** Teams complete runs to qualify for the Finals Round.
  - **Finals Round:** Teams complete runs on the Finals Course.

| Date | Event | Location |
|---|---|---|
| **May-June** | Design Documentation (prior to on-site competition) | Online |
| **19 June** | Early Team Check-in | Nathan Benderson Park |
| **20 June** | Team On-Site Orientation<br>Vehicle Assembly + Safety Inspections<br>Practice Course Open | |
| **21 - 23 June** | Practice Course Open<br>Design Documentation Presentations (on-site and online) | |
| **24 June** | Semi-Finals Round | |
| **25 June** | Finals Round<br>Awards | |

Table 2. RoboBoat 2022 Schedule

### 2.1.1 Daily Team Meeting (In-Person Teams)

Each competition day ends with a mandatory team meeting for in-person teams, conducted by the Technical Director. Team leads are required to attend. All participants are strongly encouraged to attend.

- **Daily Team Meeting:** Technical Director summarizes the day's events, describe any course changes for the following day, and teams are encouraged to provide feedback.

## 2.2 Design Documentation

Prior to the on-site competition, teams provide a variety of design documentation. During the competition, teams provide an oral presentation and their ASV is assessed by subject matter expert judges. Teams have the option to conduct their presentation in-person (travel to Florida, USA) or online (from home/school location).

### 2.2.1 Delivered Prior to On-Site Competition

The following design documentation is delivered prior to the on-site competition. How to submit deliverables can be found in Section 5.2 Pre-Competition Requirements.

**Team Website**

Teams are required to submit a website in English that documents their team, vehicle design, and competition approach, addressing the following areas:

1) Website Content: Layout and detailed contents of the website are left for the teams to develop; however, the team website should include:

- Team name and contact information
- Team name, picture and contact information for each contributing member
- Vehicle diagrams
- Instructional/Informative videos
- Procedures (text, images)
- Design decision documentation (text, images, videos)
- Blogs for historical records of build progress
- List of sponsors with logos

2) Website Quality: Websites are often the first impression of a project. Potential supporters such as supervisors, sponsors, or advisors must find the website visually appealing and easy to navigate. Development of the website should include careful consideration of user experience, including:

- Written in English, or English translation provided
- Clear prioritization of key content
- Site search functionality
- Basic design elements: contrast, repetition, alignment and grouping to organize/highlight content
- User accessibility, as defined by the W3C Web Accessibility Initiative: www.w3.org/WAI
- Cross browser compatibility for modern web browsers (Chrome, Firefox, Safari, MS Edge)
- A mobile friendly display

**Technical Design Report**

Teams are required to submit a technical design report in English that describes the design of their ASV autonomy systems, propulsion system, and control systems, as well as strategies for their approach to the tasks. This paper should include the rationale for their design choices. Guidelines for this report are available in Appendix A: Technical Design Report.

**Competition Video**
Each team is required to create a video. The video content guidelines are being finalized and will be provided at a later date.

Format Requirements:

1. Teams must abide by all applicable social distancing protocols.
2. Video must be conducted in English or include subtitles in English.
3. Videos must be hosted by team:
   OPTION 1: Hosted on team's YouTube Channel.
   - Videos shared on the RoboNation YouTube Channel.
   - Must follow YouTube Rules & Policies, including appropriate music copyright management.

   OPTION 2: Host/Embed on Team Website.

### 2.2.2 Delivered During On-Site Competition

**Design Presentation**
Teams give a design documentation presentation to a panel of judges. Each team must present their competition strategy and how that plan impacted their design and selections. This oral presentation must be conducted in English and may include visual aids. This presentation includes:

- Team presentation (20 minutes)
- Judges' question and answer (5 minutes)
- Judges' inspection of vehicle (5 minutes)

*In-Person Teams:* Teams competing in-person conduct this presentation in-person at the competition. Teams receive an assigned 30-minute presentation time on 22 or 23 June. After the presentation, teams should make themselves available for a team photo, and optional video interview.

*Online Teams:* Teams competing online conduct this presentation virtually. Teams receive an assigned 30-minute presentation time on 22 or 23 June.

## 2.3 Autonomy Challenge

These challenges showcase ASV performance through autonomous behaviors designed to represent research and real-world applications. Teams have the option to conduct the Autonomy Challenge with a live demonstration in-person (travel to Florida, USA) or a video demonstration online (from home/school location).

### 2.3.1 Live Demonstration (In-Person Teams)

Teams who can travel to the competition site showcase their vehicle performance through autonomous completion of a range of tasks onsite at the competition site.

**Mandatory Activities**
Prior to entering any of the Autonomy Challenge courses, teams are required to demonstrate their ability to safely operate their ASV.

**Qualifying Round**
Practice Courses are available for teams to practice, demonstrate proficiency, and qualify for the Semi-Finals Round. During this round, multiple courses are available, and each course includes all tasks. Teams may schedule times to practice or qualify on these courses. Multiple teams may be on a Practice Course at the same time. (Section 2.6 Qualifying Round)

**Semi-Finals Round**
Teams who qualify for the Semi-Finals Round are assigned a timeslot to conduct their Semi-Finals run. (Section 2.7 Semi-Finals Round)

**Finals Round**
Upon completion of the Semi-Finals Round, the judges announce the top-scoring teams who progress to the Finals Round. The judges have the discretion to select the number of teams advancing to the Finals Round. (Section 2.8 Finals Round)

### 2.3.2 Video Demonstration (Online Teams)
Teams who cannot travel to the competition site showcase their vehicle performance through a video demonstration. The videos are not scored; however, the videos are shared online on the RoboNation YouTube Channel and can be eligible for special awards and recognition.

## 2.4 Mandatory Activities
Prior to entering any of the Autonomy Challenge courses, teams must demonstrate their ability to safely control their ASV.

### 2.4.1 Live Demonstration (In-Person Teams)
In-Person teams showcase their vehicle performance through a live demonstration of autonomous completion of a range of tasks onsite at the competition site.

**Static Safety Inspection**
Prior to deploying in the water, the ASV must meet all safety requirements. At a minimum, the following areas are checked:

- Emergency Stop System (location of switches, on-board and remote functionality)
- Safety issues related to propellors or hazards
- All systems are properly secured

More details on system requirements are available in Section 4.3.1 ASV Requirements.

**Weight and Thrust Measurements**
Vehicles are weighed at the start of each day during the Qualifying Round and at the start of each run during the Semi-Finals and Finals Rounds. Teams transport the vehicle on their cart to the scale (similar to a veterinary scale, available at scaleline.com) for weight measurement. The stable scale reading weight is recorded.

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. Teams may opt to repeat their thrust measurement at each deployment.

| Parameters | Points |
|---|---|
| ASV 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:<br>- three feet of width or<br>- three feet of height<br>- six feet of length | **Disqualified!!!** |
| Thrust (t) vs weight (w) | *100*(t / w)* |

Table 3: Weight and Thrust Scoresheet

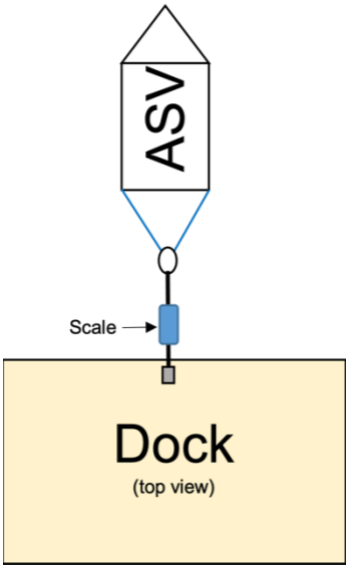



Figure 2: Thrust Measurement

**Navigation Channel Demonstration**

After the ASV Static Safety Inspection, teams must demonstrate that the ASV can navigate through two pairs of red and green buoys in a fully autonomous manner. The entire ASV must pass through both sets of the gates, without touching the buoys. The ASV must start its autonomous navigation a minimum of 6 ft. before the first set of gates.

