robosub

Logarithmic Spiral

2024

TEAM HANDBOOK

Version 2.0 (July 2024)

Introduction

Welcome to the RoboSub Competition!

This Team Handbook contains information needed to compete at the RoboSub 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.

Why compete in RoboSub? RoboSub is an international student program established to generate, cultivate, and enhance a community of innovators by challenging new generations of engineers. Student teams tackle fundamental challenges in the design of ocean systems, while getting hands-on experience by designing, building and testing a fully autonomous underwater vehicle (AUV). By providing a venue and mechanism to share knowledge and innovate, students are primed for jobs in developing, testing and managing state-of-the-art systems. Teams must also document their designs.

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.

Why robotics competitions? The goals of the RoboNation student competitions are to provide opportunities for students to experience the challenges of system engineering, to develop skills in accomplishing realistic missions with autonomous vehicles, and to foster relationships between young engineers and the organizations developing and producing autonomous vehicle technologies. The objective is to produce the people who will push the envelope in the future. Competitors gain an appreciation for the tradeoffs inherent in any system design and the lessons learned in transitioning from a working bench prototype to operating reliably in the real world.

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

ROBOSUB ORGANIZERS

The 2024 RoboSub Competition is hosted by RoboNation.

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Version Updates

Version	Changes	Date
V1	First release of RoboSub 2024 Team Handbook.	08 June 2024
V2	• 2.2.2 Added a scoring breakdown for design presentations and system assessments. • 2.4 Updated orientation of the courses, all launching on same side. • 2.4.6 Added clarification on “far torpedoes” for Mapping • 2.5 Added new section with vehicle launch/recovery operations and expectations • 3.1.2 Modified wording in scoring for fixed heading to “maintain control”	30 July 2024

Table 1. Document Version Log

SECTION 1: RoboSub Overview

1.1 Dates & Venue

The 2024 RoboSub Competition (RoboSub 2024) will be held 5-11 August 2024 at the Woollett Aquatics Center in Irvine, California, USA.

1.2 Mission and Theme

The ocean provides new discoveries in geology, biology, and archaeology while permitting scientific exploration of the seafloor. Our ocean regulates our climate and weather patterns, it provides goods, services, food, medicine and recreation. It provides benefits to our planet and all the creatures that live here.

The fundamental goal of the mission is for an Autonomous Underwater Vehicle (AUV) to demonstrate its autonomy by interacting with various tasks. Orange path markers help direct the AUV to the beginning tasks. Acoustic pingers guide the AUV to the remaining tasks. The AUV is able to interact with these tasks:

- *Rough Seas* (Coin Flip)
- *Enter the Pacific* (Gate)
- *Hydrothermal Vent* (Buoys)
- *Ocean Temperatures* (Bins)
- *Mapping* (Torpedoes)
- *Collect Samples* (Octagon)

1.3 Competition Structure

RoboSub includes the (1) Autonomy Challenge that demonstrates autonomous performance and safety; and (2) Design Documentation that presents each team's work and vehicle design.

1.4 Eligibility

Student teams from anywhere in the world are eligible to participate. All teams must build an AUV to compete and may enter one or two vehicles in the competition. *

**__First-year teams__ are eligible to participate in RoboSub without an AUV. These teams are expected to participate in Design Documentation and send representatives on-site at the event as a learning experience. First-year teams are expected to indicate this option in their registration form.*

1.4.1 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 AUV.
- 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.

1.5 Points of Contact

RoboSub Questions:	Registration Questions:	Technical Questions:	On-Site Logistics/Safety:
autonomy@robonation.org	support@robonation.org	robosub.org/discord	events@robonation.org 850.642.0536

SECTION 2: Competition

This section includes important competition details including an overview of the competition schedule, design documentation criteria, and autonomy challenge course and tasks.

2.1 Competition Schedule At A Glance

The competition includes:

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

See Appendix A: Competition Schedule for the detailed competition schedule.

Date	Event	Location
24 June	Design Documentation (prior to on-site competition)	Online
05 August (afternoon)	Team Check-in / Orientation *All teams are required to attend with at least one representative.*	Hilton Irvine / Orange County Airport
06-08 August	Vehicle Assembly + Safety Inspections Practice & Qualification Attempts Design Presentations + System Assessments	Woollett Aquatics Center
09-10 August	Semi-Finals Round Wild Card	
11 August	Third Chance / Finalist Practice Runs Finals Round Awards	

Table 2. RoboSub Schedule At A Glance

2.2 Design Documentation

Prior to the on-site competition, teams are required to develop and submit (1) team website, (2) technical design report, and (3) team introduction video. On-site at the competition, teams are required to conduct an oral presentation and system assessment by subject matter expert judges.

2.2.1 Delivered Prior to On-Site Competition

The following design documentation is delivered prior to the on-site competition. Instructions on how to submit deliverables can be found in 5.2 Pre-Competition Requirements. Deadlines can be found in 5.3 Timeline. Teams are encouraged to refer to the past top-scored deliverables: robosub.org/past-programs.

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 must include:

- Current team name and contact information
- Vehicle photos and/or videos
- Supporting media, which may include:
  - 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

Team Website Scoring Metrics *(Total Maximum Points: 180)*

The website submission is worth a total of 180 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Team Information *(20% of score)*

Outstanding	Team website includes all required team information, including the team's name and contact information, and a list of team members and sponsors. All mentions of the vehicle are relevant to the current competition year.
Strong	Team website provides a brief introduction to the team, team members and sponsors. There is supporting media on the vehicle.

Continued on next page

Average	Team website introduces the team and/or team members.
Below Average	Team website provides little to no information on the team. There is no mention of the vehicle.
Requirements Not Met	The required team information is not included on the website.

Vehicle Design Documentation *(40% of score)*

Outstanding	Vehicle development and testing process is thoroughly documented with instructional and informative supporting media and historical recording. This could include photographs, diagrams, videos, procedures (text + images), design documentation (text + images + video), or blogs for historical records.
Strong	Good documentation on vehicle development and testing process is provided. Supporting media is accessible.
Average	Vehicle development and testing process is adequately presented with some evidence of supporting media.
Below Average	Few pictures or videos of the vehicle, but no instructional or informative documentation included.
Requirements Not Met	No visuals or documentation of the vehicle is available on the website.

Website Quality *(40% of score)*

Outstanding	Website places a heavy emphasis on human factors. Layout is visually appealing, easily maneuverable, and does an excellent job of drawing user's attention to relevant content.
Strong	Website considers user experience. Layout does a good job of drawing user's attention. Users can navigate the site easily and quickly.
Average	Website quality was adequate. Users can navigate the site to find most information.
Below Average	Layout and/or design makes it difficult to find information. Website does not have a user-friendly display.
Requirements Not Met	Website is busy and difficult to read; no guidance on maneuvering site.

Technical Design Report (TDR)

Teams are required to submit a technical design report in English that describes the design of their AUV 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. Requirements and scoring metrics for this report are outlined in Appendix B: Technical Design Report.

Team Introduction Video

Teams are required to create a video introducing their team members and highlighting their team personality. This video is meant to be a creative showcase of what makes each team unique, such as the mission of the team or the team culture. Teams should consider this video as an "elevator pitch" or project proposal for an opportunity to earn additional funding or support.

Format Requirements:

1. Video must be conducted in English or include subtitles in English.
2. Video must be no more than three (3) minutes in length.
3. Video may include graphics, vehicle performance, and/or simulation.
4. Videos must be hosted by team. Teams have the choice of hosting on YouTube or on their Team Website. The video must follow YouTube Rules & Policies, including appropriate music copyright management.

Team Video Scoring Metrics *(Total Maximum Points: 120)*
The team video submission is worth a total of 120 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Formatting *(10% of score)*

Strong	All formatting guidelines are followed. Video is conducted in English or includes English subtitles, video is no more than 3 minutes in length, and video is hosted on the team's website or YouTube channel.
Requirements Not Met	Video does not follow formatting requirements.

Video Quality *(20% of score)*

Outstanding	Visuals immediately draws attention. Overall, the video is solid in frame (not shaky), correctly lighted, in precision focus, appropriately segmented, and visually clear in all respects. Transitions between segments are clear and smooth. The video is less than 3 minutes total runtime.
Strong	Good visual impression. Majority of video is clear, adequately lit, and places people and objects in recognizable scale and perspective. Video segments are generally of the appropriate length, transition well, and are related to each other. Use of video effects is good. Runtime is less than 3 minutes.
Average	Video quality is satisfactory.
Below Average	Frames and segments are shaky, distracting or poorly lit. Some segments are out of focus. Some heavy shadows are obscuring viewpoint. Visual effects are distracting rather than informative. Video exceeds 3 minutes in length.
Requirements Not Met	No focus on visual quality. Video exceeds 3 minutes in length.

Information Organization *(25% of score)*

Outstanding	Video is a complete introduction of the team makeup including team members, sub-teams, activities, mentors, and major sponsors. Organization of video information is logical and compelling.
Strong	The viewer is left with good understanding of the information shared in video.
Average	Video information is somewhat scattered throughout video, leaving the viewer lacking complete understanding of project.
Below Average	Video provides incomplete information regarding the team members, activities, or progress. The information presented is extraneous, confusing, or low quality.
Requirements Not Met	No organizational strategy is apparent.

Clear and Effective Communication *(25% of score)*

Outstanding	Effective and compelling use of video medium to communicate the introduction of the team. Easy for non-technical viewer to understand and support. [You're left wanting to learn more.]
Strong	Exhibits moderately compelling use of video medium to communicate the introduction of the team. Strong potential, moderately compelling, mostly understandable to non-technical viewer. [You're left strongly considering to learn more.]
Average	Adequately uses the video medium to introduce the team. Not difficult to understand, but not compelling either.
Below Average	Exhibits some ability to use video to attempt to introduce team and project overview. Difficult for viewer to understand and/or was not compelling. [You're left unenthused.]
Requirements Not Met	Poorly used video medium to convey team introduction. Information was as not clearly understood and was not compelling. [You're left with little information.]

Creativity *(20% of score)*

Outstanding	Team creativity and enthusiasm is clearly evident in the video. Appropriate use of humor is understated and well done. Video captures user's attention without diminishing or obscuring the information delivered. Effects of careful post-production editing are clear.
Strong	Some creativity has been used throughout video. The visual style and tone are consistent throughout video.
Average	Exhibits a moderate attempt at creativity.
Below Average	Little attempt made to include creative or imaginative ideas in video. Poor visual effects and enthusiasm for the project.
Requirements Not Met	Little imagination or creativity is evident in production. Information is presented lacking enthusiasm.

2.2.2 Delivered During On-Site Competition

Design Strategy Presentation

Teams are required to give a design strategy presentation to a panel of subject matter expert judges. The goal of the presentation is to share the team's system design approach to the challenges presented in the Autonomy Challenge, specifically the capabilities required for each task. The presentation should include:

- a concise description of the team's strategic vision, and
- how the vehicle design compliments the team's goals.

This oral presentation must be conducted in English and may include visual aids (i.e. digital slides, poster board). If digital slides are used, teams must provide their own computer and adapters for an HDMI connecter to use the presentation display monitor. Teams receive an assigned 15-minute presentation time. Please find the latest presentation schedule here: robosub.org/2024. This presentation includes:

- Team presentation – 10 minutes
- Judges' question and answer – 5 minutes

Design Presentation Scoring Metrics *(Total Maximum Points: 180)*
The design presentation is worth a total of 180 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Competition Strategy *(30% of score)*

Outstanding	Presentation includes a concise description of the team's strategic vision and how the vehicle design compliments their goals. The team clearly explains how they developed their competition strategy.
Strong	Presentation describes their competition strategy and how their vehicle design aligns with meeting their competition goals.
Average	Presentation includes a brief overview of how the vehicle design aligns with the team's competition strategy and goals.
Below Average	Team mentions a competition strategy but no additional details on how it was developed or how it led to their strategic vision.
Requirements Not Met	Team does not mention their competition strategy, vision or how their vehicle design is aligned with vision.

Design Rationale *(30% of score)*

Outstanding	Team presents their design process and how their decisions relate to their overall competition strategy. Lessons learned from testing or previous competition experience are described, including application throughout the design process.
Strong	Presentation includes a description of the team's design process and includes narrative on how testing or previous experience influenced vehicle design.
Average	Team describes the rationale behind the vehicle design process.
Below Average	Presentation includes mention of the design process, lacking a clear rationale of design choices.
Requirements Not Met	No mention of the team's design process or the rationale behind the design process.

Effective Communication & Professionalism *(20% of score)*

Outstanding	Presentation materials and team members' knowledge are effective and support the team's message. Team members are engaging, respectful, and professional, while interacting positively with the judges and each other.
Strong	Presentation materials are presented in a professional manner and support the team's message. Presentation is well prepared and appears to be rehearsed in advance.
Average	Presentation materials are presented in a mostly professional manner and support the team's message.
Below Average	Presentation materials and styles are adequate but less than engaging.
Requirements Not Met	The message was not effective, and the presentation was not organized.

Judge Questions & Dialogue *(20% of score)*

Outstanding	The team effectively uses evidence, experience, and research from their project to inform responses to all questions and discussion posed by the judges.
Strong	The team responded professionally and knowledgeably to judges' questions.
Average	The team responded adequately to most or all of the judges' questions, mostly interacting with courtesy and professionalism.
Below Average	The team did not provide sufficient answers to the judges' questions and interacted with minimal courtesy and professionalism.
Requirements Not Met	Team members were not able to respond to many or all questions and did not take the initiative to engage in dialogue with the judges.