The mandatory Navigation Channel Demonstration is designed to demonstrate basic autonomous control and sensing capabilities.

This must be completed each day before attempting any tasks on the Autonomy Challenge courses. Teams may be required to repeat this demonstration each time the ASV is re-deployed in the water.

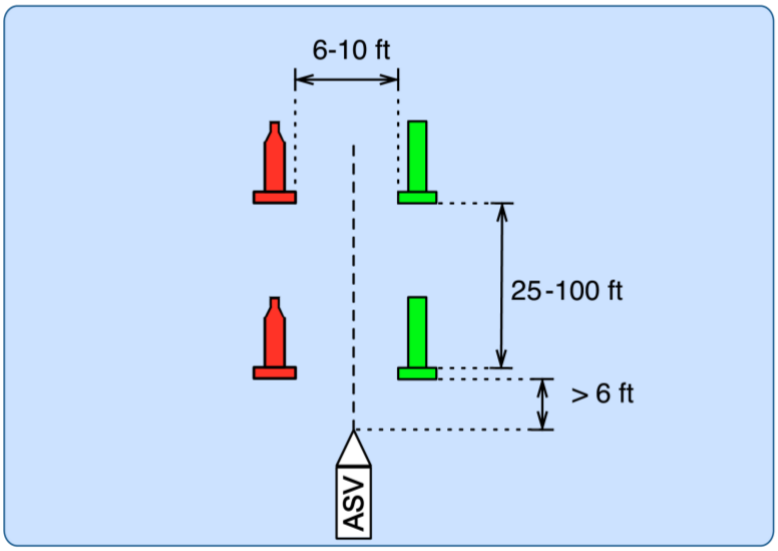



Figure 3: Navigation Channel Demonstration

Task elements for Navigation Channel Demonstration are detailed in Table 4 below.

| Task Element | Description | Model No. | Color | Ht. Above Waterline | Base Diam. |
|---|---|---|---|---|---|
| Port Marker Buoy | Taylor Made Sur-Mark Buoy | 950410 | Red | 39in | 18in |
| Starboard Marker Buoy | Taylor Made Sur-Mark Buoy | 950400 | Green | 39in | 18in |
| Navigation Channel Demonstration buoys are supplied from Taylor Made, www.taylormadeproducts.com. | | | | | |

Table 4. Task Elements for Navigation Channel Demonstration

### 2.4.2 Video Demonstration (Online Teams)

Online teams showcase their vehicle performance through a video demonstration of autonomous completion of a range of behaviors. This video is not scored; however, the videos are shared online on the RoboNation YouTube Channel.

Teams must choose at least one (1) behavior to demonstrate. Teams may use creativity to build something similar to the published course elements in 2.5 Task Descriptions. If teams do not have access to water, the vehicle behaviors can be demonstrated in a simulation environment.

**Vehicle Behaviors**

The behaviors are listed in rank order of difficulty from 1 (least) to 5 (most).

1. Station keeping: Stay in place without drifting. (Ex: Task 5)
2. Navigation: Travel toward a destination with intent and/or follow a path. (Ex: Task 2)
3. Object avoidance: Travel without contacting any objects unintentionally. (Ex: Task 3)
4. Orientation: Turn clockwise and/or counterclockwise, intentionally. (Ex: Task 3)
5. Two-step behaviors: Visual ID and navigation—Show the vehicle identifying an object, transiting toward object, and exhibiting additional behavior. (Ex: Task 4)

**Video Guidelines**

An individual video should be submitted for each behavior attempted. Teams must include the following sections in each video:

- Introduction: Identify the school/team name and the behavior(s) demonstrated.
- Behavior Demonstration: Clearly show each behavior on video; this may include different angles. Each behavior may take up to 2 minutes of the video.
- Behavior Summary: Summarize each attempted behavior and a brief assessment of success.
- Closing: Provide brief closing statement for viewers; this may include acknowledgements.

**Format Requirements**

1. Teams must abide by all applicable social distancing protocols.
2. Video must be conducted in English or include subtitles in English.
3. Individual videos must be no more than five (5) minutes in length.
4. Video must include text or icon in upper left corner of screen indicating the vehicle is operating in autonomous mode.
5. Video must include text in upper right corner of screen indicating which behavior is being demonstrated.
6. Videos must be hosted by team:

   OPTION 1: Hosted on team's YouTube Channel.
   - Videos shared on the RoboNation YouTube Channel.
   - Must follow YouTube Rules & Policies, including appropriate music copyright management.

   OPTION 2: Host/Embed on Team Website.

## 2.5 Task Descriptions

This section provides details of the RoboBoat 2022 Autonomy Challenge tasks. Teams are encouraged to develop a strategy approaching these tasks that best suits their ASV.

### 2.5.1 Task 1 – Avoid the Crowds

The Avoid the Crowds task demonstrates the ability for the ASV to sense and maneuver through a complex path, staying with the defined pathway, and avoiding contact with obstacles along the way. The task consists of multiple sets of gates designated by pairs of red and green buoys. The ASV passes between the sets of gates without touching the buoys and avoids intermittent yellow buoys (may be various sizes) placed within the pathway.

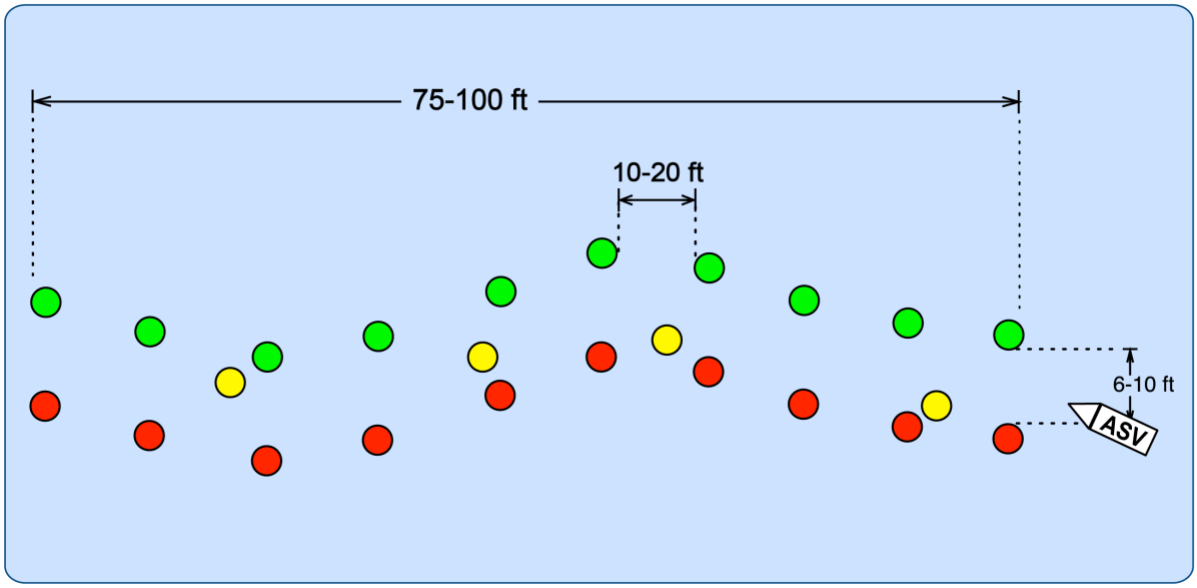



Figure 4: Example Avoid the Crowds Task

**Task Elements**

Task elements for the Avoid the Crowds task are detailed in Table 5.

| Task Element | Description | Model No. | Color | Ht. Above Waterline | Base Diam. |
|---|---|---|---|---|---|
| Gate Buoy | Polyform A-0 | A-0 | Red | 0.5 ft | 20.3 cm |
| Gate Buoy | Polyform A-0 | A-0 | Green | 0.5 ft | 20.3 cm |
| Obstacle Buoy | Polyform A-0 | A-0 | Yellow | 0.5 ft | 20.3 cm |
| Obstacle Buoy | Polyform A-2 | A-2 | Yellow | 1 ft | 36.8 cm |
| Avoid the Crowds buoys are supplied from Polyform US, shop.polyformus.com. | | | | | |

Table 5: Task Elements for Avoid the Crowds

### 2.5.2 Task 2 – Find a Seat at the Show

The Find a Seat at the Show task demonstrates the ability for the ASV to correctly sense, locate and maneuver into an assigned docking bay. Teams are assigned a color and / or shape before their time slot begins. The ASV must locate the bay matching this color and / or shape and attempt to enter the bay. The ASV must not make contact with any part of the docking bay.

The exact build of the task is still being developed. There are two alternative build options, one using PVC pipe for the tines and the second using floating dock pieces for the tines.

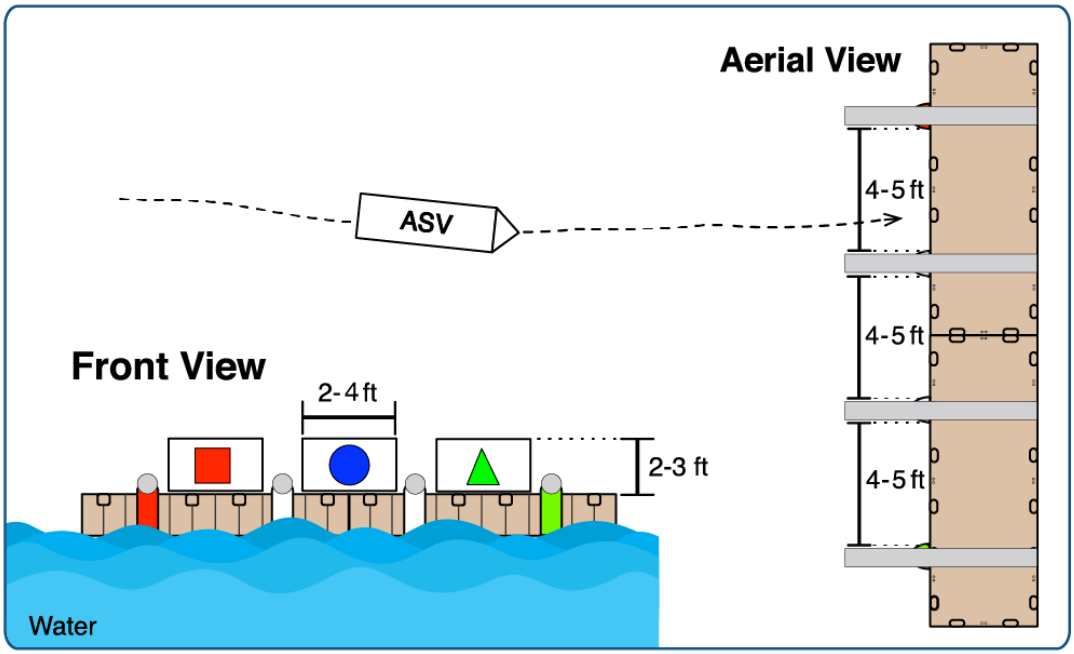



Figure 5: Example Find a Seat at the Show Task

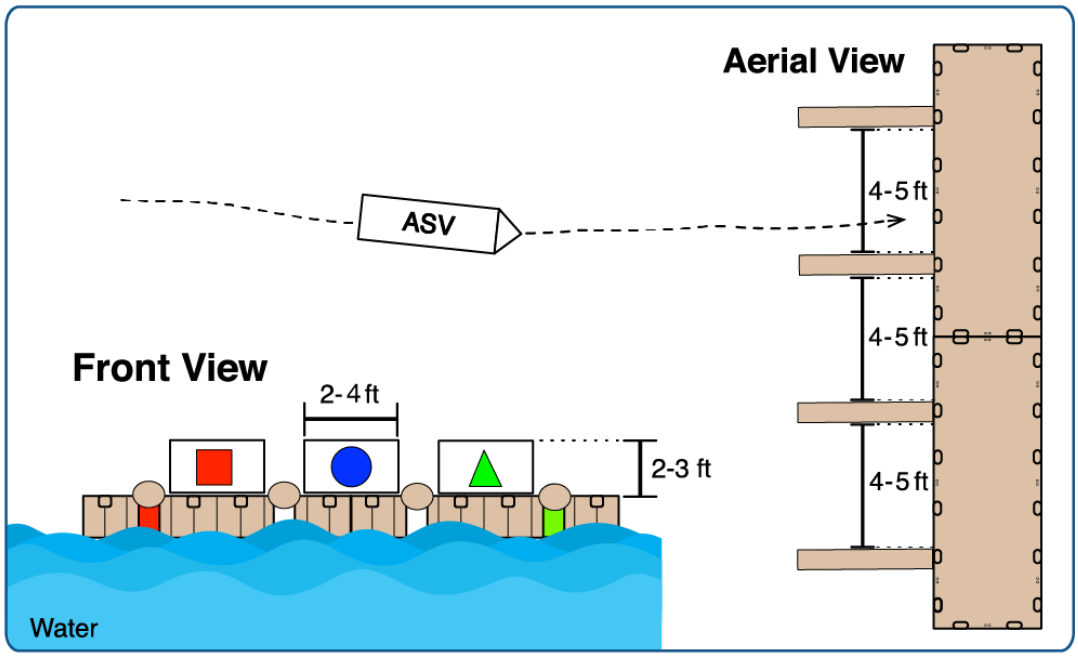



Figure 6: Alternate Build - Find a Seat at the Show Task

**Task Elements**

Task elements for the Find a Seat at the Show task are detailed in Table 6.

| Task Element | Description | Color |
|---|---|---|
| Floating Dock | 40 in. “Baby” EZ Dock | Beige |
| Shape/Color Display | Vinyl banner | Red, Blue, Green |
| Tines | PVC Pipe | White |
| Tines (Alternate build) | Large Cube Jet Dock | Beige |
| Dock units are supplied from EZ Docks, www.ez-dock.com, and Jet Dock, www.jetdock.com. | | |

Table 6: Task Elements for Find a Seat at the Show

### 2.5.3 Task 3 – Snack Run!

The Snack Run task demonstrates the ability for the ASV to sense the task elements with object recognition and decision making. This task demonstrates hull form efficiency coupled with its propulsion system, and the resulting maneuverability.

As quickly as possible, the ASV enters through gate buoys, goes around the mark buoy (counterclockwise or clockwise), and exits through the same gate buoys. The gate buoys are moored 3 to 6 ft apart, and the mark buoy is placed 40 to 100 ft, from the gate buoys.

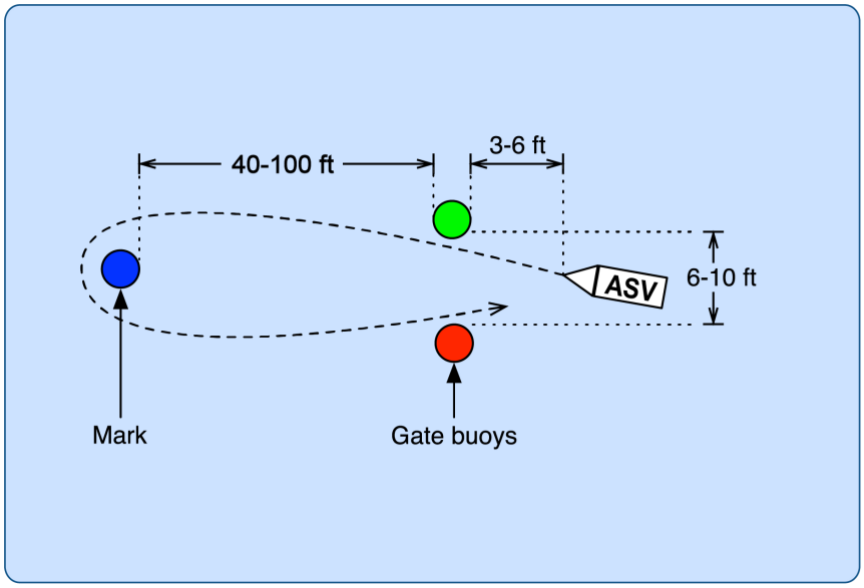



Figure 7: Example Snack Run Task

This is a timed task. Time starts when the bow (front) of the ASV crosses the gate buoys (entry) and stops when the stern (back) of the ASV crosses the gate buoys (exit).