System Assessment

Judges inspect the team's ASV and assess technical design, technical innovation, and craftsmanship of the design. Team members should be present to answer technical questions posed by the judges during this inspection and be prepared to explain their design strategy and how decisions made impacts on the technical design, functionality, and craftsmanship.

Teams receive an assigned 15-minute slot. After the assessment, teams should make themselves available for a team photo and optional video interview. Please find the latest schedule here: robosub.org/2024.

System Assessment Scoring Metrics *(Total Maximum Points: 180)*

The system assessment is worth a total of 180 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Technical Design *(45% of score)*

Outstanding	Design and implementation of systems and subsystems are well aligned with team's strategy, design decisions, and engineering principles. Clear and thoughtful design choices are evident in the technical functions, key decisions, and testing regimen.
Strong	Good and knowledgeable rationale and execution of design selections made, aligning with team's strategy, design decisions, and engineering principles.
Average	Adequate explanation of technical design decisions, equipment selections, and testing regimen, mostly evident in the vehicle and subsystems.
Below Average	Rationale of technical design is briefly covered with minimal alignment with team's strategy, design decisions, and engineering principles.
Requirements Not Met	Design and implementation of systems and subsystems are not aligned with team's strategy, design decisions, and engineering principles.

Innovation *(30% of score)*

Outstanding	Full system demonstrates creative and innovative solutions by applying existing technology in novel ways within the system, using existing technology in a previously unintended way, or creating new technology or products incorporated into the system.
Strong	Clear evidence of innovative approaches across multiple sub-systems. Research and testing were conducted throughout the development process.
Average	There is moderate evidence that creative and innovative solutions were incorporated into system to improve performance.
Below Average	Little evidence of creativity or innovation in design choices throughout the system.
Requirements Not Met	No technical innovation noted.

***Craftsmanship** (25% of score)*

Outstanding	System is assembled with exquisite care and thoughtful attention to detail and aesthetics. Construction and improvisations are neatly executed to maintain high levels of functionality, durability, and adherence to the team's design philosophy. Any vehicle adornment demonstrates creativity, originality, etc.
Strong	System is assembled with care and attention to detail and aesthetics. Construction and improvisations maintain acceptable levels of functionality, durability, and adherence to the team's design philosophy.
Average	System is assembled to execute acceptable levels of functionality, durability and adherence to team's design philosophy.
Below Average	Minimal evidence that system is assembled with care and attention to detail and aesthetics. Adherence to team's design philosophy is vague and unclear.
Requirements Not Met	Evident hazards or potential hazards throughout the system. The system was assembled with minimal care and attention to detail. Little to no attention to aesthetics.

2.3 Mandatory Activities

Before entering the Autonomy Challenge courses, teams must demonstrate their AUV adheres to the vehicle requirements outlined in 4.3 Vehicle Requirements, and the ability to safely control their AUV with the following mandatory activities.

Static Safety Inspection

Before operating in the water, all systems must pass a safety inspection by the Technical Director (TD), as outlined in 4.2 Safety Inspections. The TD may disqualify any vehicle that is deemed unsafe. The system requirements are listed in 4.3 Vehicle Requirements.

Weight Measurement

Vehicles are weighed before each semi-finals and finals run. Teams transport the vehicle on their cart to the scale for weight measurement. **Error! Not a valid bookmark self-reference.** shows the bonuses and penalties associated with a vehicle's weight in air.

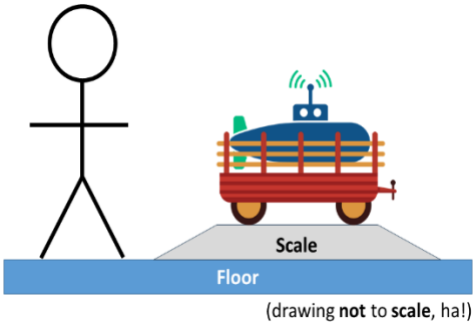

Figure 1: Example Vehicle Weight Measurement

Table 3: Vehicle weight in air with Bonus or Penalties

	BONUS	PENALTY
AUV Weight > 125 lbs (56.7 kg)	N/A	Disqualified!
125 lbs ≥ AUV Weight > 84 lbs (38 kg)	N/A	Loss of: 250 + 5*(lb – 125) 250 +11*(kg – 56.7)
84 lbs ≥ AUV Weight > 48.5 lbs (22 kg)	Bonus: 2*(84 - lb) 4.4*(38 - kg)	N/A
AUV Weight ≤ 48.5 lbs	Bonus: 80 + (48.5 - lb) 80 + 2.2*(22 - kg)	N/A

2.4 Task Descriptions

This section provides details of the RoboSub Autonomy Challenge tasks. Teams are encouraged to develop a strategy approaching these tasks that best suits their AUV. The launch point, gate, or any of the tasks are placed such that no three elements are along a line.

Figure 3: RoboSub Course Layout & Dimensions

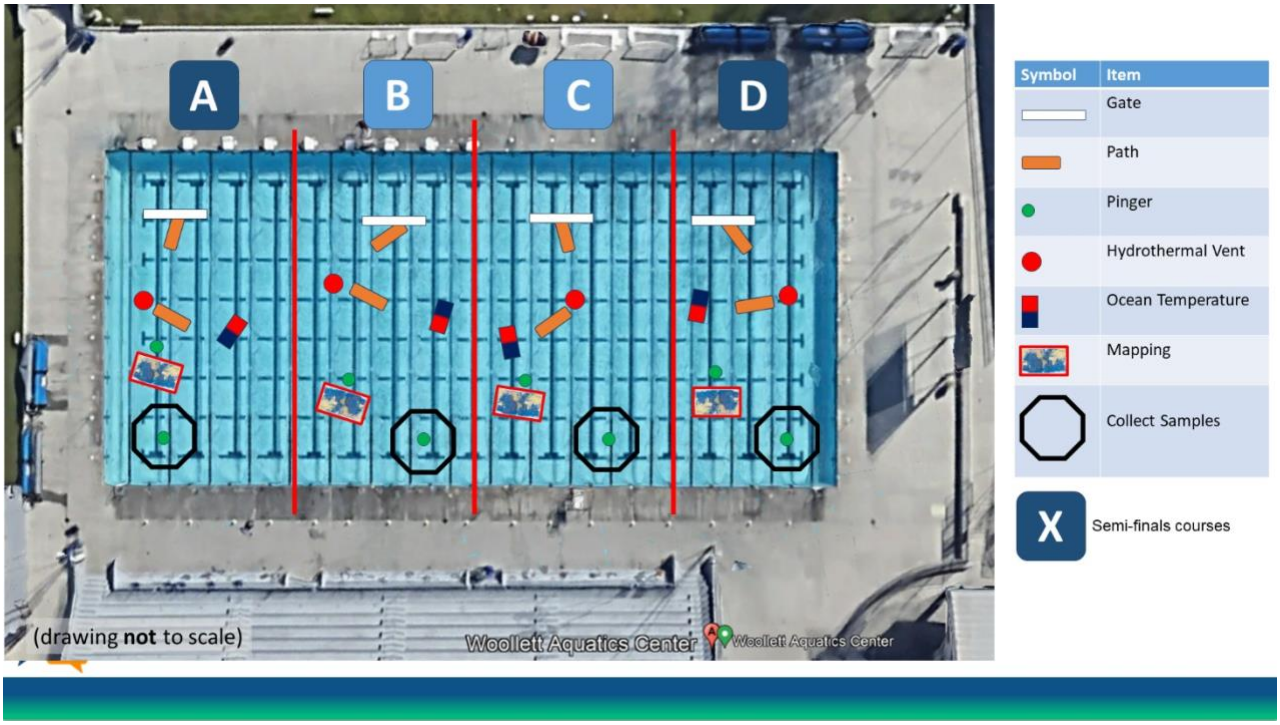

Figure 2: Example Practice and Semi-finals course layout

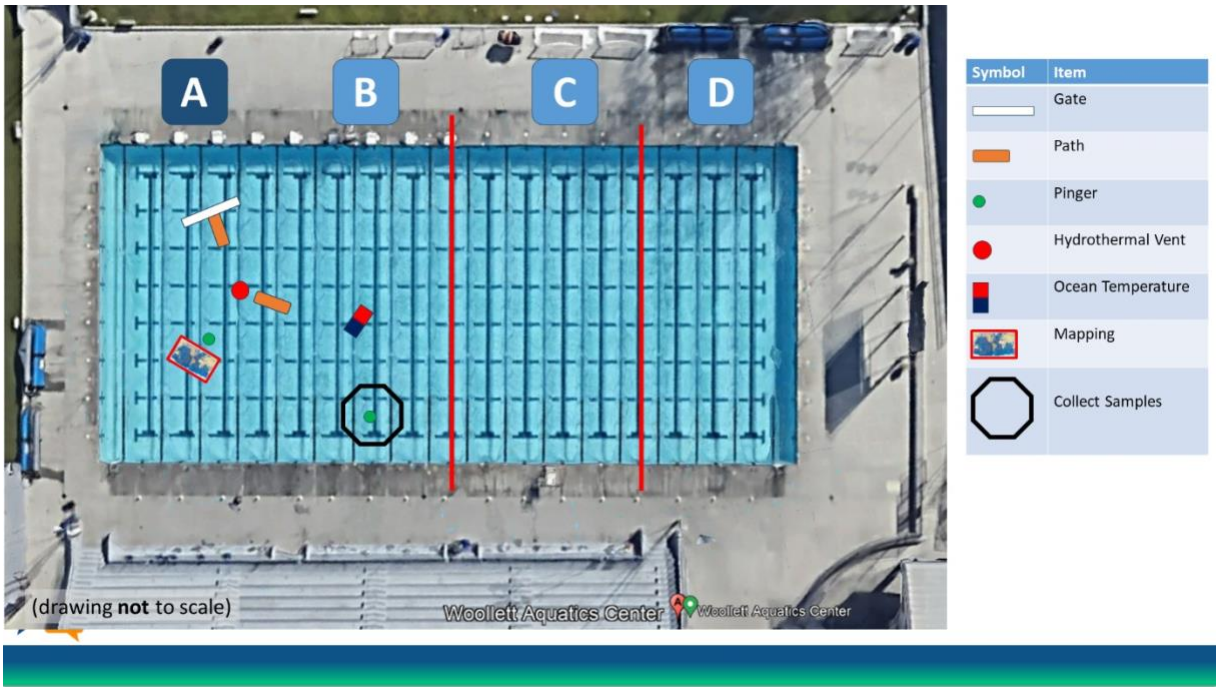

Figure 4: Example Finals course layout

2.4.1 Rough Seas—Coin Flip

From the starting location, a team may point their AUV in any direction. Before the start of a run, and for additional points, teams may request a coin flip which determines the heading of the AUV for the start. If the coin lands on **Heads,** the AUV is positioned ~parallel to the gate. If the coin lands on **Tails**, the AUV is positioned so its tail is ~pointed toward the gate (the AUV is backward).

When starting a run, the AUV must *submerge* first and then either head toward the gate or rotate to align with the gate and then head toward the gate. AUVs that do not submerge first do not receive the extra points.

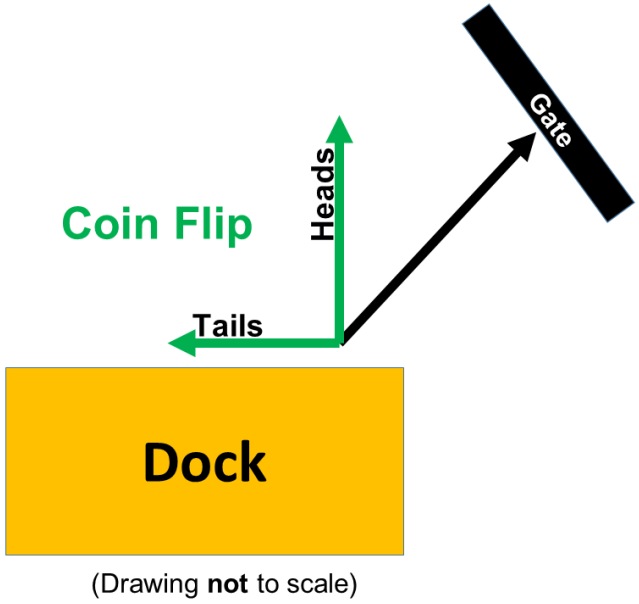

Figure 5: Rough Seas

2.4.2 Enter the Pacific—Gate

The validation gate is composed of PVC pipe and 3-inch boxes made from corrugated plastic sheet. It is buoyant, floating just below the surface and moored to the bottom. The boxes are colored **BLACK** and **RED**. **RED** is on top on the right-hand side (Red, Right, Above). The AUV can pass through the gate at any depth from the floor to just below the gate.

A 2-inch **RED** corrugated flat sheet is used to divide the gate in half. **Cold**/CCW on one side (could be either side), **Hot**/CW on the other. The AUV chooses a temperature/rotation by passing under a specific side.

Teams can gain extra points by passing through the gate with "style". For every 90° change in orientation, the AUV increases the accumulated points. However, returning to the last previous orientation won't count. I.e. an AUV that rolls 90° and then back to 0° would not get points. Roll and Pitch are worth more than Yaw.

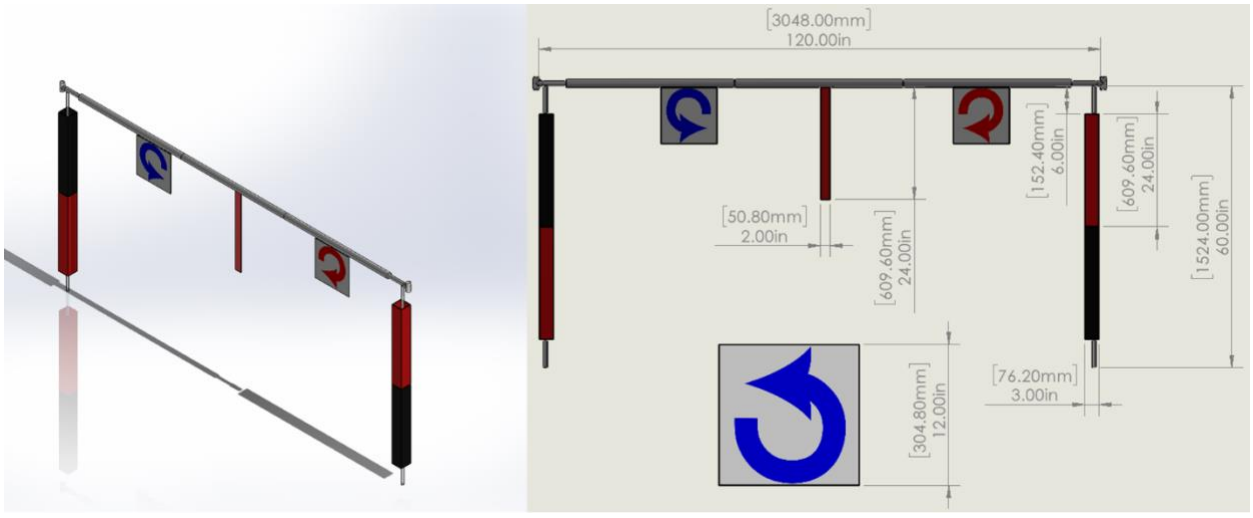

Figure 6: Enter the Pacific

Task Element	Description	Color	Base Dimensions
Gate	¾", ½" PVC, Foam, 3 in. Box Corrugated plastic	White / Black/ Red	120" x 60"
Gate Divider	2" Flat plate	Red	24"
Cold	CCW Blue Arrow	Vinyl print	12" x 12"
Hot	CW Red Arrow	Vinyl print	12" X 12"

2.4.3 Path

The path markers are ~4 feet (~1.2m) long by 6 inches (15cm) wide. The path is colored **ORANGE**. Each path marker is placed directly after the current task and points to the next task. The path is a straight segment. No points are awarded for following the path, the path is intended to help guide the AUV to the next task.

There are two path markers to aid in navigation. One path marker is positioned at the gate that points to the *Hydrothermal Vent* (buoy) task. From *Hydrothermal Vent*, the second path points to *Ocean Temperature* (bins). Those are the only path segments which can be used to visually orient the AUV to the next task.

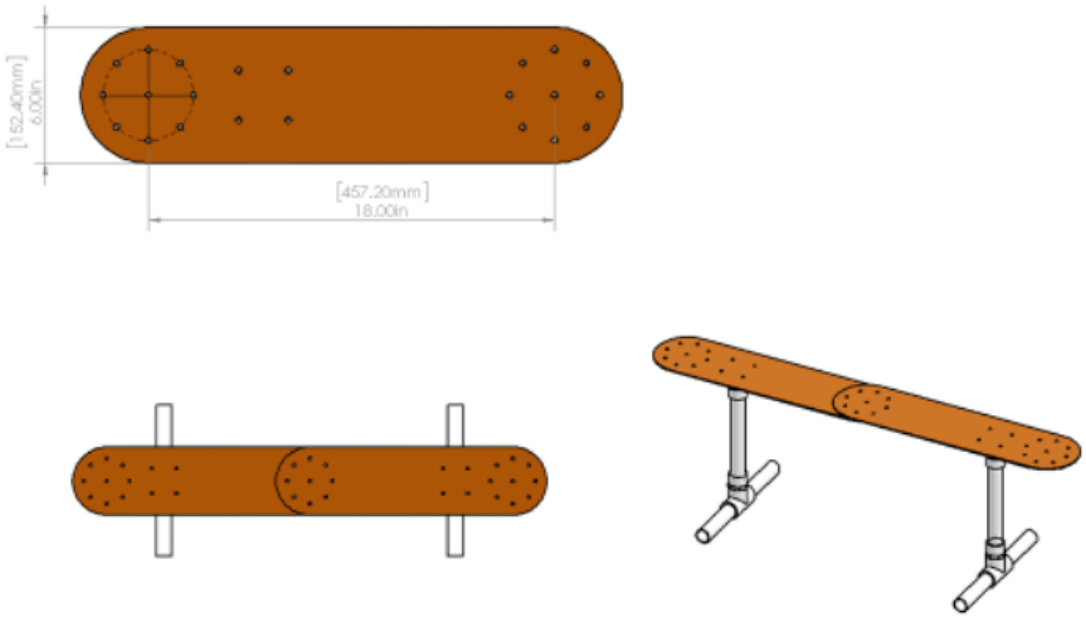

Figure 7: Path markers

Task Element	Description	Color	Base Dimensions
Path Markers	Orange plates on PVC stand	Orange	24” x 6”

2.4.4 Hydrothermal Vent—Buoy

The single red buoy is moored to the floor.

Partial points are awarded if you track the buoy but you brush by, instead of a deliberate bump. Full points for touching the buoy and tilting it at least 10°. Manipulation of only the rope holding the buoy will not count for points (even if you touch the buoy after touching the rope). More points are awarded for circumnavigating around the buoy in the correct direction. Vehicles must do one or the other (touch **or** circumnavigate). A vehicle that touches the buoy cannot also get points for circumnavigation.

An AUV is also able to accumulate points for firing torpedoes at the buoy. Full points are awarded when the torpedo strikes the buoy.

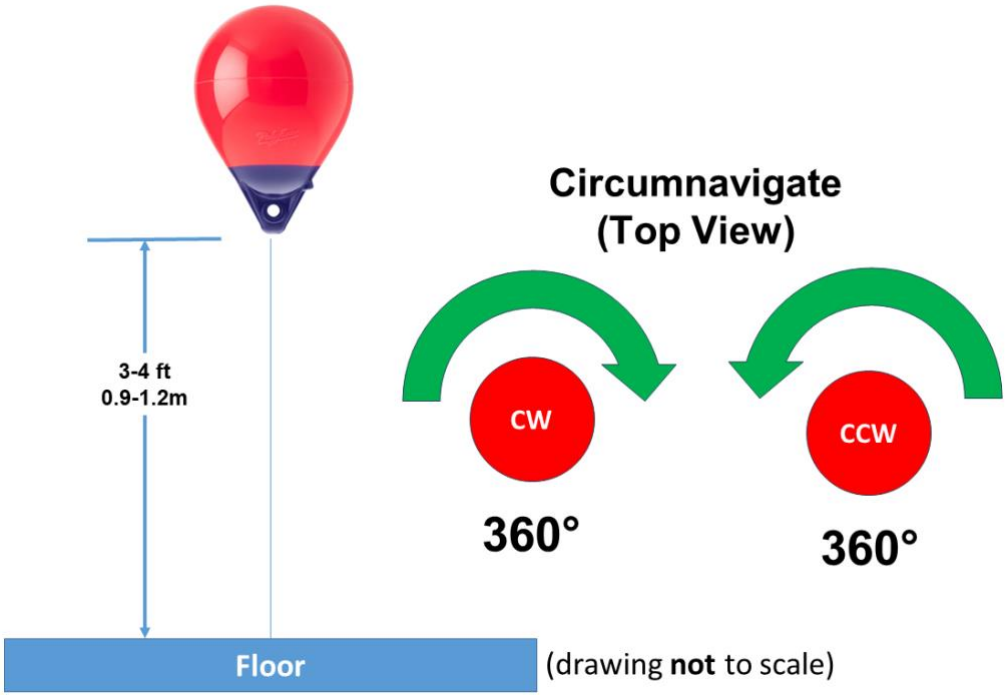

Figure 8 : Hydrothermal Vent

Task Element	Description	Base Dimensions
Buoy	Polyform A0	9”

2.4.5 Ocean Temperatures—Bin

This task consists of a single bin. Inside the bin is a split image of **RED**/**BLUE**.

Points are awarded for dropping markers into either side of the bin, based on where a marker finally comes to rest. More points are awarded for dropping markers in the appropriate bin based on *Enter the Pacific* (Gate).

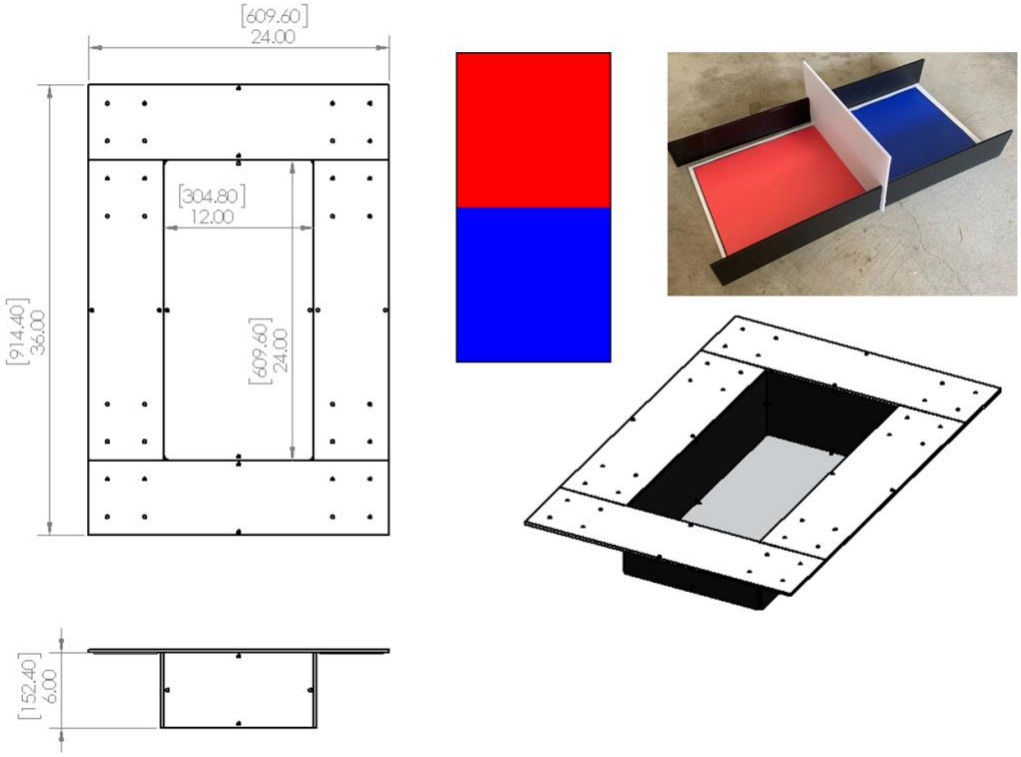

Figure 9: Ocean Temperatures

Task Element	Description	Base Dimensions
Bin	Bin with split color insert	24” x 12” X 6”
Temperature	Vinyl Print	24” x 12”

2.4.6 Mapping —Torpedoes

This task consists of one vertical board with images on the front side. The board is divided by two sea floor images (right-side up and upside down). There are four different size octagons on the image.

Points are awarded for firing torpedoes through any opening. A torpedo must pass through the opening for full points. Partial points are awarded if the torpedo touches the task without passing through. More points are awarded for firing torpedoes through the two smallest openings (**order matters**, smallest, 3", to next smallest, 4"). Additional points are awarded for firing torpedoes further away from the board. The distance is denoted by the horizontal bars at the bottom of the board. A vehicle at that distance or farther will obtain "far" points.

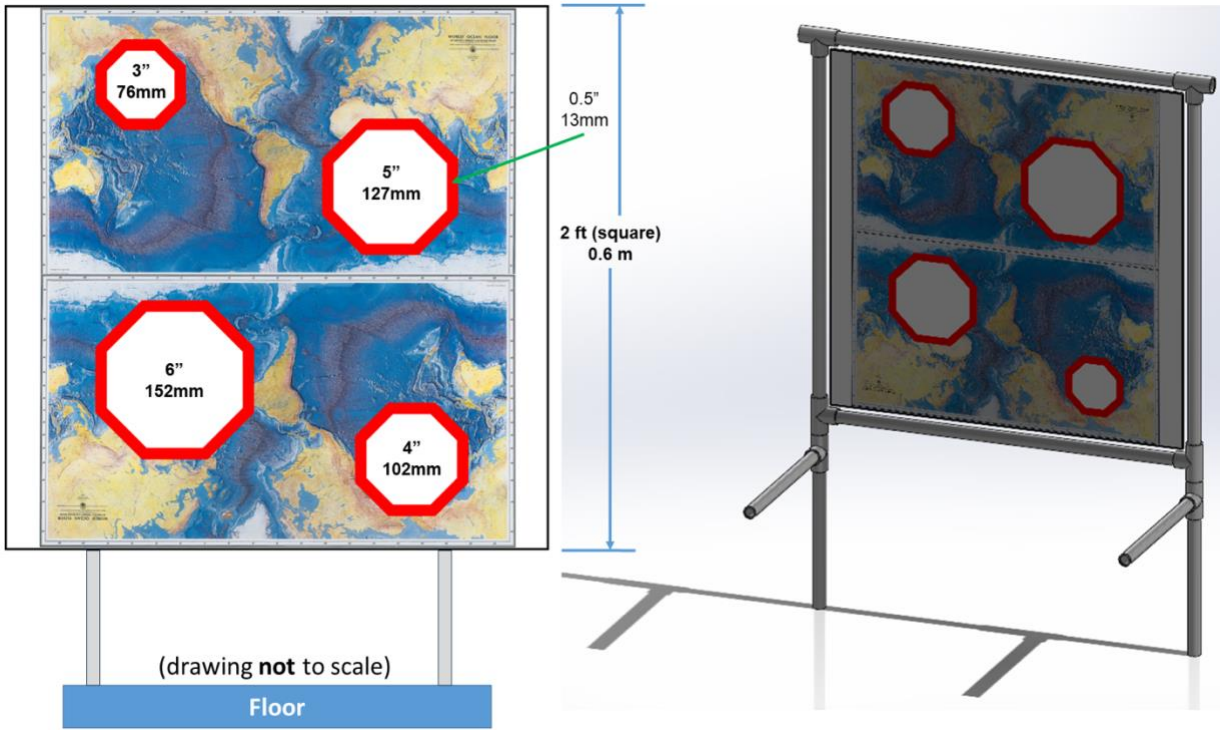

Figure 10: Mapping

Task Element	Description	Base Dimensions
Mapping	Images of the seafloor and octagonal openings, Vinyl Print, Corrugated plastic backing	24" x 24"

2.4.7 Collect Samples—Octagon

A 9 ft (2.7m) diameter octagon floats on the surface and an acoustic pinger, located on the floor near the center of the octagon, guides the AUV to this task. Located in the center of the octagon is the samples table. On the table are three different samples: Tube Worm, Coral, and Nautilus. Along each edge is a basket to place one of the samples.