**Task Elements**

Task elements for the Snack Run task are detailed in Table 7.

| Task Element | Description | Model No. | Color | Ht. Above Waterline | Base Diam. |
|---|---|---|---|---|---|
| Gate buoy | Polyform A-2 | A-2 | Red | 1 ft | 36.8 cm |
| Gate buoy | Polyform A-2 | A-2 | Green | 1 ft | 36.8 cm |
| Mark buoy | Polyform A-2 | A-2 | Blue | 1 ft | 36.8 cm |
| Snack Run buoys are supplied from Polyform US, shop.polyformus.com. | | | | | |

Table 7: Task Elements for Snack Run

### 2.5.4 Task 4 – Skeeball Game

The Skeeball Game task demonstrates the ability for the ASV to sense and interact with its environment. The ASV must find the "shooting gallery" side of the task using the purple frame, and then deploy/shoot balls through the frame and onto the skeeball table, in any of the three holes. The ASV may make contact with the dock and will not be penalized. Balls may only be delivered through the purple frame, the other sides of the task may be closed off with netting or another material, not shown in Figure 8.

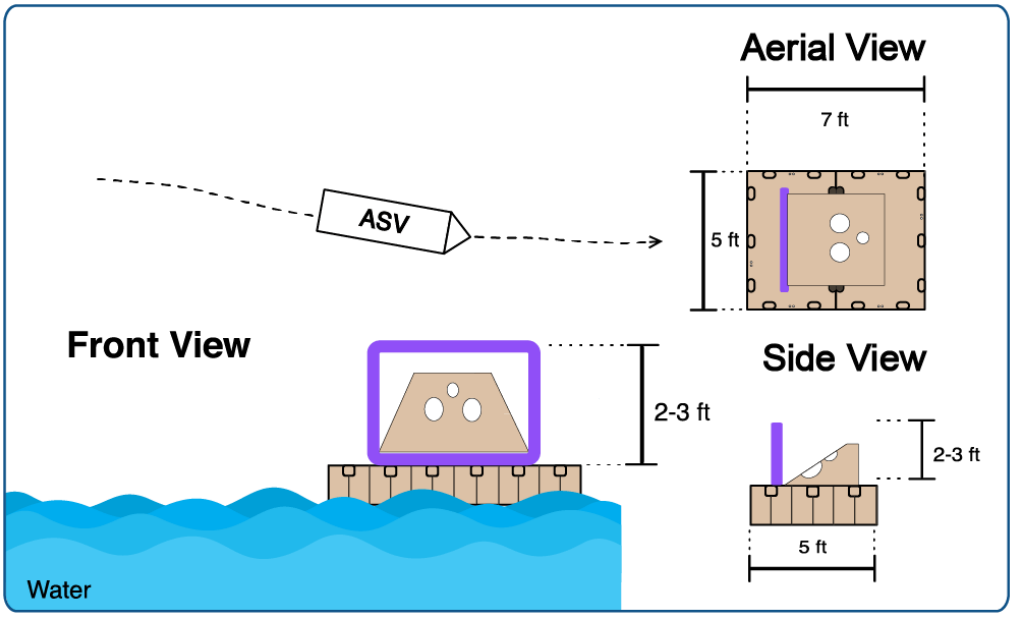



Figure 8: Example Skeeball Game Task

**Task Elements**

Final task dimensions and build plan will be provided at a later date.

### 2.5.5 Task 5 – Water Blast

The Water Blast task demonstrates the ability for the ASV to sense and interact while demonstrating percise control and aiming. The ASV must locate the target face of the task and deliver water through the center of it. The ASV must deliver enough water to raise the ball above the green line without making contact with the dock the task sits on. The ASV may pump the water from the environment versus storing it on board the vehicle.

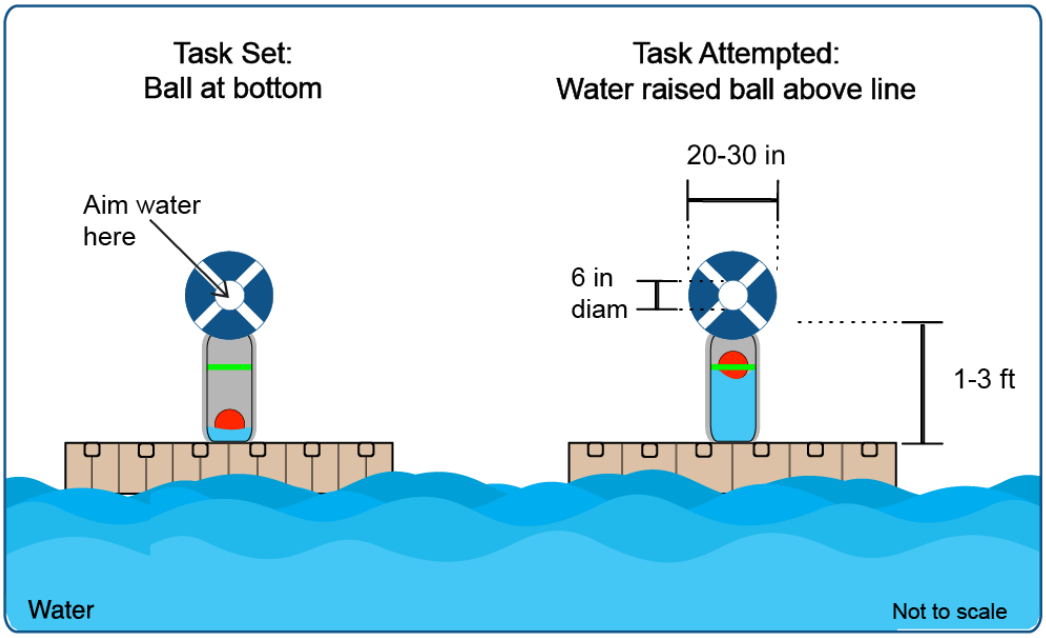



Figure 9: Example Water Blast Task

**Task Elements**

Final task dimensions and build plan will be provided at a later date.

### 2.5.6 Task 6 – Return to Home

The Return to Home task demonstrates the ability for the ASV to navigate back to the launch point while avoiding interaction with any obstacles.

The ASV returns to the dock in autonomous mode after attempting all Autonomy Challenge tasks. The ASV avoids all obstacles and task equipment (buoys, floating docks, etc.) on the way back. The ASV comes to a full stop within six feet of the dock from which the ASV launched.

## 2.6 Qualifying Round

Autonomy Challenge courses are available for teams to practice or qualify for the Semi-finals Round. The preliminary layout for the Practice Course will be provided at a later date.

## 2.7 Semi-Finals Round

More details on the Semi-Finals Round will be provided at a later date.

## 2.8 Finals Round

More details on the Finals Round will be provided at a later date.

# SECTION 3: Scoring & Awards



## 3.1 Scoring

Details of scoring, are in development. These will be provided at a later date. Scores are calculated by the judges; all decisions of the judges are final.