Points are awarded for surfacing inside the octagon and for surfacing with each sample (stay inside the octagon to continue your run). Points are awarded for moving the samples to any of the four baskets. Maximum points are awarded for placing each sample in its own basket.

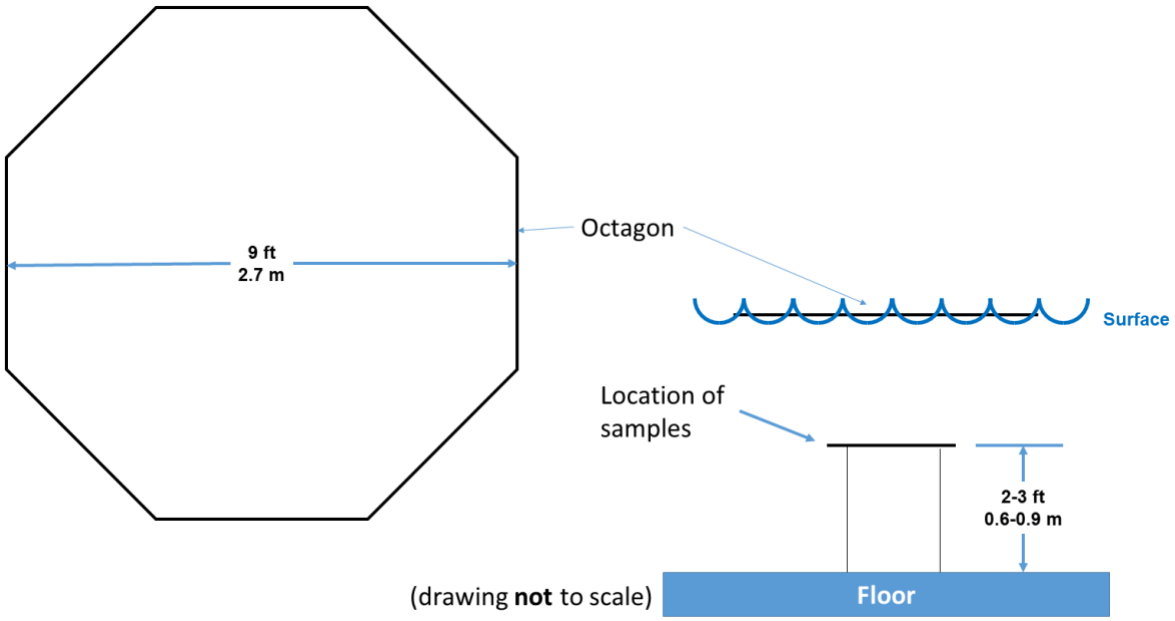

Figure 11: Collect Samples - Octagon and Table

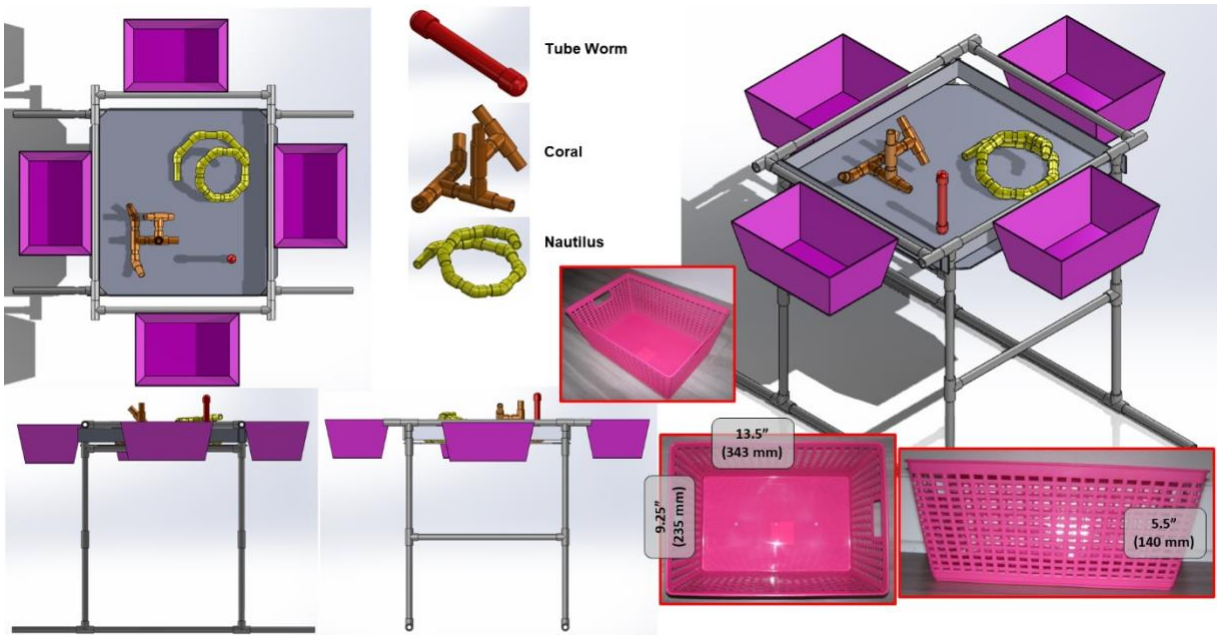

Figure 12: Collect Samples

Task Element	Description	Base Dimensions
Octagon	½" PVC Surface marker	9 ft. diameter
Table	½" PVC Table containing samples and collection bins	2 ft. x 2 ft.
Samples	½" PVC, 3 different samples (Tube Worm, Coral, Nautilus)	Various
Basket	Collection baskets	13.5" x 9.25" x 5.5"

2.5 Vehicle Launch / Recovery

Teams will be responsible for getting their vehicle in and out of the water. They are free to lower and raise their vehicle from the side of the pool (at their section: A, B, C, D), if they feel they can safely do so.

The pool is 7 ft deep to the bottom, and there is a 1 ft drop from the pool deck to the water's surface. At each launch, we will provide a 10 ft (3m) long pipe with a four-point harness connection. Teams can secure their vehicle's hard points to the harness, and using two team members, lift the vehicle from their stand, position the vehicle over the water, and lower it into the water. From the edge of the pool a team member can then reach down and unhook the four points and away they go. The reverse procedure can be followed to retrieve the vehicle.

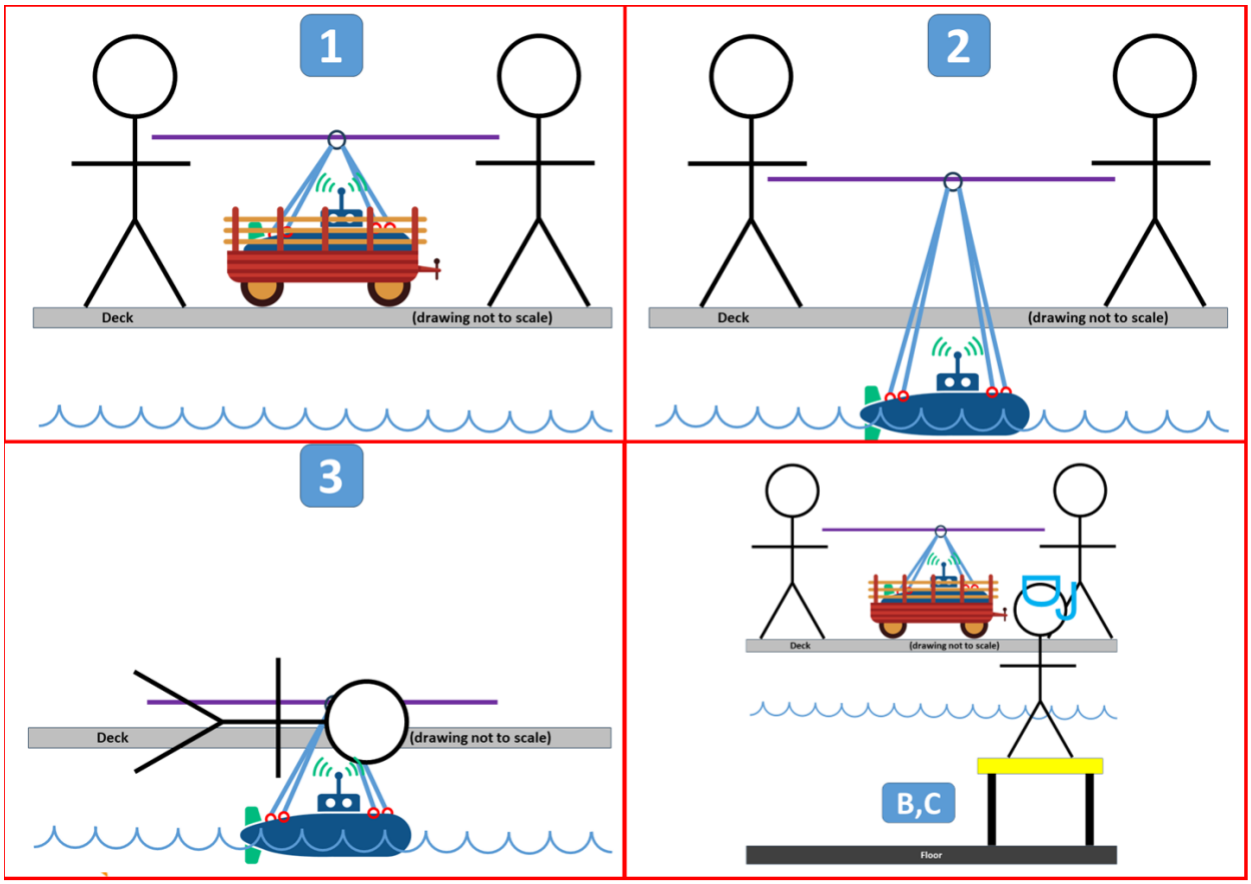

Figure 13: Raising and lowering the vehicle

For Alpha (A), and Delta (D), we recommend bridging the corner to lower/raise your vehicle. For Bravo (B) and Charlie (C), a platform will be in the water for the divers to use to assist lowering/raising your vehicle in/out of the water. The diver (and team member) will be there to help keep the vehicle off the wall as the team is lowering/raising the vehicle.

Figure 14: Location of launch/recovery hoists

2.6 Competition Sequence of Events

This section outlines the sequence of events for the Autonomy Challenge. The competition allows for days of practice, qualifying, semi-final, and finals runs.

2.6.1 OPTIONAL Pre-Qualification Attempt

Prior to the on-site competition, teams may attempt to pre-qualify their vehicle. The vehicle used to pre-qualify must also be the vehicle that is entered into the competition. A team that successfully passes the pre-qualification will automatically qualify for Semi-Finals and is not required to qualify on-site during the practice days of the competition. A team that chooses not to attempt pre-qualification or does not successfully pre-qualify, is required to complete a qualification run on-site (see **Qualification Runs** below).

How to Build Pre-Qualification Course

The approved pre-qualification course consists of:

(1) horizontal **Gate**, and
(2) vertical **Marker**.

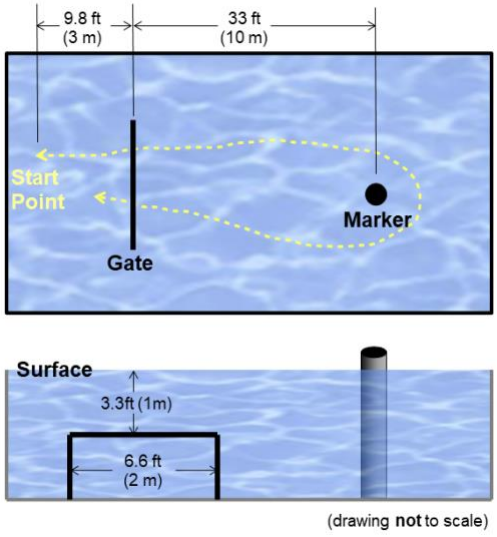

Figure 15: Pre-Qualification Runs

The **Gate** is 6.6 ft (2m) in length and is positioned 3.3ft (1m) below the surface of the water. The **Gate** can be any diameter and any color the team chooses. The **Gate** can be anchored to the floor by any means necessary (ex. using PVC elbows to create two vertical legs, with a line on each end to moor the **Gate** to the floor, etc.). The vertical **Marker** can be any diameter and any color the team chooses. It must be positioned 33ft (10m) beyond the **Gate** and must touch the floor and break the surface of the water.

If a team is unable to build a course to meet these specifications, notify RoboNation for alternative instructions to attempt pre-qualification.

Pre-Qualification Maneuver
In a fully autonomous run, the vehicle must

- submerge and start 9.8 ft (3m) behind the **Gate**,
- pass through the **Gate**,
- circle around the **Marker**, and
- pass back through the **Gate.**

Everything attached to the vehicle must submerge with the vehicle (nothing floating on the surface). The maneuver is successful if this is all accomplished without breaching the surface. The entire run must be recorded from start to finish with no breaks in the video.

Submit Pre-Qualification Attempt Video
Teams can submit pre-qualification video attempts at the following link: robosub.org/pre-qual. This video is submitted to RoboNation for evaluation. Once evaluated, the team is notified of the results. If a team's attempt is denied and the deadline for submissions has not passed, they may submit another attempt.

2.6.2 Practice Runs

Practice time slots are scheduled on an ad-hoc basis by the TD team during the practice days. Teams are provided as much practice time as the venue setup allows. Each vehicle must be cleared by the TD team with a mandatory safety inspection before it can enter a practice course. Teams can sign up for one 30-minute practice timeslot at a time. Once their timeslot has completed, the team is permitted to sign up for the next available timeslot for that practice day.

2.6.3 Qualification Runs

To advance in the competition, teams are required to complete a qualification run. On practice days, a team may request that their run be observed as a qualification run anytime during a team's practice run. In order to successfully qualify, the vehicle must pass through the gate autonomously with everything attached to the vehicle submerging with the vehicle. Qualification allows the team to have two (2) time slots during the semi-finals days, one on the first day and one on the second day.

Wild Card Slots
For any team that has not qualified during the practice days, wild card slots are available during the semi-finals days. Teams must first qualify (pass through the gate) before they are able to choose the next available wild card slot. Only one slot per day can be used by a non-qualified team.

2.6.4 Semi-Finals Round

There are two semi-finals days. Each qualified team is assigned one time slot on each day to perform the mission. Two of the practice courses are converted into semi-finals courses. Qualified teams are required to conduct a run in each of the two courses across the two semi-finals days. Twenty minutes before the beginning of their time slot, the team may enter the staging area near the launch site. At the beginning of their time slot, the team may move to the launch site.

Semi-Finals Timeslot

A team will have 20 minutes for their semi-finals timeslot. The first 5 minutes are for preparation (*preparation time*). During this period, the vehicle may not be deployed in the water. When the 5-minute limit has expired for the *preparation time* (or the team has waived the balance of the preparation time), officials begin the *performance time* clock once the vehicle is in the starting position. These competition minutes are for the vehicle to perform the mission. Once this period has begun, the team may ask to have their vehicle placed in the water to begin its run.

Vehicle Recovery / End of Run

The run continues until the *performance time* limit has expired, the team lead requests the end of the run, the judges order the termination of the run, or the vehicle breaches the surface. The judges may order termination of the run at their discretion. Once the judges order the end of the run, no further points may be scored. The judges' decisions on the termination of the run are final. As long as a vehicle has passed through the gate, the *performance time* is stopped during the retrieval of the vehicle.

2.6.5 Finals Round

After the semi-finals round, the judges rank-order the teams based on the semi-finals scores and select the top teams to compete in the finals round. The point totals and ranking from the teams not selected for the finals are frozen. For the finals round, all point totals are set to zero.

SECTION 3: Scoring & Awards

3.1 Scoring

Scores are calculated by the judges; all decisions of the judges are final.

3.1.1 Design Documentation Scoring

Design documentation must be submitted in accordance with the requirements outlined in Section 2.2 and the deadlines listed in Section 5.3., to be eligible for full points. After the competition, overall standings for design documentation will be published.

Design Documentation	Maximum Points
Technical Design Report	200
Team Website	180
Team Introduction Video	120
Design Presentation	180
System Assessment	180
Total Potential Points	**860**

3.1.2 Autonomy Challenge Scoring

The Autonomy Challenge occurs in three rounds: Qualifying, Semi-Finals, and Finals. Points are awarded only in the Semi-Final and Final Rounds, as outlined in this section. 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 Autonomy Challenge overall standings. Any team accepted into the Finals Round will be ranked ahead of all teams that did not participate in the Finals Round.

Point Breakdown

Each of the tasks has a point value associated with it. The tasks can be completed in any order by one or more vehicles. The recovered object must be attached to the vehicle when the vehicle is on the surface to obtain maximum points for "surfacing with object".

During a scored timeslot, the team lead may end the run at any time and keep the accumulated points. The team may decide to start another run, in an attempt to accomplish more/different tasks.

Semi-Finals Points – Last Run

For semi-finals, at the start of a new run, the points accumulated from the previous run are forfeit. The only points which are recorded are from the very **last** run.

Finals Points – Best Run

For the finals, the **best** run will be used for the final points. Therefore, a team may try to accomplish as many runs as time allows, and the run that has accumulated the most points will be used for their final score. If the minimum requirements have been met, the remaining time after each run will be recorded and used to calculate a time bonus. For example, after the first run, a team has met the time bonus requirements with 10 minutes remaining on the clock. Those 10 minutes are used to calculate the time bonus for that run. Regardless of what happens with the next run.

Task	Maximum Points
Weight	See Table: Weight
Marker / Torpedo exceeding weight or dimensional spec by <10%	-500 / item
Gate: Pass through	100
Gate: Maintain control	150
Gate: Coin Flip	300
Gate: Style Yaw, Roll/Pitch	+100, +200/90° (8x max)
Hydrothermal Vent: Touch / Circumnavigate (wrong, correct)	300 / 600, 800
Hydrothermal Vent: Fire torpedoes	200 / torpedo
Ocean Temperature: Any bin, Correct side	400, 800 / marker (max 2)
Mapping: Any	600 / torpedo (max 2)
Mapping: Correct sequence	1400
Mapping: "Far" torpedoes	300 / torpedo
Collect Samples: Surface in Area	800
Collect Samples: Surface with object	400 / object
Collect Samples: Drop object	200 / object
Collect Samples: Object in bin (TW, C, N)	300, 500, 700
Collect Samples: Individual bin	300 / object
Random Pinger first task	500
Random Pinger second task	1500
Inter-vehicle Communication	1000
Finish the mission with T minutes (whole + fractional)	Tx100

Pinger Tasks

Mapping and **Collect Samples** will *only* be marked with a pinger. There will be no path markers that point to either task. A team may request that a specific pinger be switched on (pinger near **Mapping**, or pinger near **Collect Samples**). At any time during the run, the team lead may ask to have the pinger switched to the other task. This switch can be done as many times as the team lead asks. Additional points are awarded if the team requests a random pinger.

Random Pinger

If a vehicle can score points at both pinger tasks, the team lead may request a random pinger selection. The only randomization is the selection of the first task(s) marked with a pinger, the second task(s) will always be the other task(s) marked with a pinger. If the vehicle obtains any points from the first task(s), associated with the random pinger, bonus points are awarded. At any time after the vehicle has obtained points from the task(s) associated with the random pinger, the team lead may ask to switch the pinger. If the vehicle obtains any points from the second task(s), associated with the random pinger, bonus points are awarded. If the team lead requests to switch the pinger before the vehicle has acquired any points, the run reverts back to a specific pinger request run and no random pinger points will be awarded.

Breaching

When completing a sequence of tasks, a team may choose to complete the surfacing task (surface within the floating area) at any time. A vehicle may breach the surface within the floating area and then submerge again to compete the remaining tasks without the risk of ending the run. For a vehicle to continue after breaching, it must surface within the floating area, and may be touching the surfacing task. A breach outside of the floating area will end the run of that vehicle. If there are multiple vehicles

underway (and underwater) this does not end their run. The remaining vehicles may continue their own autonomous mission and continue to score points for their run. If the breached vehicle cannot be removed safely without interfering with the remaining vehicle(s), it will be allowed to continue its run, but will not score any more points for that run.

Interference
Vehicles that interfere with competition elements may be disqualified at the judges' discretion. "Interference" does not include cases where, in the opinion of the judges, a vehicle is attempting to complete one of the tasks. If a vehicle becomes entangled on a competition element the run will be declared complete. Teams may keep the points earned on that run or may have the vehicle returned to the dock and start another run. If a new run is begun, all points from the previous run are forfeit.

Passing through the validation gate: The judges' discretion will determine whether or not the vehicle satisfactorily passes through the validation gate.

Maintain control through the gate: Did the sub conduct control as it passed through the validation gate? This is intended to separate a vehicle that is maintaining a heading, or otherwise accomplishing something autonomously versus a vehicle that is initially pointed at an angle to correct for the vehicle's uncompensated drift. For example, a vehicle that has a slight sinusoidal motion due to PID tuning, but on average is maintaining a heading has maintained control through the gate. Or a vehicle that is searching for the gate, finds it and heads through it has maintained control through the gate. A vehicle that is pointed away from the gate to compensate for un-tuned motors and drifts through the gate has not maintained control through the gate.

Surface within the Area: The vehicle must fully surface within the floating area to obtain max points. Partial points will be awarded based on how much the vehicle is inside the area.

Grabbing the Object: The object must be captured and constrained by the vehicle to obtain full points. Partial points may be awarded for a partial capture (i.e. a hook/magnet).

Releasing the Object: The object must fall free from the vehicle to obtain full points. An object hanging on the vehicle may be awarded partial points with judges' discretion.

Inter-vehicle Communication (IVC): When there are multiple vehicles in the water, they must communicate with each other in order to obtain IVC points (multiple vehicles are not *required* to communicate with each other). Proof of the communication must be presented to the judges to evaluate. Having indicator lights which help to draw attention when they are transmitting and receiving IVC messages would help with the confirmation (but are not required). The level of the communication and the complexity of the behaviors derived by the communication are what determine the level of points awarded.

Time Bonus: At a minimum, a vehicle must touch a buoy, drop at least one marker in the bin (or fire one torpedo through the opening), and fully surface within the floating structure to obtain a time bonus. These tasks can be completed in any order.

The time bonus is a calculation of whole minutes remaining plus fractional seconds. For example, with a remaining time of 7:13, a team will receive: (7+13/60)*100 = 721.667 points (approximately).

Additional Scoring Considerations

1. There is a 10ft (3m) radius imaginary buffer (spherical) around each task. When a vehicle enters the buffer, an attempt for that task has started. When a vehicle exits the buffer the attempt for that task has ended.
2. If multiple tasks are grouped such that there isn't the required separation, the attempt on the first task has ended when the vehicle has clearly moved on to the next task.
3. If a task is a single event (pass through the gate, touch buoys, etc.), points for a task are awarded on a per attempt basis.
4. If a task can collect items (i.e. it has a bin), points are added until the maximum points are reached. I.e. If there is a maximum of two markers in a bin, one vehicle drops 1 marker in the bin, and a second vehicle drops 2 markers in the bin, the points are capped at 2 markers in the bin.
5. The higher value for a task during a run replaces the previous score. If a vehicle revisits a task in the same run, the higher score is used.
6. Semi-Finals Round: Each vehicle is scored independently, the run starts when the vehicle leaves the starting location and ends when the team lead calls to kill that vehicle, the vehicle breaches, or the time runs out. The scores are based on the last run of each vehicle.
7. Finals Round: The "Best of" run for each vehicle is used to determine the final score.

3.2 Awards

Awards are provided in three categories: Design Documentation, Overall Final Standings (combines Autonomy Challenge and Design Documentation scores) and Special Awards.

3.2.1 Final Standings

Teams are awarded prize money reflective of their overall ranking after scores are calculated. The Autonomy Challenge and Design Documentation scores are combined for the final standings. The first-place teams receive a RoboNation champion banner.

3.2.2 Special Awards

Throughout the competition, everyone is on the lookout for exemplary behavior from teams to acknowledge with special awards. Competitors, judges and staff are invited to submit nominations at the following link, until the day before finals: robosub.org/award-nominations.

SECTION 4: Rules & Requirements

4.1 Rules

1. **Vehicle Requirements:** 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)
2. **Team Composition:** Teams must be comprised of 75% or more full-time students. (Section 1.4: Eligibility)
3. **Prizes:** Only the student component of each team is eligible for cash awards.
4. **Team Lead:** 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 competition runs.
5. **Course Entry:** No team member is allowed to enter the course at any time (this includes wading, swimming and diving as well as floats, boats, etc.) Competition officials are responsible for recovering lost vehicles. Officials make all reasonable efforts to recover a lost vehicle but cannot guarantee that they will be able to do so. All teams recognize that by entering the competition, they risk damage to or the loss of their vehicle. The judges, officials, hosts, and sponsors can take no responsibility for such damage or loss.
6. **Retrieving Vehicle:** At any time, the team lead may signal the end of the run and request the retrieval of the vehicle. Only officials may retrieve a vehicle and return it to the dock. The countdown clock for the semi-final performance period stops when the official touches the vehicle and continues its countdown once the vehicle is safely back at the starting location, or the team establishes communication with the vehicle, whichever is first (i.e. if a team has wireless communication with the vehicle, the countdown lock continues while the official returns the vehicle to the start).
7. **Competition Suspended:** The officials may suspend the competition at any time they deem that it is required (i.e. for safety or security reasons).
8. **Attendance:** At least one team member is required to remain on-site at the competition venue during the competition hours to be eligible for prizes. If your team does not make it into the finals, it is expected that your team displays your vehicle and remains present in the Team Village during this time. (ALL teams, ALL days, ALL open hours!)
9. **AUV Safety:** Prior to entering the Autonomy Challenge courses, teams must demonstrate the ability to operate their AUV safely.
10. **Interference:** If a vehicle experiences significant interference from a piece of equipment, line, cable or official deployed in support of the competition, the team lead may ask, at that time, to have the clock stopped, the vehicle returned to the dock, and for the judges to add back to the clock their best estimate of the time used in that run up to the point of interference. If the team lead does not make this request in a timely manner (as determined by the technical director) then the option is lost. Interfering with the competition tasks does not qualify for this option, and a vehicle interfering with tasks may be disqualified at the judges' discretion.
11. **Lock Score:** After a run, a team may lock in their current score and use any remaining time to survey the arena. The survey must be completed autonomously. Unlike performing a competition run, the clock will continue to run while retrieving a vehicle. This is subject to change depending on timing and the number of teams.