All teams that meet the minimum Qualifying Round requirements will be eligible to compete in the Semi-Finals Round. Upon completion of the Semi-Finals Round, the judges will announce the top-scoring teams who will progress to the Finals Round. The judges have the discretion to select the number of teams advancing to the Finals Round.

After the competition, the judges will issue overall standings. Any team accepted into the Finals Round will be ranked ahead of all teams that did not participate in the Finals Round.

## 3.2 Awards

Awards are provided in three categories: Design Documentation, Autonomy Challenge Final Standings and Judges' Special Awards.

### 3.2.1 Final Standings

Teams are awarded prize money reflective of their overall ranking after scores are calculated. The first-place teams receive a RoboNation champion banner.

### 3.2.2 Judges' Special Awards

Throughout the competition, judges and staff are always on the lookout for exemplary behavior from teams to acknowledge with special awards.

# SECTION 4: Rules & Requirements



## 4.1 Rules

1. Teams must build an ASV to compete and only enter one vehicle in the competition. (Section 4.3: Vehicle Requirements)
2. Teams that arrive at the competition failing to meet the vehicle requirements will not be permitted on the course, until the vehicle is modified to meet all requirements. (Section 4.3: Vehicle Requirements)
3. No combustion engines of any type may be used on the ASV.
4. Teams must be comprised of 75% or more full-time students. (Section 1.3: Eligibility)
5. One student member of the team must be designated as the "team lead". The team lead must be conversationally fluent in English. The team lead, and only the team lead, will speak for the team during the competition runs.
6. Team leads are required to attend daily team meetings conducted by the Technical Director. (Section 2.1: Schedule)
7. In-Person teams must remain onsite at the competition venue during the competition hours to be eligible for prizes.
8. Prior to entering the Autonomy Challenge courses, teams must demonstrate the ability to operate their ASV safely. (Section 2.4: Mandatory Activities)
9. At any point, the Technical Director Team may require a team to repeat the ASV Demonstration to re-deploy. (Section 2.4: Mandatory Activities)
10. Course boundaries are clearly identified. The ASV must stay within the course or task boundaries while attempting any tasks.
11. An Autonomy Challenge run will be terminated if the ASV interferes with course elements or crosses through a different course. This includes entangling, dragging, pushing, or damaging course elements or landscape.
12. All decisions of the judges are final.
13. RoboBoat organizers are not responsible for any damage to a team's ASV as the consequences of participating in the competition.

## 4.2 Safety

Safe operations are a priority for the RoboBoat staff. All considerations to maintain safety for operators and the surrounding environment must be made. These guidelines are the minimum requirements for all teams and their systems during the competition.

1. All Radio Frequency (RF) equipment must be operated within the rules and regulations of the host country. This includes, but is not limited to, frequency, transmitting power, antenna height, etc. This is summarized in Appendix D: Radio Communications Restrictions.
2. ASV power systems must follow the safety rules and regulations of the host country as well as the team's home country.
3. RoboBoat staff may suspend team operations at any time for safety considerations. The staff is not required to advise the team prior to the decision to terminate the run attempt. In all matters of safety, the decisions of the RoboBoat staff are final.

### 4.2.1 Safety Inspections

Before operating in the water, all systems must pass a safety inspection. This includes, but is not limited to:

1. A Safety Inspector completes a safety checklist, verifying successful operation of all safety features at each unmanned system launch.
2. Teams demonstrate compliance with all the requirements, to include identifying all actuators, and moving parts and their associated protection mechanisms (shrouds, etc.).
3. Verification of both kill switches' operation (remote and physical). This is repeated each time a team enters the water.

### 4.2.2 Battery Safety Requirements

Teams are required to understand and follow battery safety best practices on the battery chemistry selected by the team. Lithium-ion chemistry batteries may become damaged and create a hazard if misused/abused, representing the greatest risk to people, facilities, and the environment. The following safety rules and requirements must be followed:

1. Teams must submit battery specifications, Material Safety Data Sheets (MSDS), and proper disposal procedures, sourced from the battery manufacturer for all batteries.
2. Teams must keep a hard copy of the battery safety documentation for all batteries in Team Village (onsite) at all times, for reference.
3. Teams must bring a LiPo safe bag(s) adequate for the lithium batteries used. LiPo bag(s) must be available at the competition and the hotel.
4. Li-Po (Lithium Polymer) battery packs need cell level safety and balancing circuits and must be labeled HAZMAT when shipped.
5. Each team must understand and follow their own country's regulations as well as those of the host nation.
6. All batteries must be stored, used, and maintained in accordance with manufacturer guidelines.
7. Teams are required to inspect their batteries daily for signs of swelling, heat, leaking, venting, burning or any other irregularities.
    a. Lithium batteries that become too warm during use or have become swollen or malformed must be removed from use and reported to the Technical Director.
    b. Lithium batteries that do not hold a charge must be removed from use and reported to the Technical Director.
8. A team member must be present at all times to monitor charging batteries.
9. At the competition site, if any of the above battery conditions are observed students must immediately notify the Technical Director or RoboBoat staff and provide the battery specifications and safety information.
10. At the hotel, if a battery irregularity occurs at any time, students must notify RoboNation's Senior Events Manager, Cheri Koch immediately by phone at 850.642.0536 and provide the battery specifications and safety information.
11. Failed or failing Lithium-ion batteries must be handled in accordance with manufacturer's safety and disposal guidelines. In the absence of specific guidelines, batteries must be placed in a LiPo safe bag, which must then be placed in a bucket, covered with sand, and placed in a designated safety zone.
12. Teams cannot change or replace batteries when ASV is out of the water or while standing on floating docks.

### 4.2.3 Kill Switch (Emergency Stop) Requirements

The ASV must comply with the kill switch requirements detailed below. The ASV must have two emergency stop systems, also known as 'kill switches' or 'E-Stops'.

- On-Board: A hard-wired, on-board, emergency stop system.
- Off-Board: A wireless remote emergency stop, located off-board and on its own frequency and link.

Both systems must operate in a failsafe fashion (if any part of the system fails, system must enter emergency stop) and upon activation of either system (on-board or off-board), the switch must instantaneously disconnect power from the vehicle's thruster units. An example of how to implement this is shown in Figure 9. System should be designed such that power, to the thrusters, cannot be restored until the emergency switch is reset.

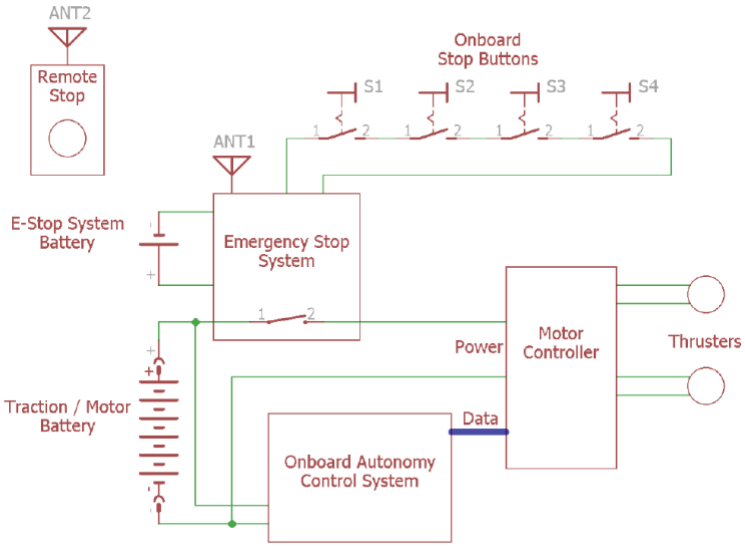



Figure 10: Example Emergency Stop Circuit

The Technical Director team will conduct a detailed engineering and safety inspection including a team demonstration of the proper operation of all emergency systems. Teams must be prepared to discuss the design and implementation of their fail-safe systems in detail, if requested.

**Onboard Emergency Stop System**

All ASVs must have an onboard emergency stop capable of being actuated by personnel from a support craft. For personnel safety, the switch may be triggered from a distance by a wooden or plastic pole/paddle. Keeping this in mind, teams should select rugged and reliable components for their safety system.

**Emergency Stop Button**

A large, red button should be installed in such a way that safety personnel, from the support craft can easily actuate the button. The engage/disengage button should be red in color and have a 'press to activate and twist/pull to reset' feature. This button, momentary contact switch or not, should cut power to the thrusters immediately on actuation. The thrusters must remain in a powered-down state until the judge gives permission for the team to reinitialize the system. An example of a suitable button is shown in Figure 11 and can be found at www.mcmaster.com.

Figure 11: Example Kill Switch

**Wireless Emergency Stop**

All ASVs must be equipped with a portable, handheld, Wireless Emergency Stop controller. This controller must immediately (less than 1 second) disconnect power to the vehicle's thruster units when activated. This system must also meet the host country RF guidelines for frequency and transmit power.

### 4.2.4 Visual Feedback System Requirements

Teams are required to implement a visual feedback system to clearly indicate the operational status of the ASV to improve the safety of RoboNation support operations. This lighting system serves as a visual status indicator for the ASV. Resources and general guidelines outlined here may be used by teams to acquire, integrate, and test a system that meets the RoboBoat safety requirements.

**Basic Requirements**

The lighting system shall consist of a minimum of three lights: red, amber / yellow, and green / blue. Lights must be in a vertically arranged 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 8. The lights may be flashing or steady on/off according to the state of the system.

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

Table 8: Light Color and Correlating Modes

Lighting systems can be purchased commercially or can be a custom array of RGB LEDs. Examples from previous competitions are shown in Figure 12. Design and selection of the final system is the team's decision.

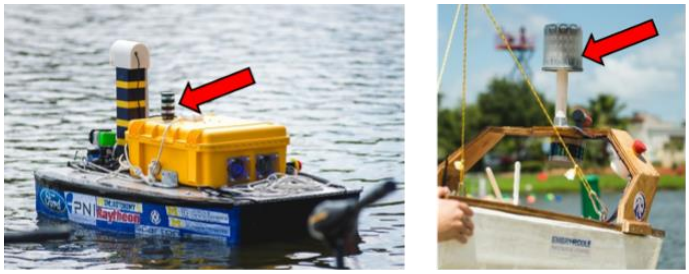


Figure 12: Example Visual Indicators
(Left – Commercial ; Right – Custom)

**Detailed Specification**

- The minimum height of the lighting systems must be 12.5cm.
- The maximum height and diameter of the lighting system are at the team's discretion and may be dependent on the number of additional lights included.
- Teams must procure lighting systems that are visible in sunlight and can be observable from the shore and the on-water support craft (approximately 150m). Teams should use lighting systems that have clear enclosures rather than colored enclosures with standard light bulbs. Generic versions of these lighting systems are used indoors on machines and equipment for status indication across several industries and are available globally.

## 4.3 Vehicle Requirements

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 the vehicle requirements will not be permitted on the course, until the vehicle is modified to meet all requirements.**

### 4.3.1 ASV 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).
- **Towable**: The vehicle must have a multi-point tow harness installed at all times to allow staff to attach a rope and tow the vehicle through the water. 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. (Section 4.2.3 Kill Switch Requirements)
- **Wireless 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. (Section 4.2.3 Kill Switch Requirements)
- **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.
- **Visual Feedback**: Teams are required to implement a visual feedback system, indicating status of their ASV. (Section 4.2.4 Visual Feedback System Requirements)
- **Weight**: The entire maritime system 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.

### 4.3.3 System Management & Monitoring Requirements

1. Each team's ASV must include an Operator Control Station (OCS) capable of controlling and monitoring the system.
   a. The OCS must have the ability to start and stop autonomous operations.
   b. The OCS must have the ability to remotely kill the platform as described in Section 4.2.3 Kill Switch Requirements
   c. The ASV must stop operating if it goes out of range from the OCS.
   d. Teams are responsible for providing robust and reliable communications between the OCS and ASV to attempt the Autonomy Challenge tasks.
   e. All shore-based equipment used by the team during in-water runs must be contained to the team's designated operating tent and table.
2. Teams are required to implement a clearly visible indicator on the ASV showing operational status. Specifications for a sample indicator are provided in Section 4.2.4 Visual Feedback System Requirements.
3. Teams are required to implement aand provide a graphical display for use by judges as described in the sections: Qualifying Round, Semi-Finals Round, Finals Round.

## 4.4 Obstacle Avoidance

The ability to avoid obstacles is a core capability for unmanned systems. Each buoy on the course represents an object to be avoided or approached in some way. In addition, obstacle buoys may be placed throughout the operating areas in an effort to provide a more representative real-world challenge.

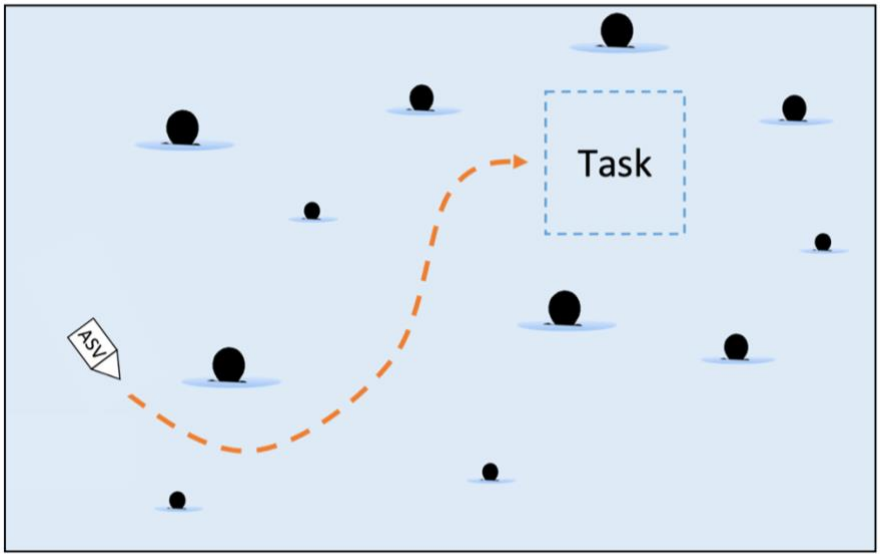



Figure 13: Obstacle Avoidance

# SECTION 5: How to Compete



## 5.1 Register and Intent to Compete

### 5.1.1 Intent to Compete

Before the RoboBoat 2022 Registration opens, teams are invited to complete an Intent to Compete form expressing intent to compete in the 2022 RoboBoat Competition. The Intent to Compete form is available on the RoboBoat website, RoboBoat.org/2022.

**SPECIAL OFFER:** RoboNation will provide a special BOGO (Buy One, Get One free) deal for RoboBoat 2022 teams to buy one 2022 registration fee, and get a FREE 2023 registration fee. Any RoboBoat team that completes the Intent to Compete form before registration opens will be eligible for the BOGO deal.

### 5.1.2 Register to Compete

All teams are required to register to compete using the Registration form found on the RoboBoat website, RoboBoat.org/2022. This registration collects each team's point of contact information, demographics, and the Pre-Competition Requirements outlined in Section 5.2.

**Registration Fees**

To complete the RoboBoat 2022 registration, teams must pay the registration fee. Teams who register early are eligible for the early-bird fee.

- Early-Bird Fee: $650 USD *(Register before February 13, 2022.)*
- Registration Fee: $750 USD

### 5.1.3 Data Sharing Access Requirements

During the registration process, teams must provide a generic email account and a team acronym that is used in the Data Sharing project (Section 5.6). The generic email can be associated with any email provider. An example of the Generic Email is: roboboat-team@outlook.com. The team acronym must be within 2-10 characters, abbreviating the team's school or organization. Examples of the team acronym are: RN or ROBOTEAM.

Access is given to teams that complete the Intent to Compete form and/or Registration form. Only official registered teams maintain access to the Data Sharing project for the RoboBoat 2022 season.

## 5.2 Pre-Competition Requirements

These requirements are collected prior to participation on-site at the competition, during the registration process.

### 5.2.1 Team Information Package

Teams are required to submit a team roster including all participants that support the RoboBoat 2022 effort, liability waivers, forms, and other contact information.

### 5.2.2 On-Site Requirements (In-Person Teams)

All In-Person teams are required to submit battery specifications, a COVID-19 plan, and a shipping plan.

**Battery Safety Requirements**
Teams are required to submit battery specifications, Material Safety Data Sheets (MSDS), and proper disposal procedures, sourced from the battery manufacturer for all batteries. More information can be found in Section 4.2 Safety.

**COVID-19 Team Plan**
Teams are required to submit a COVID-19 Plan prior to arrival. This plan must include:

1. Plan for isolating team members showing COVID-19 symptoms, including plans to obtain/pay for an additional hotel room / isolation area.
2. Plan for testing of team members showing COVID-19 symptoms or those having contact with COVID-19 positive team member.
3. Plan for quarantining team members testing positive for COVID-19, including contingency plans for extended stay until a negative test is received.
4. Emergency plan in case student is hospitalized for COVID-19. Must include:
   - Emergency contact info for all team members.
   - Health insurance / travel insurance information for each team member.
   - Plan for travel home once team member is released from medical care.

**Shipping Plan**
Teams are required to submit a shipping plan to facilitate shipment receipt/handling at the competition hotel. Shipping guidelines can be found in Section 5.4.3 Shipping. This shipping plan must include:

1. Box/Crate count (How many total boxes/crates are in the shipment?)
2. Weight of each box/crate
3. Dimensions of each box/crate
4. Name of shipping company used
5. Pick-up Address
6. Return Address
7. Name and contact information for Team Shipping Point of Contact
8. Battery specific provisions for shipments that include batteries.
   *(Note: Shipping guidelines for lithium batteries differ by country and by shipping company. Check with your shipping company to determine requirements for shipping new batteries vs. used batteries AND make sure that you are familiar with your shipper's facilities, operating hours, and requirements shipping your vehicle / batteries back home after the competition.)*

### 5.2.3 Design Documentation Package
Teams are required to submit the team website, technical design report, and skills video of their Design Documentation prior to being on-site at the competition. Guidelines can be found in Section 2.3 Design Documentation.

### 5.2.4 Video Demonstration (Online Teams)
Online teams showcase their vehicle performance through a video demonstration of autonomous completion of a range of behaviors. Instructions can be found in Section 2.4.1 Video Demonstration.

### 5.2.5 Optional Community & Outreach
Teams are invited to outline their educational outreach efforts. This activity is not scored; however, it will be shared online for the community and can be eligible for special awards and recognition. Teams may submit a description (500 word limit) of their activities and any supporting documents.

## 5.3 Timeline

| Date/Deadline | Event |
|---|---|
| June – January 2022 | Intent to Compete |
| January 26 – March 31, 2022 | Registration |
| April 24, 2022 | Pre-Competition Deadlines:<br>• Team Information<br>• On-Site Requirements (In-Person Teams) |
| May 15, 2022 | Pre-Competition Deadlines:<br>• Design Documentation<br>• Video Demonstration (Online Teams)<br>• Optional Community & Outreach<br>Full Refund Cancellation Deadline |
| June 20-25, 2022 | RoboBoat 2022 |

## 5.4 Logistics

### 5.4.1 Health and Safety

**COVID-19 Protocols and Local Guidance**
The Health and Safety of the RoboNation community is our number one priority. RoboNation follows all local and state health guidelines. We will continue to communicate with any changes to on-site protocols as we approach RoboBoat 2022. Please follow safety guidelines at work, at home, and in the community to help slow the spread of coronavirus.

Updated rules and restrictions for travel to and within Florida are available at the following websites:

- Sarasota County's COVID-19 website, scgov.net
- Florida's COVID-19 website, floridahealthcovid19.gov
- Domestic Travel in the United States, cdc.gov
- International Travel to the United States, cdc.gov

### 5.4.2 Travel + Lodging

Teams are responsible for coordinating their own lodging and travel plans.

**Lodging—Hotels**
Information on the selected event hotel and reservations will be released in future issues of this Team Handbook.

**International Travel**
*Invitation Letter* – During the registration process, international teams are given the opportunity to request an invitation letter issued by RoboNation.

*VISA Process* – It is recommended for international teams to acquire a B-1 Visitor VISA to attend the competition. However, if the team has plans for any other activities besides the competition, they may choose to investigate other types of visas. Explore the different types of visas: travel.state.gov.

### 5.4.3 Shipping

Additional shipping guidelines will be released in future issues of this Team Handbook.

**Equipment Arrival**

Teams should arrange shipments should arrive no earlier than 3 days prior to event.

**Equipment Outbound Pick-Up**

Teams should arrange shipments to ensure their package(s) is picked up / dropped off BEFORE the team departs to return home. RoboNation and the hotel staff are not responsible for ensuring that team's outbound shipment gets picked up.

### 5.4.4 On-site Logistics

**Team Village**

Each team is provided with a 10' x 10' working area in a tent that includes two tables / 6 chairs, one electrical outlet ( 120V 60 Hz 15A), and a wireless internet connection. The Team Village is a tent with sidewalls that resides on a flat grassy field surface. Although the covered workspace is weather resistant, teams are discouraged from leaving sensitive electronics/equipment exposed in the tent.

Teams should conduct development, maintenance, and repair of their systems in their designated area in Team Village. Batteries may be charged during the day at the Team Village but may not be left charging overnight.

**Team Course Operating Areas (Shoreline)**

Teams are provided with an area along the shoreline near the course areas where they are able to set up their shore equipment. Each course has a 10' x 10' tent-covered area with a single table per tent, 120V 60Hz 15A power, and a hard-wired Ethernet connection to the Technical Director network. The power provided is for Operator Control Station (OCS) use only and shall not be extended to any platforms on the beach. This space is shared between all teams utilizing the course.

**Power**

The United States uses a 120V 60Hz 15A electrical outlet plug. Usually three pins, two parallel blades (one wider than the other), and an offset semi-round pin. The wider blade is Neutral, the shorter blade is Hot/Line and the third pin is Ground.

Figure 14: US electrical outlets

**Vehicle Transit**
Teams must provide a cart to move the vehicle around the competition site.

- Cart must be manually propelled on site, no motorized carts.
- Cart's handle must be solid, no rope or chain.
- Cart's width must be less than thirty-six (36) inches.
- Carts are recommended to have six (6) inch (or more) diameter rubberized wheels.

Suggested carts: garden cart, available at homedepot.com; or dump cart, available at homedepot.com.

Figure 15: Example Vehicle Carts

**Vehicle Deployment and Recovery**
Vehicles are deployed and recovered in the water on their cart, using a portable rollout mat. The temporary walkway is similar to the Mobi-mat, available at shop.mobi-mat.com. The cart will get wet as it's submerged during deployment and recovery. RoboBoat staff are responsible for recovering any lost vehicles. All reasonable efforts to recover a lost vehicle will be made, but the recovery of a lost vehicle cannot be guaranteed. All teams recognize by entering the competition, they risk damage to, or the loss of, their vehicle.

**Open to the Public**
This event is open to the public. Consider the high possibility that a potential future employer or sponsor may also be there to observe the event.

## 5.5 Communications

### 5.5.1 Pre-Competition Communications

RoboBoat teams have a variety of opportunities to interact with each other and the RoboBoat staff.

**Team Time Meetings**
Leading up to the on-site competition, there are regularly held virtual meetings where teams are asked to have a team representative join. These Team Time meetings are hosted by the RoboBoat organizers and technical team to provide teams with competition updates and the opportunity to ask questions.

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

**Band App**
The RoboBoat Community in the Band App is used to keep registered RoboBoat teams updated on the latest announcements, resources, and special deals throughout the competition season. Each team member is encouraged to download the Band App (band.us), available on Android and iOS, and get to know the other RoboBoat teams. Access information is provided in the team registration process, outlined in Section 5.1 Register and Intent to Compete.

### 5.5.2 On-site Communications

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

**Technical Director Team**
The RoboBoat Technical Director Team consists of:

- Technical Director
- Safety Inspectors
- Course Managers

**Other RoboBoat Staff**
The RoboBoat Staff are identified with "Staff" on the back of their RoboBoat shirts.

### 5.5.3 RoboBoat Website

The official competition website is www.RoboBoat.org/2022. This website includes all official documents and a detailed list of the registered RoboBoat teams. Helpful resources, past competition results, and other engagement opportunities can be found on this website. Information and documents are updated regularly, and it is the team's responsibility to check the website for updates.

## 5.6 Data Sharing

A Data Sharing project has been established for registered teams competing in RoboNation's RoboBoat, RoboSub, and RobotX competitions. This project aims to increase collaboration between teams and to provide access to shared resources and test data to validate and debug the reliability and robustness of teams' machine vision algorithms. Access information is provided in the team registration process, outlined in Section 5.1 Register and Intent to Compete.

For more information on Data Sharing, visit the RoboNation Data Sharing website: RoboBoat.org/data-sharing.

# SECTION 6: Glossary & Acronyms



## 6.1 Glossary

| Phrase | Definition |
|---|---|
| **Practice Courses** | These courses are designed to provide opportunities to demonstrate proficiency in one task at a time. They contain an instance of each task. |
| **Team Lead** | Designated spokesperson for each team. |
| **Technical Director Team** | Technical team that runs the courses, safety inspections, set-up, and tear-down. |
| **RoboBoat Staff** | RoboBoat support personnel. |
| **Judge** | Subject Matter Experts that observe and score the Autonomy Challenge and Design Documentation. |
| **Sponsor** | Organizations that provide support to RoboBoat. |

## 6.2 Acronyms

| Acronym | Definition |
|---|---|
| **ASV** | Autonomous Surface Vehicle |
| **N/A** | Not available |
| **OCS** | Operator Control Station |
| **RGB** | Red, Green, Blue |
| **RF** | Radio Frequency |
| **TD** | Technical Director |
| **TDR** | Technical Design Report |

# Appendix A: Technical Design Report (TDR)



## A.1. Paper Preparation Overview

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 below.

## A.2. Format

The format of the written paper shall adhere to the following guidelines:

- **5 page limit (excluding References and Appendices)**
- 8.5 x 11 in. page size
- Margins ≥ 0.8 in.
- Font: Times New Roman 12pt
- Header on every page including team name and page number
- Submitted in .pdf format

Access all past competitor's papers on the Past Teams' page, roboboat.org/past-programs. (Click on the year you'd like to view and scroll down to the team section.)

## A.3. Paper Contents

The written paper consists of six mandatory Sections and one mandatory Appendix. Additional sections may be included; however, the overall limit of 10 pages applies (excluding References and Appendices). In general, the editorial style for IEEE Conference Proceedings should be followed: www.ieee.org/conferences/publishing/templates.html. The two-column format is optional. We recommend that papers be peer-reviewed prior to submission. You can utilize resources at your institution, teams entering other RoboNation competitions, or on the community forum for this peer-review. Professional editing services are also available: secure.aje.com/en/default/submitb/select.

### A.3.1 Abstract

The abstract is a short summary of the main points in the paper. The paper should primarily describe the linkage between your overall competition strategy and your system architecture, design and engineering decisions.

### A.3.2 Competition Strategy

This section should discuss how the team plans on approaching the course and how the vehicle design relates to this approach. The course consists of multiple tasks with associated points for accomplishment. The only required task is passing through the start gate. Other tasks are optional and can be attempted in any order. The more tasks a vehicle is designed and engineered to accomplish, the more complex the overall vehicle system will be. The discussion should include the team's consideration of the trade-offs between system complexity and reliability. For example, teams have a limited number of working hours to prepare for the competition; this time could be spent adding additional capabilities or testing and improving the reliability of an existing capability. As system complexity grows, changes in subsystems can propagate in unmanageable ways when time is limited. Clearly, the goal of a competition is to score more points than the other teams. There are many ways to do this. Studying past

competitions may be instructive. Based on history and the system engineering talents of your current team, describe your strategic vision.

### A.3.2 Design Creativity

Given your strategy for winning and your approach to managing complexity, describe the creative aspects of your system. Novelty may occur at component, subsystem, and/or integrated system levels. Describe your experience in making both architectural/design decisions and system engineering decisions. This section should **not** include detailed component descriptions and/or specifications not of original design. The latter should be described in the TDR Appendix A.

### A.3.2 Experimental Results

This section should describe various tests planned and/or accomplished to date, both in-water and in simulation. There is a strong correlation between in-water testing time and competitive performance in the arena. Given unique challenges leading up to this year's competition like the global Covid-19 pandemic in addition to typical student time constraints, balancing creative design and system engineering with testing and experimentation can be a challenge. How did your team estimate the amount of testing required to meet your reliability goals? How did/sill you balance the demands of design and engineering with those of testing and experimentation?

### A.3.2 Acknowledgements

Participating in the competition, as in all research projects, involves marshalling resources and support beyond the efforts of individual team members. This support can take many forms, such as technical advice, labor, equipment, facilities, and monetary contributions. Acknowledging those who have underwritten your efforts is important.

### A.3.2 References

As with any technical publication, original ideas and content not generated by the paper's authors should be properly cited. While there are many citation styles, the IEEE Conference Proceedings style should be used, found on the following link: www.ieee.org/conferences/publishing/templates.html.

### A.3.2 Appendix A: Component Specifications

In the past, detailed descriptions of components constituted the bulk of many written paper submissions. Such detail often distracts from understanding the team's underlying strategic thinking, design and engineering decisions, or novel contributions. Teams should list and indicate the "status" of components selected/purchased/installed for the vehicle in the table below. Where components were developed by the team versus purchased off the shelf, this information should be included. Also, if commercial off the shelf equipment was significantly modified this should be noted. This standardized table will help document and track trends in component (hardware and software) usage and team metrics. Under the column marked "Specs" you may provide a web link to the manufacturer's specifications. The form below is generic and you should report all components you have included in your vehicle design.

| Component | Vendor | Model/Type | Specs | Cost (if new) | Status |
|---|---|---|---|---|---|
| ASV Hull form/platform | | | | | |
| Waterproof connectors | | | | | |
| Propulsion | | | | | |
| Power system | | | | | |
| Motor controls | | | | | |
| CPU | | | | | |
| Teleoperation | | | | | |
| Compass | | | | | |
| Intertial Measurement Unit (IMU) | | | | | |
| Doppler Velocity Logger (DVL) | | | | | |
| Camera(s) | | | | | |
| Hydrophones | | | | | |
| Aerial vehicle platform | | | | | |
| Motor and propellers | | | | | |
| Power system | | | | | |
| Motor controls | | | | | |
| CPU | | | | | |
| Camera(s) | | | | | |
| Autopilot | | | | | |
| Algorithms | | | | | |
| Vision | | | | | |
| Acoustics | | | | | |
| Localization and mapping | | | | | |
| Autonomy | | | | | |
| Team Size (number of people) | | | | | |
| Expertise ratio (hardware vs. software) | | | | | |
| Testing time: simulation | | | | | |
| Testing time: in-water | | | | | |
| Inter-vehicle communication | | | | | |
| Programming Language(s) | | | | | |