12. **Mission End:** The run ends when any of the following occurs:
    - The performance period time limit ends;
    - The judges' order the end of the run;
    - The team lead requests the end of the run; or
    - The vehicle breaches the surface outside the octagon.
13. **Judges Decisions:** All decisions of the judges are final.

4.2 Safety

Safe operations are a priority for RoboNation. 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.
2. AUV power systems must follow the safety rules and regulations of the host country as well as the team's home country.
3. RoboSub staff may suspend team operations at any time for safety or security 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 RoboSub 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. Clear identification of kill switch and verification of operation.
2. Shrouded propellers.
3. Components safely secured on the vehicle (that should remain in the vehicle).
4. Safe areas identified for the diver to grab/secure the vehicle.

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 (on-site) 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 RoboSub 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 are only permitted to change or replace AUV batteries in their designated areas in Team Village.

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 AUV Requirements

- **Inspection:** Each team may enter one or multiple vehicles into the competition. Each vehicle is physically inspected by the TD team. The TD team may disqualify any vehicle that they deem to pose an unreasonable safety hazard to participants, staff, or the host facility. The sponsors and the host organization, their employees and agents, as well as the organizing committee, are in no way liable for any injury or damage caused to or by any vehicle.
- **Autonomy:** Vehicles shall be fully autonomous and shall have all autonomy decisions made onboard the AUV. During qualifying, semi-finals, or finals run, each vehicle must operate autonomously. While carrying out the run, no communication is permitted between the vehicle and any person or off-board computer. Each vehicle must operate solely on its ability to sense and maneuver in the arena using on-board resources. Autonomy is not necessary for practice runs.
- **Submerge:** When performing a qualifying, semi-finals or finals run, everything attached to the vehicle must be submerged with the vehicle. Any part that breaks the surface is considered a breach. During practice days, and practice runs, the vehicle and buoys may be used on the surface for communication.
- **Weight and Size:** The weight of each individual vehicle must be less than the maximum allowed. Note that bonus points are awarded to vehicles below a certain weight, and penalties assessed for those that exceed it, see Table 3. The entire vehicle must fit within a 3ft x 3ft x 6ft (0.9m x 0.9m x 1.8m) volume.

- **Batteries:** Vehicles must be battery powered. All batteries must be sealed to reduce the hazard from acid or caustic electrolytes. Batteries must not be charged inside of sealed vessels at any time. The open circuit voltage of any battery (or battery system) in a vehicle may not exceed 60 VDC. If a team has any questions or concerns, they are encouraged to contact the Technical Director Discord's RoboSub Channel. (Section 4.2.2 Battery Safety Requirements)
- **Markers:** No materials (except for the markers/torpedoes and compressed air) may be released by the vehicle into the waters of the arena. (Section 4.4.1 Markers)
- **Torpedoes:** For the safety of your team and those around you, no loaded torpedoes are allowed within the team tent. If you must test your launchers, tests may be conducted either in the water or in an open area pointing away from everyone and everything. (Section 4.4.2 Torpedoes)
- **Harness:** When a hoist or crane is used, vehicles are required to be slung on a harness or sling of some type. Even if the vehicle is light enough to hand carry, this requirement is in place to avoid harm to the vehicle. The harness/sling is used to weigh the vehicle and launch/recover. Since the diver in the water will be responsible for removing and placing the harness on the vehicle, make sure this is as easy as possible to do. If a hoist or crane is not used, a harness is not required. (Appendix D. Harnessing the Submarine)
- **Sled:** If a hoist or crane is not used, a ramp will be used to deploy and recover the vehicle(s). The sled will be provided by the team, the vehicle will be placed on the sled and slid into and out of the water. Since the diver in the water will be responsible for removing and placing the vehicle on the sled, make sure this is easy as possible to do.
- **Kill Switch:** All vehicles must contain a clearly marked kill switch that a diver can easily and readily activate. The switch must disconnect the batteries from all propulsion components and devices on the AUV. Note, this does not have to kill the computer. Upon reactivation, the vehicle must return to a safe state (props do not start spinning). Vehicles will not be allowed in the water without a properly working kill switch.
- **Shrouded:** All props must have shrouds. The shrouds must surround the prop and have at least a 2" (5.1cm) distance between the spinning disk of the prop and the edges of the shroud (front and back). If you have a guard across the opening to prevent the insertion of a finger, this distance can be minimal. Commercial shrouded thrusters can be used as is. Vehicles will not be allowed in the water without prop shrouds.
- **Buoyancy:** All vehicles must be positively buoyant by at least one half of one percent (0.5%) of their mass when they have been shut off via the kill switch.
- **Suspension:** The officials will suspend the operation of a vehicle at any time they deem that it is required by safety or security considerations. If teams have any questions or concerns, they should submit technical descriptions of their vehicle to the officials in advance of the competition, with the goal of identifying potential safety concerns well in advance. Such technical information submitted to the officials will be held in confidence until the end of the competition.

4.3.2 Multiple Vehicle Requirements

Up to two vehicles per team are allowed in the competition. Along with the 4.3.1 AUV Requirements, teams who enter multiple vehicles must follow these specifications:

- **Volume:** The total dry volume for all the vehicles must fit within the maximum volume defined in the requirements. The vehicles are not required to start joined together, nor are they required to rejoin at the end of the run.
- **Weight and Size:** Each vehicle is weighed, and the bonuses/penalties are calculated on a per vehicle basis (Weight Measurement

- Vehicles are weighed before each semi-finals and finals run. Teams transport the vehicle on their cart to the scale for weight measurement. **Error! Not a valid bookmark self-reference.** shows the bonuses and penalties associated with a vehicle's weight in air.

- Table 3: Vehicle weight in air with Bonus or Penalties).
- **Gate:** From the dock, each vehicle must pass through the validation gate first before heading off for its desired task.
- **Run Time:** A team may elect to kill one vehicle and bring it back to the dock. If one (or more) vehicles are still out on the course, the competition time continues to count down (think of them as a swarm). Any vehicle that has been killed or has breached are returned to the dock and can be redeployed at any time.
- **Time Stop:** The competition timer is only stopped when the last vehicle out on the course is under diver control and returning to the dock. The timer starts again once this last vehicle has returned to the dock, or the first vehicle leaves the dock (starting its new run).
- **Inter-Vehicle Communication:** Teams wishing to have communication between each vehicle must post their method and frequencies on the RoboSub Discord's technical-forum channel. Acoustic frequencies that are the frequency range used by the pingers, are always off limits for inter-sub communication. Inter-vehicle communication and cueing of one vehicle by another is an advanced behavior that merits special points. If such behavior is executed, teams are required to present post-run supporting documentation (e.g., vehicle logs) to the judges.

4.4 Competition Specifications

4.4.1 Markers

- Each marker must fit within a box 2.0" square and 6" long (5.1 x 5.1 x 15.2 cm).
- Each marker must weigh no more than 2.0 lbs (0.91 kg) in air. Any marker that exceeds these limits by less than 10% results in a 500-point penalty. Any marker that exceeds these limits by more than 10% is disqualified.
- Each marker must bear the team's name, color or emblem.
- Markers are cleared from the arena after each run.
- A vehicle may carry up to two markers.
- It is recommended to bring backup markers in case of lost markers.

4.4.2 Torpedoes

The torpedo size, weight, and marking requirements are the same as the Markers.

- Each torpedo must fit within a box 2.0" square and 6" long (5.1 x 5.1 x 15.2 cm).
- Each torpedo must weigh no more than 2.0 lbs (0.91 kg) in air. Any torpedo that exceeds these limits by less than 10% results in a 500-point penalty. Any marker that exceeds these limits by more than 10% is disqualified.
- Each torpedo must bear the team's name, color or emblem.
- Torpedoes must travel at a "safe" speed. A "safe" speed is one that would not cause a bruise when it strikes a person underwater from close range.
- Torpedoes are cleared from the arena after each run.
- A vehicle may carry up to two torpedoes.
- It is recommended to bring backup torpedoes in case of lost torpedoes.

4.4.3 Pingers

The pingers are Benthos ALP-365. The Benthos ALP-365 is user selectable from 25 to 40 kHz in 0.5 kHz increments. The pingers in each section use the same frequency.

For example, the two pingers in section A both have the same frequency, and the two pingers in section B both have the same frequency (but different from section A). There are four different frequencies used, one for each section, and only one pinger in each section is active at a time. The ping for each section is deconflicted with the pings in other sections such that only one pinger pings at a time. The frequencies for the sections are:

- A – 30kHz
- B – 40kHz
- C – 25kHz
- D – 35kHz

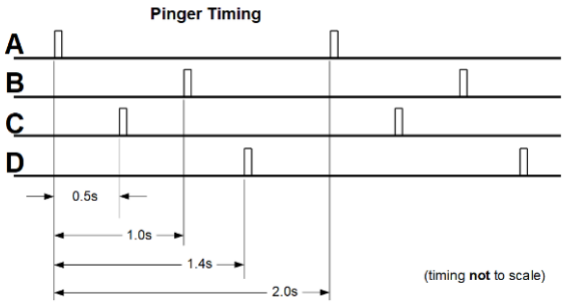

Figure 16: Pinger timer for the four sections

SECTION 5: How to Compete

5.1 Register and Intent to Compete

All teams are required to register to compete using the Registration form found on the RoboSub website, RoboSub.org/2024. 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 RoboSub 2024 registration, teams must pay the registration fee of $1,250 USD. Teams are not seen as official RoboSub teams until this payment is collected. Once registered, teams are added to the team list on the RoboSub website and are eligible to request an invitation letter.

Cancellation Policy

In the unfortunate case that a team decides to cancel their participation, they must complete the Cancellation Form. Cancellation requests submitted via email will not be accepted. Refunds may be available dependent on the date the cancellation is submitted. Review the cancellation policy here: robosub.org/cancellation-policy.

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: robotx-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 Registration form. Only official registered teams maintain access to the Data Sharing project for the RoboSub 2024 season. The RoboSub Data Sharing platform can be accessed at robosub.org/data-sharing/access.

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 RoboSub 2024 effort, liability waivers, forms, and other contact information.

5.2.2 On-Site Requirements

All teams are required to submit battery specifications 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 4.2.2 Battery Safety Requirements.

Shipping Plan
Teams are required to submit a shipping plan to facilitate shipment receipt/handling at the competition hotel. Refer to 5.4.2 Shipping for shipping instructions. This shipping plan must include:

1) Organization name
2) Team name
3) Shipping POC
4) Shipping POC mobile number
5) Shipping POC e-mail
6) Number of crates
7) Dimensions for each crate
8) Estimated shipping date
9) Shipping company
10) Type of shipment – Air, ground, ocean
11) Has initial pick-up or drop off been scheduled – include date of pick-up or drop off
12) Is this a dangerous good shipment? If so, has a dangerous goods shipment been arranged?
13) Have you scheduled your outbound shipment pick-up or drop off? Provide pick-up details (date/time) for any pick-up from the hotel.
14) Additional information for shipment, if needed.

(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.)

5.2.4 Design Documentation Package
Teams are required to submit the team website, report, and video of their Design Documentation prior to being on-site at the competition. Guidelines can be found in Section 2.2 Design Documentation.

5.2.6 Optional Pre-Qualification Maneuver
Teams may attempt to pre-qualify their vehicle for the Autonomy Challenge with a video performing the qualification maneuver. Approved pre-qualification attempts advance to Semi-Finals. Instructions can be found in Section 2.5.1 OPTIONAL: Pre-Qualification Attempt.

5.2.7 Optional Community & Outreach
Teams are invited to outline their educational outreach efforts. This activity is not scored; however, it is shared online for the community and can be eligible for special awards and recognition. Teams may submit a description of their activities and any supporting documents, photos, or videos.

5.3 Timeline

Date/Deadline	Event
November 1 – March 18, 2024	Registration
May 20, 2024	Full 100% Refund Cancellation Deadline
June 17, 2024	Event Submissions Deadline: • Team Information • Background Checks (teams with minors) • Merchandise Order • On-Site Requirements • Award Information Collection
~~**June 24, 2024**~~ ***Extended to July 1, 2024***	Design Documentation Deadline: • Team Website • Technical Design Report • Team Introduction Video • Optional Community & Outreach 50% Refund Cancellation Deadline
July 22, 2024	Optional Pre-Qualification (Click here to submit)
August 05-11, 2024	RoboSub 2024

5.4 Logistics & Travel

5.4.1 Travel + Lodging

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

Lodging—Event Hotel
RoboNation has a contract with a local hotel to provide a special rate for RoboSub teams. Teams are not required to book at the event hotel. The selected hotel and booking links can be found here on Discord.

International Travel
Invitation Letter – During the registration process, international teams are given the opportunity to request an invitation letter issued by RoboNation. Contact support@robonation.org with any questions.

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.

5.4.2 Shipping

Teams are responsible for coordinating the necessary shipping to ensure arrival of AUV and equipment. Any shipping questions can be directed to Cheri Koch at ckoch@robonation.org / 850.642.0536. Detailed shipping guidelines are available in Appendix E.

- **Equipment Arrival:** Shipments should arrive no earlier than 3 days prior to Day 1 of event.
- **Equipment Outbound Pick-Up:** Shipments should be picked up / dropped off BEFORE the team departs to return home. RoboNation and the competition venue staff are not responsible for ensuring that team's outbound shipment gets picked up.

5.4.3 On-site Logistics

Team Village
Each team is provided with a 10’ x 10’ covered working area that includes two tables, seven chairs, one electrical outlet (120V 60 Hz 15A), and a wireless internet connection. The Team Village is filled with side-by-side tents near to the competition venue and resides on an asphalt 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
Teams are provided with a designated area near each course where they are able to set up their equipment. This space consists of a tent-covered area with tables, power, and a hard-wired Ethernet connection.

Figure 17: US electrical outlets

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.

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

RoboSub teams have a variety of opportunities to interact with each other and the RoboSub 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 RoboSub organizers and technical team to provide teams with competition updates and the opportunity to ask questions.

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

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 RoboSub staff. Teams who do not have members fluent in English should contact RoboSub staff as soon as possible.

Technical Director Team
The RoboSub Technical Director Team consists of:

- Technical Director
- Course Managers

Other RoboSub Staff
The RoboSub Staff are identified with black "Staff" shirts.

5.5.3 RoboSub Website

The official competition website is www.RoboSub.org/2024. This website includes all official documents and a detailed list of the registered RoboSub 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 RoboSub, 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.

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

SECTION 6: Glossary & Acronyms

6.1 Glossary

Phrase	Definition
Semi-Finals & Finals Courses	These courses are designed to allow demonstration of autonomous execution of multiple tasks. 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.
RoboSub Staff	RoboSub support personnel.
Judge	Subject Matter Experts that observe and score the Autonomy Challenge and Design Documentation.
Sponsor	Organizations that provide support to RoboSub.

6.2 Acronyms

Acronym	Definition
AUV	Autonomous Underwater Vehicle
N/A	Not available
TBD	To be determined
TD	Technical Director
TDR	Technical Design Report

Appendix A: Competition Schedule

RoboSub 2024 *www.robosub.org*

Woollett Aquatics Center Address: 4601 Walnut Ave, Irvine, CA 92604
Hilton Irvine/Orange County Airport Hotel Address: 18800 MacArthur Boulevard, Irvine, CA 92612

DATE	TIME	EVENT	LOCATION
Monday, August 5	3:00 pm – 4:00 pm	Team Check-in	Hilton Irvine/Orange County Airport Hotel
	4:00 pm – 5:30 pm	Team Orientation	
	5:30 pm – 7:30 pm	Sponsor Showcase	
	10:00 pm – 2:00 am	Overnight Pool Testing	
Tuesday, August 6	7:00 am – 6:00 pm	Autonomy Challenge Practice / Qualifying	Woollett - Pool 1
	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	8:00 am – 5:00 pm	Presentations / Assessments – Day 1	Woollett – Classroom
	11:30 am – 2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	7:00 pm	Venue Closed	Woollett
	10:00 pm – 2:00 am	Overnight Pool Testing	Hotel
Wednesday, August 7	7:00 am – 6:00 pm	Autonomy Challenge Practice / Qualifying	Woollett - Pool 1
	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	8:00 am – 5:00 pm	Presentations / Assessments – Day 2	Woollett – Classroom
	11:30 am – 2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	12:15 pm	Group Photo	Team Village / Bleachers / Lawn
	7:00 pm	Venue Closed	Woollett
	10:00 pm – 2:00 am	Overnight Pool Testing	Hotel
Thursday, August 8	7:00 am – 6:00 pm	Autonomy Challenge Practice / Qualifying	Woollett - Pool 1
	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	8:00 am – 5:00 pm	Presentations / Assessments – Day 3	Woollett – Classroom
	10:00 am – 2:00 pm	Media Day - ***tentative***	Woollett
	11:30 am – 2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	4:00 pm – 5:30 pm	Course Judge Training	Woollett – Classroom
	6:00 pm	Team Meeting *Semi-Finals Day 1 Schedule determined*	Team Village
	7:00 pm	Venue Closed	Woollett
	10:00 pm – 2:00 am	Overnight Pool Testing	Hotel

DATE	TIME	EVENT	LOCATION
Friday, August 9	7:00 am – 6:00 pm	Autonomy Challenge Semi-Finals – Day 1	Woollett - Pool 1
	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	11:30 am –2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	6:00 pm	Team Meeting *Semi-Finals Day 2 Schedule determined*	Team Village
	7:00 pm	Venue Closed	Woollett
	10:00 pm – 2:00 am	Overnight Pool Testing	Hotel
Saturday, August 10	7:00 am – 6:00 pm	Autonomy Challenge Semi-Finals – Day 2	Woollett - Pool 1
	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	11:30 am –2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	6:30 pm	Team Meeting *Finals Schedule determined*	Team Village
	7:00 pm	Venue Closed	Woollett
	10:00 pm – 2:00 am	Overnight Pool Testing	Hotel
Sunday, August 11	7:30 am – 10:30 am	Breakfast Available for Purchase	Food Truck/Catering
	8:00 am – 11:00 am	Third Chance / Finalist Practice Runs	Woollett – Pool 1
	11:30 am –2:30 pm	Lunch Available for Purchase	Food Truck/Catering
	12:00 pm – 4:00 pm	Autonomy Challenge Finals	Woollett – Pool 1
	6:00 pm – 7:00 pm	Awards	Woollett – Pool 2
	6:00 pm	Tear Down	Woollett – Pool 1
	7:00 pm – 10:00 pm	Pool Party *Teams Only*	Woollett – Pool 2
Monday, August 12		Team Travel Day (or Fun Day in California!)	

Appendix B: Technical Design Report (TDR)

B.1. Paper Preparation Overview

Each team is required to submit a TDR that describes the team's design principles and competition priorities. The report should address the rationale for which autonomy challenge tasks have been chosen to attempt and how this competition strategy influenced the design decisions for the hull, propulsion system, control systems, and autonomy system. Teams must follow the TDR instructions provided below. To be eligible for full points, teams must submit their TDR by the deadline found in Section 5.3.

A strong TDR provides a coherent narrative and addresses the elements of the rubric as well as possible, including citing references used. The competition strategy justifies the choices of autonomy challenge tasks and design decisions that trace back to those task choices. The report also identifies which software tools allow the team to accomplish the tasks chosen.

The technical design report is worth a total of 200 points. The outline of each content section includes a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

B.2. Format

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

- **6 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

RoboNation Tip: It is recommended that papers be peer-reviewed prior to submission. For example, teams can utilize resources at their institution, fellow students, or professional editing services.

Optional Formatting: Teams may choose to follow the two-column format, editorial style for IEEE Conference Proceedings: www.ieee.org/conferences/publishing/templates.html.

Formatting Scoring Metrics *(5% of score)*

Strong	Paper follows page limit, and all formatting guidelines are followed. The document is professionally organized. All required sections are included and easy to identify. All grammar, punctuation, and spelling are correct. The style follows that expected of a scientific paper submitted for publication.
Requirements Not Met	Formatting guidelines are not followed and the layout is unorganized.

B.3. Paper Contents

The TDR consists of the following mandatory sections: abstract, technical content, acknowledgements, references, appendix A, and appendix B.

B.3.1 Abstract

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

Abstract Scoring Metrics *(10% of score)*

Outstanding	Abstract is engaging, lists the scope of the work, and provides a thorough summary of the paper.
Strong	Abstract provides a strong overview of the scope of work and a detailed summary of the paper.
Average	An adequate explanation of the scope of work is included with a brief summary of the paper.
Below Average	Abstract provides a basic summary of the paper.
Poor	Abstract section is included but does not serve the intent of an abstract. The abstract is treated as an introduction and provides no summary of the paper.
Requirements Not Met	No abstract is included.

B.3.2 Acknowledgements

Participating in the competition, as in all research projects, involves leveraging 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 supported efforts is important.

Acknowledgements Scoring Metrics *(5% of score)*

Strong	Acknowledgements detail supporting personnel and their contributions as well as resources. Sponsors and their contributions are acknowledged.
Average	Acknowledgements include a list of supporters and sponsors with little or no detail of the support provided.
Poor	Acknowledgements provide a general thank you but do not specify particular contributions.
Requirements Not Met	No acknowledgements are included.

B.3.3 References

As with any technical publication, original ideas and content not generated by the paper's authors should be properly cited. The references should follow the IEEE Conference Proceedings citation style.

References Scoring Metrics *(5% of score)*

Strong	Sources include notable technical references including technical papers and articles. Use of the source materials are evident in the TDR. Sources are thoroughly documented. The IEEE citation style is correctly utilized.
Average	Sources are adequate and documented correctly with the IEEE citation style is utilized.
Poor	Limited sources are documented but there is no adherence to the IEEE citation style.
Requirements Not Met	No sources or citations are documented.

B.3.4 Technical Content

The technical content of the paper outlines the goals determined for the competition, and strategy for the system design and the testing approach. This portion of the paper should not include detailed descriptions of components as it can distract from understanding the team's underlying strategic thinking, design and engineering decisions, or novel contributions.

B.3.4.1 Competition Strategy

The paper must include details on the team's strategy for the competition, including the plans for approaching the course and how the vehicle design relates to this approach. The course consists of multiple tasks with associated points for accomplished behaviors. The only required task is navigating through the start gates. Teams may choose to attempt the other tasks and complete the tasks in any order. The more tasks a vehicle is designed and engineered to accomplish, the more complex the overall vehicle system will be.

Consider 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. Based on history and the system engineering talents of the team, include a description the team's strategic vision.

Competition Strategy Scoring Metrics *(25% of score)*

Outstanding	Detailed description of the team's strategic vision and how the vehicle design compliments their goals. Detailed discussion on trade-off studies between system complexity and reliability during design development process.
Strong	The team's goals are clearly evident but not discussed in detail. Trade-off studies evident but lacking details.
Average	Brief mention of team's strategic goals and/or trade-off studies.
Below Average	Document hints at a goal for competition and/or trade-off studies.
Poor	Discussion of the team's vision is incoherent; rationale for competition goals is not discussed.
Requirements Not Met	No mention of competition goals.

B.3.4.2 Design Strategy

Given the strategy for success at the competition and the approach to managing complexity, the paper must include a description of the system design to meet the goals they established for the competition. Justification for design choices should be clear. Discuss how components and sub-systems were selected and integrated on the vehicle. For teams that are working with a previously designed vehicle, discuss how the design meets the current competition strategy and any modifications needed at the component, subsystem, and/or integrated system levels. Describe the 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 Appendix B.

Design Strategy Scoring Metrics *(25% of score)*

Outstanding	Provides in-depth explanations on design strategy and clearly identifies creative aspects of system. Creative design methodology is justified with required calculation steps and visual aids. Content clearly exhibits a Systems Engineering approach.
Strong	Provides explanations on design strategy and identifies creative aspects of system. Creative design methodology is justified with calculation steps and visual aids. Content hints at a Systems Engineering approach.
Average	Provides some information on design strategy and creative aspects of system. Creative design methodology is supported with a few calculations. Content could be justified as a Systems Engineering approach.
Below Average	Provides little information on design and creative design methodology. Little evidence to support applications of a Systems Engineering approach.
Poor	Provides limited information on the creative aspects of system. Creative design methodology is hypothesized. No evidence to support application of Systems Engineering principles.
Requirements Not Met	Creative aspects of design are not described.

B.3.4.3 Testing Strategy

Testing and experimentation is a crucial step to preparing and innovating a system design that strongly correlates with a competitive performance in the arena. The paper must include the approach to a testing strategy, including various test plans, both in-water and in simulation. There is a strong correlation between in-water testing time and competitive performance in the arena.

Consider the time needed to thoroughly test to meet the determined goals. Additionally, consider the demands of design and engineering with those of testing and experimentation.

Testing Strategy Scoring Metrics *(25% of score)*

Outstanding	Testing approach is presented in great detail, to include test strategy and plans. Component testing, sensor and control systems testing (bench tests and in-water) done in accordance with a test plan.
Strong	Detailed testing approach, test strategy, and plans. Documentation shows good overview of components, sensors and control system testing (bench tests and in-water).
Average	Testing approach is presented with sufficient detail, including mention of test strategy and plans. Documentation shows components, sensors and control system testing.
Below Average	Testing approach is presented with little to no detail. No mention of components or sensors testing.
Poor	Testing is done to a certain degree. No components and sensors are tested independently. There are no test plans.
Requirements Not Met	No mention of testing or connection with the system design.

B.3.5 Appendices

B.3.5.1 Appendix A: Component List

This appendix documents a list of all components utilized in the system design. In cases where components were developed by the team versus purchased off the shelf, this information should be included. Additionally, if commercial off the shelf equipment were significantly modified this should be noted. Under the column marked "Specs" a web link to the manufacturer's specifications may be provided. This standardized table will help document and track trends in component (hardware and software) usage and team metrics.

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase
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						
Algorithms						
Vision						
Localization and Mapping						
Autonomy						
Open-Source Software						

B.3.5.2 Appendix B: Test Plan & Results (Optional)

Based off the testing approach outlined in the paper, this appendix showcases the test plan that was developed and the detailed results that came out of testing. Teams should present their plans for testing, including algorithm testing in a virtual environment, component testing in a laboratory setting, sub-system testing in a relevant environment, and full system testing in a pseudo-competition environment. Test set up should be included and results presented. Any design modifications or changes in competition strategy as a result of testing should be discussed.

While this appendix is not required, excellence seen in this section can be eligible for a special judges' award.

The appendix may include detailed documentation covering the following areas:

- *Scope:* Objectives and test cases (this may also specify what was not included in tests)
- *Schedule:* Start/end dates and deadlines
- *Resource and Tools:* Resources and tools needed to conduct tests and assess results
- *Environment:* Description of the test environment, configurations, and availability
- *Risk Management:* Outline potential risks that could occur throughout testing
- *Results:* Detailed outcomes of test cases

Appendix C: Acoustic Pinger Specifications

The pinger type and configuration used in the competition are described in this appendix for reference so that teams may acquire a comparable unit for testing.

C.1. Pinger Model

The pinger selected for use is the Benthos ALP-365. This model has a selectable frequency between 25 and 40kHz with a 0.5kHz increment. It also has multiple options for repetition rate.

Pinger specifications can be found at: robonation.org/benthos-locator.
NOTE: These pingers are no longer in production and are unavailable for purchase. RoboNation is working to replace the pinger system in future competition years.

Pingers are activated as described in the applicable task descriptions. The frequency and pulse rate of the pingers in each field may change daily; this information will be made available to teams on site. The full range of frequencies (25 – 40 kHz) and pulse rate (0.5 Hz to 2 Hz) is used throughout the competition.

Figure 18: Benthos ALP-365 Pinger

During the competition there are multiple units active at any time, with at least one in each course. To mitigate interference issues, each active pinger is separated by at least 2 kHz in frequency. The pingers are also controlled such that they send out a pulse at time intervals in sequence with the other courses.

Appendix D: Harnessing the Submarine

For the safety of your vehicle, we required it to be slung on a harness or sling of some type. Even if the vehicle is light enough to hand carry, we don't want anyone to slip and destroy your vehicle or a piece of equipment. It's safter to lower it from a hoist, besides the vehicle also needs to be weighed, and would need to be slung somehow for the scale. Better for you (the builder) to incorporate a way to sling it, then for us (the competition coordinators) to have to put something together quicky on-site.

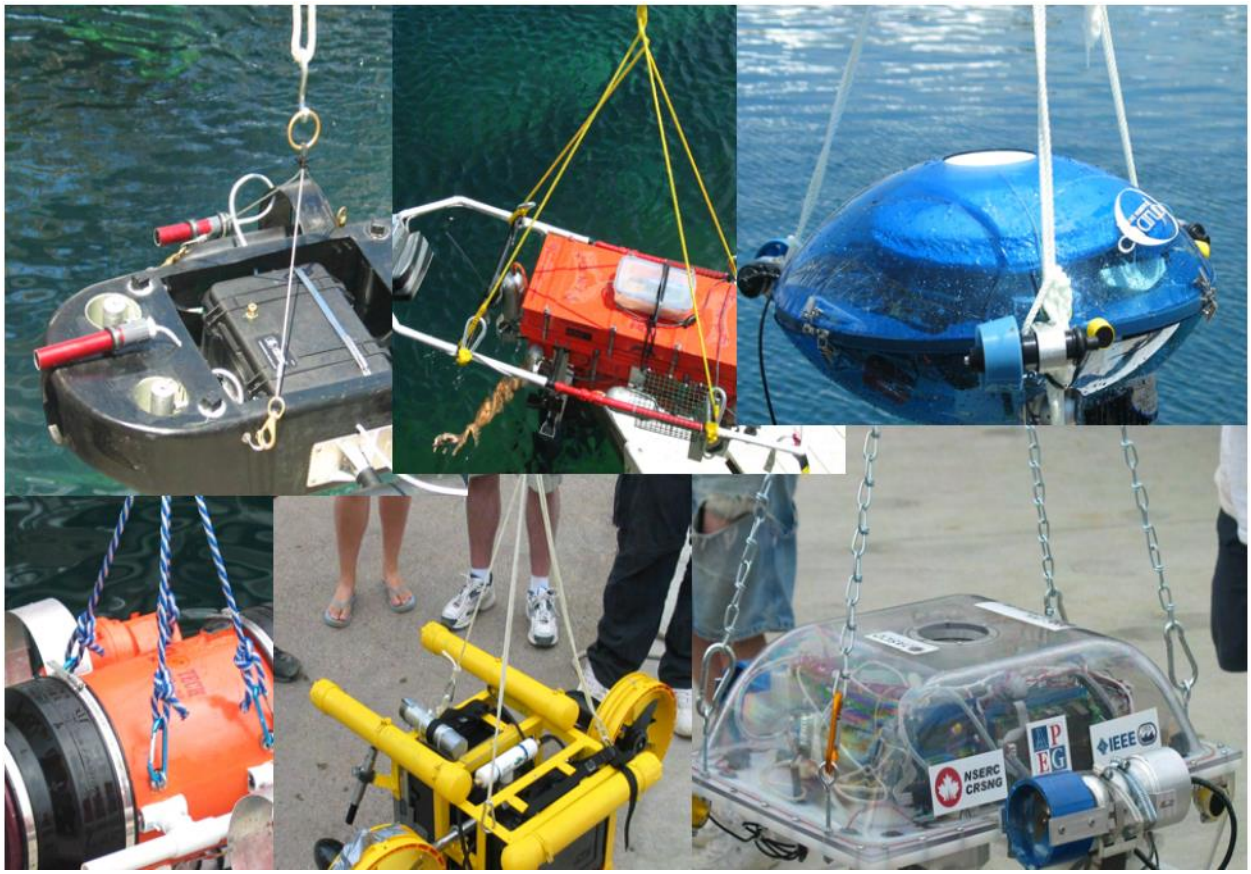

Figure 20: Examples of harnessess

So, what do you need to consider when making a harness? You'll need to incorporate some hard points into the vehicle which will support the vehicles weight, some chain or rope, and a way to attach/detach the harness (the easier, the better). The hard points are your concern (well, actually, everything is, but we can help with the rest).

Figure 19: Sewn slings (runners)

If you go with chain, your job us just about done. With rope, you'll have to tie some knots in the ends so that you can attach it to the vehicle's hard points. Another alternative to rope is to use sewn slings (a.k.a. Runners). You can find them in all sorts of lengths at a

rock-climbing store, or REI (and, of course, online). They come in assorted materials such as Nylon, Spectra, and Dyneema. Any of these materials will be strong enough for your application.

Back to rope, or more specifically, knots, those fiddly things that you tie at the end. There are only a few knots that you need to concern yourself with. Any knot reduces the breaking strength of a rope, but different knots affect the rope differently.

A **Figure 8** rewoven retain about 80% of the rope strength, it is easy to tie, and check. The only drawback to a figure 8 is that it can be hard to untie of heavily loaded.

The **Bowline** is another great knot to create a loop at the end of a rope. It retains 67% of the rope strength but can be easily untied after heavy loading (that can be good and bad).

If you need to join two ends of rope together (two separate pieces, or to make a loop out of one piece), the **Double (or Triple) Fisherman's** (a.k.a. Grapevine) know is the way to go.

Finally, to attach your harness (chain, rope, or slings) to your vehicle, your best bet is to use carabineers. Again, taking from the climbing community, the Black Diamond oval would do nicely, and are cheap. You can also find similar items in your favorite home supply store, but make sure they can take the weight of your vehicle.

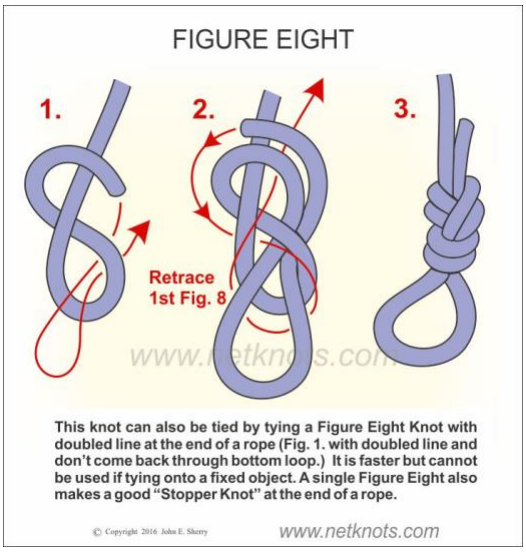

Figure 21: Figure 8 rewoven knot

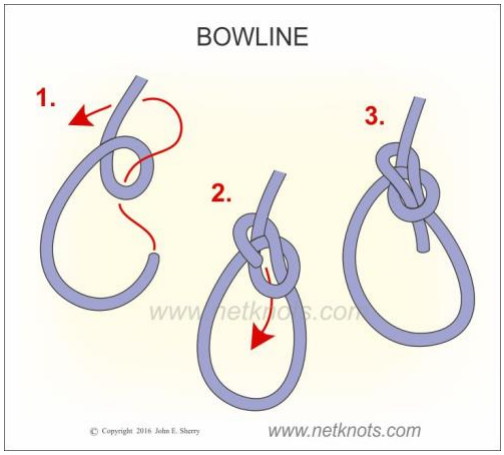

Figure 22: Bowlineknot

Remember, the key is to make it simple, KISS principle (Keep It Simple, Stupid), to attach and remove. Your goal is to make it easy for a diver in the water to detach and reattach the harness.

Figure 24: Black Diamond oval carabiner

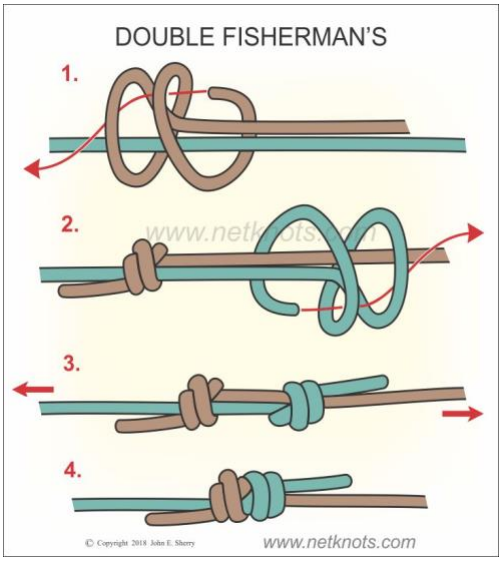

Figure 23: Double Fisherman's knot

Appendix E: Shipping Guidelines

Teams may ship their equipment to the conference hotel (Hilton Irvine / Orange County Airport). Team must pickup their shipment at the hotel by Monday, August 5 and crates must be shipped back to schools/home no later than Wednesday, August 14.

If you have questions or need assistance, please contact Cheri Koch at ckoch@robonation.org / 850-642-0536.

E.1. Inbound Shipping

Shipments cannot arrive prior to July 29th. The hotel does have a loading dock to facilitate your large containers. Schedule deliveries during weekday business hours so that management staff will be on-site to direct the shipment. Please provide the hotel's direct phone number to the shipping company so that they can call with questions. Hilton Irvine / Orange County Airport – +1-949-833-9999.

Shipping to the Competition – Shipments should be sent to the hotel using the applicable shipping label below.

Inbound Shipping Label:

FROM: School Name

Address
City, State, Zip
Country

Hilton Irvine/Orange County Airport
Attn: RoboSub / School Name – Guest Name
18800 MacArthur Blvd.
Irvine, CA, USA 92612

On-site Team POC Name: Phone:

E.2. Outbound Shipping

Begin working on your outbound shipping arrangements now! Batteries are exceptionally difficult to ship.

Shipment must be picked up no later than August 14. Shipments remaining after August 14 will incur a storage fee.

Shipments must be picked up from the hotel BEFORE the team departs or shipments must be dropped off at a local shipping facility. All shipments must be pre-paid – NO EXCEPTIONS.

LOCAL SHIPPING OUTLETS:

FedEx Ship Center (4 miles from event)
Accepts Dangerous Goods
7000 Barranca Parkway
Irvine, CA 92618
800-463-3339

FedEx Office Print and Ship Center (5.7 mi from event)
4187 Campus Drive, Suite M170
Irvine, CA 92612
(949) 854-7557
USA0590@FEDEX.COM

The UPS Store – Heritage Plaza (.7 miles from event)
14252 Culver Drive
Irvine, CA 92604
949-559-9007
Store0032@theupsstore.com

Hazardous Shipping: LIPO Batteries
FedEx Dangerous Goods **dghotline@fedex.com**
1-800-463-3339 x 81

A pick-up for a dangerous goods shipment can also be coordinated through FedEx. Team must create a label and arrange a dangerous goods pick-up. The team must ensure that a team member is present until the shipment is picked up. This must be done Monday – Friday 9:00 am – 5:00 pm. It will be very difficult if not impossible to schedule this pick-up on the weekend, so make arrangements early!!! The best way to get this shipment on its way is to drop it off at the FedEx Ship Center that accepts this type of shipment.

Outbound Shipping Label:

FROM:
School Name / Team Name
18800 MacArthur Blvd.
Irvine, CA, USA 92612

School Name
c/o School POC
Address
City, State, Zip
Country

Team POC Name: Phone: