



# Final Mission and Scoring

## 20 Years Under the Sea

20<sup>th</sup> Annual International RoboSub Competition

[www.RoboSub.org](http://www.RoboSub.org)

July 24-30, 2017

SSC Pacific TRANSDEC

San Diego, CA



## 1 COMPETITION POINTS OF CONTACT

Please direct your comments and questions to the [RoboSub forum](#) at the [robonation](#) website. Teams are encouraged to participate in the community.

### Technical Director:

David Novick: [dknovic@sandia.gov](mailto:dknovic@sandia.gov)

### Competition Questions (registration, travel, hotel or team deliverables):

[Competitions@AUVSIFoundation.org](mailto:Competitions@AUVSIFoundation.org)

## 2 REMINDER

The official source for all information concerning rules, interpretations, and information updates for the International Autonomous Underwater Vehicle Competition (RoboSub) is the World Wide Web home page: [www.RoboSub.org](http://www.RoboSub.org). On the main site, you can find information regarding eligibility, registration (the form and fees), websites, social media, journal paper requirements, team presentations & videos and much, much more.

## 3 THEME

This year's theme is based on Jules Verne's *20,000 Leagues Under the Sea* (as well as the 1954 Disney movie of the same name).

## 4 MISSION

The fundamental goal of the mission is for an AUV to demonstrate its autonomy by fulfilling the role of the Nautilus from *20,000 Leagues Under the Sea*. Orange guide markers will help direct the vehicle to the beginning tasks. Two pingers will guide the AUV to the remaining two tasks. The vehicle will have to Set Sail/Disable a ship (touch buoys), Navigate a channel (pass over an obstacle), Cultivate pearls (drop a marker), Battle a giant squid (fire torpedoes), Collect and Classify marine samples (retrieve object(s), surface, move/release object(s)), and Save sailors from the maelstrom (knock balls outside the octagon).

## 5 COMPETITION OVERVIEW

### 5.1 Venue

The competition will be held at the SSC Pacific TRANSDEC facility. The large facility allows us to divide the area into **four** sections, and run full missions in **every** section. The mission will take place in 16ft (4.9m) of water. During the semi-finals, one half (the competition side, two full sections) will be devoted to the semi-final runs. The other half (practice side, two full sections) will be devoted to teams wishing to continue to polish their algorithms. For the finals, the course will be expanded to include both sections of the competition side.

### 5.2 Weight and Size Constraints

For the RoboSub competition, each entry must fit within a six-foot long, by three-foot wide, by three-foot high “box” (1.83m x 0.91m x 0.91m). Table 1 shows the bonuses and penalties associated with a vehicle’s weight in air

Table 1: Vehicle weight in air with Bonus or Penalties		
	Bonus	Penalty
AUV Weight > 125 lbs (AUV Weight > 56.7 kg)	N/A	Disqualified
125 lbs ≥ AUV Weight > 84 (56.7 kg ≥ AUV Weight > 38)	N/A	Loss of 250 + 5*(lb – 125) 250 + 11*(kg – 56.7)
84 lbs ≥ AUV Weight > 48.5 (38 kg ≥ AUV Weight > 22)	Bonus of 2*(84 - lb) 4.4*(38 - kg)	N/A
AUV Weight ≤ 48.5 lbs (AUV Weight ≤ 22kg)	Bonus of 80 + (48.5 - lb) 80 + 2.2*(22 - kg)	N/A

### 5.3 Markers

Each marker must fit within a box 2.0” square and 6” long (5.1 x 5.1 x 15.2 cm). Each must weigh no more than 2.0 lbs (0.91 kg) in air. Any marker that exceeds these limits by less than 10% will result in a 500 point penalty. Any marker that exceeds these limits by more than 10% will be disqualified. Each marker must bear the team name, color or emblem. Markers will be cleared from the arena after each run. A reasonable amount of time will be spent looking for lost markers, however consider them expendable and have backups.

### 5.4 Torpedoes

The torpedo size, weight, markings and potential “loss” are identical to the Markers. The 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.

## 5.5 Pingers

The pingers will be Benthos ALP-365. The Benthos ALP-365 is user selectable from 25 to 40 kHz in 0.5 kHz increments. They will only be set to an integer frequency (25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39 or 40). The pingers in each section will use the same frequency. For example, the two pingers in section **A** will both have the same frequency, and the two pingers in section **B** will both have the same frequency (but different from section **A**). There will be four different frequencies used, one for each section, and only one pinger in each section will be active at a time. The ping for each section will be deconflicted with the pings in other sections such that only one pinger will ping at a time, see Figure 1. As shown in Figure 4, the frequencies for the sections will be: A – 30kHz, B – 40kHz, C – 25kHz, D – 35kHz.

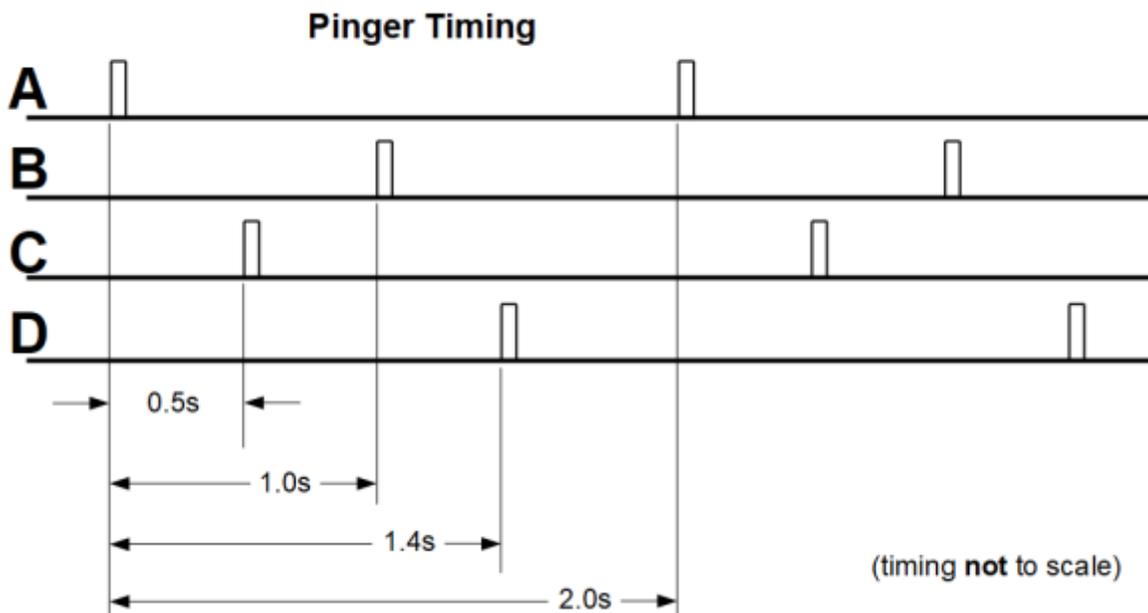


Figure 1: Pinger timer for the four sections.

## 6 COMPETITION RULES

1. The official source for all information concerning rules, interpretations, and information updates for RoboSub is the World Wide Web home page at: [www.RoboSub.org](http://www.RoboSub.org)
2. During the competition, the vehicle must operate autonomously, with no control, guidance or communication from a person or any off-board computer. The vehicle and any parts connected to the vehicle must submerge and remain submerged. No item may break the surface or be attached to the vehicle and left floating while the vehicle is underway.
3. Teams may be comprised of a combination of students, faculty, industrial partners, or government partners. Interdisciplinary teams are encouraged. Members from industry, government agencies, or universities (in the case of faculty) may participate, however, full-time students must compose at least 75% of each team. Participants must be enrolled at their schools as a full-time student per quarter/semester during winter and spring to

be considered “students.” The student members of a team are expected to make significant contributions to the development of their vehicle.

4. Only the student component of each team is eligible for the cash awards.
5. One student member of the team must be designated as the “team captain”. The team captain, and only the team captain, will speak for the team during the competition run.
6. No team member is allowed to enter the arena at any time (this includes wading, swimming and diving as well as floats, boats, etc.). Competition officials will be responsible for recovering lost vehicles. Officials will make all reasonable efforts to recover a lost vehicle but cannot guarantee that they will be able to do so. All teams recognize that by entering the competition, they risk damage to or the loss of their vehicle. The judges, officials, hosts, and sponsors can take no responsibility for such damage or loss.
7. The officials will suspend the competition at any time they deem that it is required by safety or security considerations.
8. There will be a semi-final round that most/all teams will compete in. After the semi-final round, the judges will convene and tally their scores. The judges have the discretion to select the number of teams entering the finals that they deem appropriate. Teams will be accepted into the final round in rank order from the semi-final round(s).
9. Depending on the number of contestants, in order to be considered for selection into the semi-final round, a vehicle must show that it can submerge and pass through the gate during the practice days (qualification). A vehicle that autonomously passes through the gate is guaranteed a position in the semi-final round. If this qualification requirement is necessary, it will be announced.
10. After the competition, the judges will issue overall standings. Any team that is accepted into the final round will be ranked ahead of all teams that have not participated in the final round.
11. Each team will have 20 minutes of competition time. The first 5 minutes constitute the *preparation period*. During this time, the vehicle may not be deployed in the water. The 15-minute-long *performance period* immediately follows. **These times are subject to change depending on the number of contestants.**
12. **Preparation period:** The vehicle may remain on the crane, or be placed on the dock, but not in or touching the water. A team may waive any portion of the 5-minute-long preparation period and start the 15-minute-long performance period. Once the performance period starts, the team forfeits any remaining time in the preparation period.
13. **Performance period:** When the officials signal the start of the performance period, the team may ask to have their vehicle deployed into the water and released to perform the mission. Only tournament officials may deploy and recover the vehicle. The time required to deploy and/or recover the vehicle does not count against the 15-minute limit (see: **Ending a run and retrieving a vehicle**). This is to prevent unsafe actions in an attempt to speed the recovery and deployment process.
14. **Multiple runs:** A team may attempt multiple runs during the performance period. Once a team has the officials re-deploy their vehicle, all points earned in previous runs are lost.

- 15. Ending a run and retrieving a vehicle:** At any time while the vehicle is underway, the team captain can 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 performance period stops when the official touches the vehicle to recover it. The clock continues its countdown once the vehicle is safely back at the dock, or the team establishes communication with the vehicle, whichever is first (i.e. if a team has wireless communication with the sub, the countdown clock continues while the diver is returning the sub to the start).
- 16.** 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 contestants.**
- 17.** If a vehicle experiences significant interference from a piece of equipment, line, cable or diver deployed in support of the competition, the team captain 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 captain does not make this request in a timely manner (as determined by the technical director or his designee) then the option is lost. Interference with the competition tasks does not qualify for this option, and a vehicle interfering with those items may be disqualified at the judges' discretion.
- 18.** The mission ends when any of the following occurs:
  - The performance period time limit ends.
  - The judges' order the end of the mission.
  - The team captain requests the end of the mission.
  - The vehicle breaches the surface outside the octagon (as determined by the judges, see: **Breaching** for more details)

## 6.1 Onsite Expectations

- 1.** The organizers have made every attempt to provide the competitors with maximum resources at the Competition site, including electrical power, test pools, Internet access, and practice time in the main pool. This event is not only open to the public, but there is a very high possibility that a potential future employer or sponsor may also be observing the event.
- 2.** It is expected that **ALL** teams will be present during **ALL** days of the competition. If your team does not make it into the finals, it is expected that your team will display your vehicle and be present in the team tent during this time (**ALL** teams, **All** days!)

## 6.2 Power

1. The United States uses a 120V 60Hz 15A electrical outlet plug. Usually 3 pins, two parallel blades (one wider than the other), and an offset semi-round pin. The wider blade is Neutral, the shorter blade is Hot/Line and the third pin is Ground.



## 6.3 Vehicles

1. Each team may enter one or multiple vehicles into the competition. Each vehicle will be physically inspected by the competition judges. The judges may disqualify any vehicle that they deem to pose an unreasonable safety hazard to 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 by any vehicle, nor for any damage or injury caused directly or indirectly by the disqualification of a vehicle.
2. During a qualifying, semi-final or final run, each vehicle must operate autonomously during its run. While carrying out the mission, no communication is permitted between the vehicle and any person or off-board computer. Vehicles must operate solely on their ability to sense and maneuver in the arena using on-board resources. When performing a qualifying, semi-final or final 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, buoys may be used on the surface for communication.
3. The weight of each individual vehicle must be less than the maximum allowed. Note that bonus points are awarded to vehicles that are below a certain value, and penalties assessed for those that exceed it (Table 1). The entire vehicle must fit within the volume described in the section Weight and Size Constraints.
4. All 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.
5. No materials (except for the markers/torpedoes and compressed air) may be released by the vehicle into the waters of the arena.
6. 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, test them either in the water, or in an open area pointing *away* from anyone and anything.
7. For the safety of your vehicle, we require it to be slung on a harness or sling of some type. Even if the vehicle is light enough to hand carry, we wouldn't want anyone to slip and

destroy their vehicle. Also, we need to weigh the vehicle, and require that the vehicle be slung somehow for the measurement. Please see the document *Harnessing the Submarine* for hints and ideas on how to accomplish this.

8. 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).
9. 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 thrusters qualify as is, as long as they are shrouded.
10. A vehicle will not be allowed in the water without a properly working kill switch and prop shrouds.
11. 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.
12. The officials will suspend the operation of a vehicle at any time they deem that it is required by safety or security considerations. Teams may be required to 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. When required, such technical information submitted to the judges will be held in confidence until the end of the competition.
13. Multiple vehicles are allowed in the competition. Each vehicle must include **all** the safety features mentioned above. Along with those requirements, these are specifications for multiple vehicles:
  - 1) The total dry volume for all the vehicles must fit within the maximum volume defined in the rules. The vehicles are not required to start joined together, nor are they required to rejoin at the completion of the run.
  - 2) Each vehicle will be weighed, and the bonuses/penalties will be calculated on a per vehicle basis.
  - 3) From the dock, each vehicle must pass through the validation gate first before heading off for its desired task.
  - 4) 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).
  - 5) The competition timer is only stopped when the last vehicle out on the course is returning to the dock. The timer starts again once this last vehicle is back at the dock.
  - 6) Teams wishing to have communication between each vehicle just post their method and frequencies on the official forum by a specified date (see forum for details). Frequencies that are always off limits for inter-sub communication are the frequency range used by the pingers.
  - 7) 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

encouraged to present post-run supporting documentation (e.g., vehicle logs) to the judges.

- 8) Points scored by any vehicle count toward that run regardless of whether that vehicle is killed prior to the end of the run.

## 7 SEQUENCE OF EVENTS DURING THE COMPETITION

### 7.1 Practice Runs

Practice time slots will be scheduled on an ad-hoc basis by the technical director or the designee during the practice days. It is our intent to provide as much practice time in the arena as is practical and to ensure minimal idle time in the arena. Each vehicle must be approved by the technical director or the designee before it will be allowed into the arena.

### 7.2 Qualification Runs

When necessary (greater than 24 teams registered), teams will be required to complete a qualification run. Anytime during a team's practice run (during the practice days), a team may request that their run be observed as a qualification run. The vehicle must pass through the gate autonomously (with everything attached to the vehicle submerging with the vehicle in order to qualify. Qualification awards the team with two time slots during the semi-finals days (one on the first day and one on the second day). For any team that have not qualified during the practice days, wild card slots will be held open during the semi-finals days. They must first qualify (pass through the gate) before they are able to choose a wild card slot. Only one slot per day can be used by a non-qualifying team. (**Heads up:** Starting next year, teams can pre-qualify by submitting a pre-competition video demonstrating prescribed maneuvering competency. No need to wait for on-site practice time. More details will follow.)

### 7.3 Time Slots Announced for Competition Runs

Competition time slots will be awarded based on standing after the static judging. The team that is in first place will have first choice, etc. Ties will be broken by a coin toss or random draw.

### 7.4 Timing for Rounds

The first 5 minutes are for preparation. During this period, the vehicle may not be deployed in the water. When the 5-minute limit has expired (or the team has waived the balance of the preparation time), the judges will begin the **performance time** clock. 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 mission.

### 7.5 Recovery of a Vehicle

The team captain can call for the end of a run. The time required for retrieving the vehicle back to the dock will not count against the **performance time** limit (unless the team has a way to communicate with the vehicle during its journey back to the dock). The clock is only stopped if the vehicle has passed through the gate. The clock is not stopped if the vehicle is retrieved before passing through the gate.

## 7.6 Semi-final Round of the Competition

Each qualifying team will be assigned a time slot to perform the mission. 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 launching site on the dock.

The mission will continue until the **performance time** limit has expired, or the team captain requests the end of the mission, or the judges' order the termination of the mission, or the vehicle breaches the surface. The judges may order termination of the mission at their discretion. Once the judges' order the end of the mission, no further points may be scored. The judges' decisions on the termination of the run are final.

## 7.7 Final round

After the semi-final round, the judges will rank-order the teams based on their scores from the semi-final round(s), and select the top teams to compete in the final round. The point totals and ranking from the teams not selected are frozen. For the final round, all point totals are set to zero. The ranking of teams selected for the finals will be determined by the points their vehicle scores in the final round based on the Performance Measures alone. Any team that is selected to be in the finals will finish ahead of the remaining teams which were not selected.

## 8 COMPETITION TASKS



Figure 2: Aerial photo of facility. The bridge structure has no piers or supports in the pond.

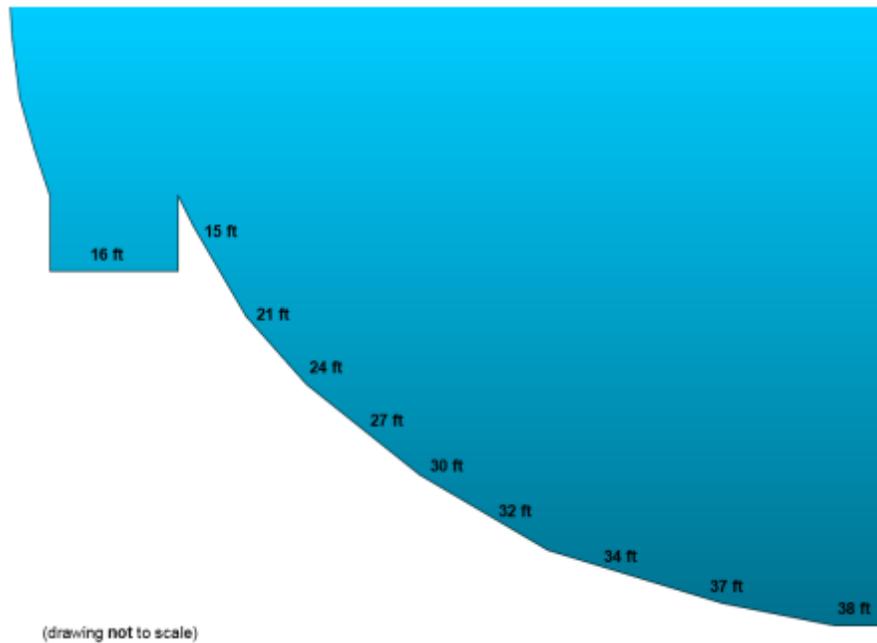


Figure 3: Cross section of facility

The launch point, gate, or any of the tasks will be placed such that no three elements are long a line.

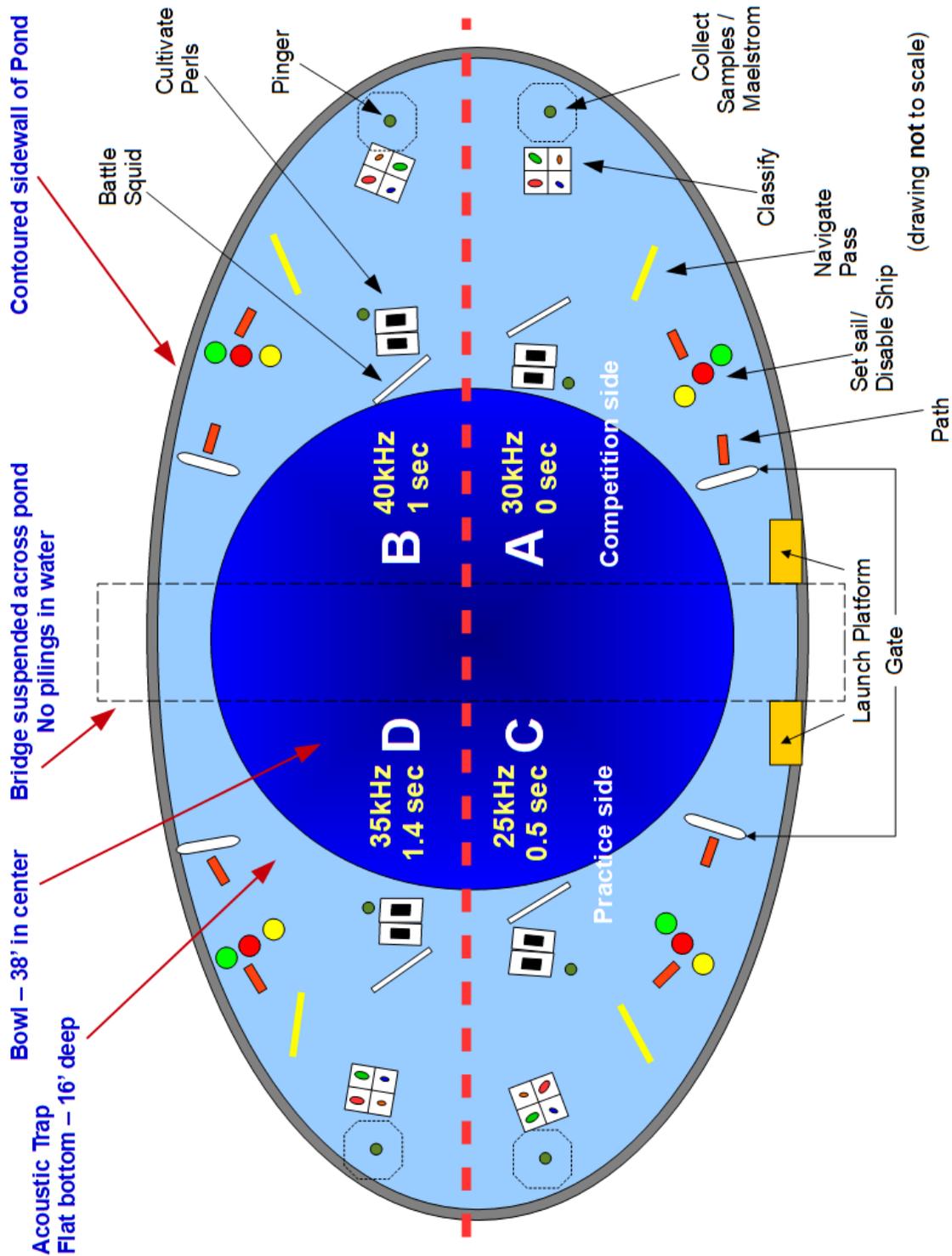


Figure 4: Course layout and pinger frequencies for Practice and Semi-finals

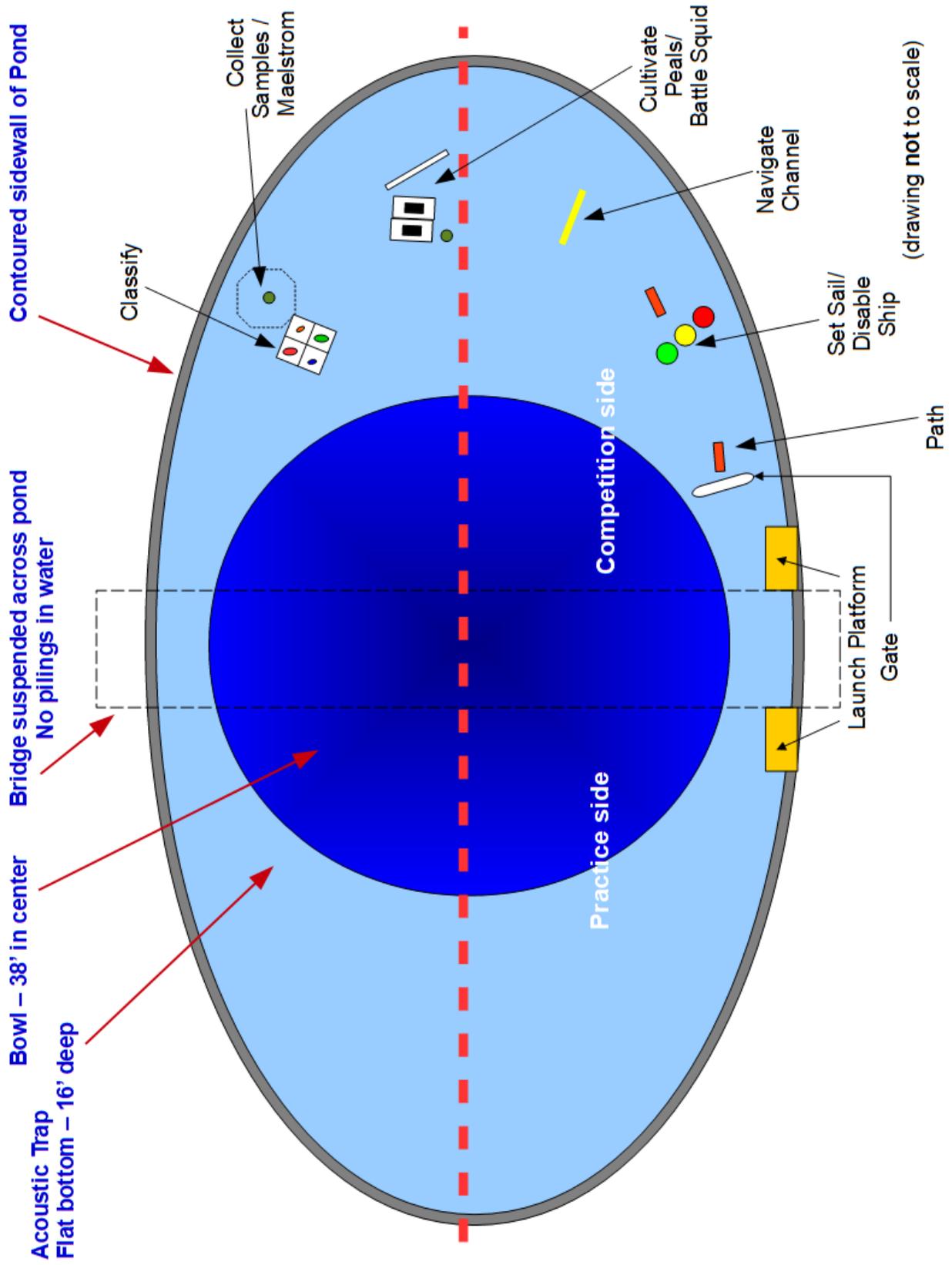


Figure 5: Course layout for Finals

## 8.1 Gate

The validation gate is made from 3 inch black PVC pipe. It will be buoyant, just below the surface and moored to the bottom. The vertical legs will be masked with **BLAZE ORANGE** colored Duck tape. The vehicle can pass through the gate at any depth from the floor to just below the surface.

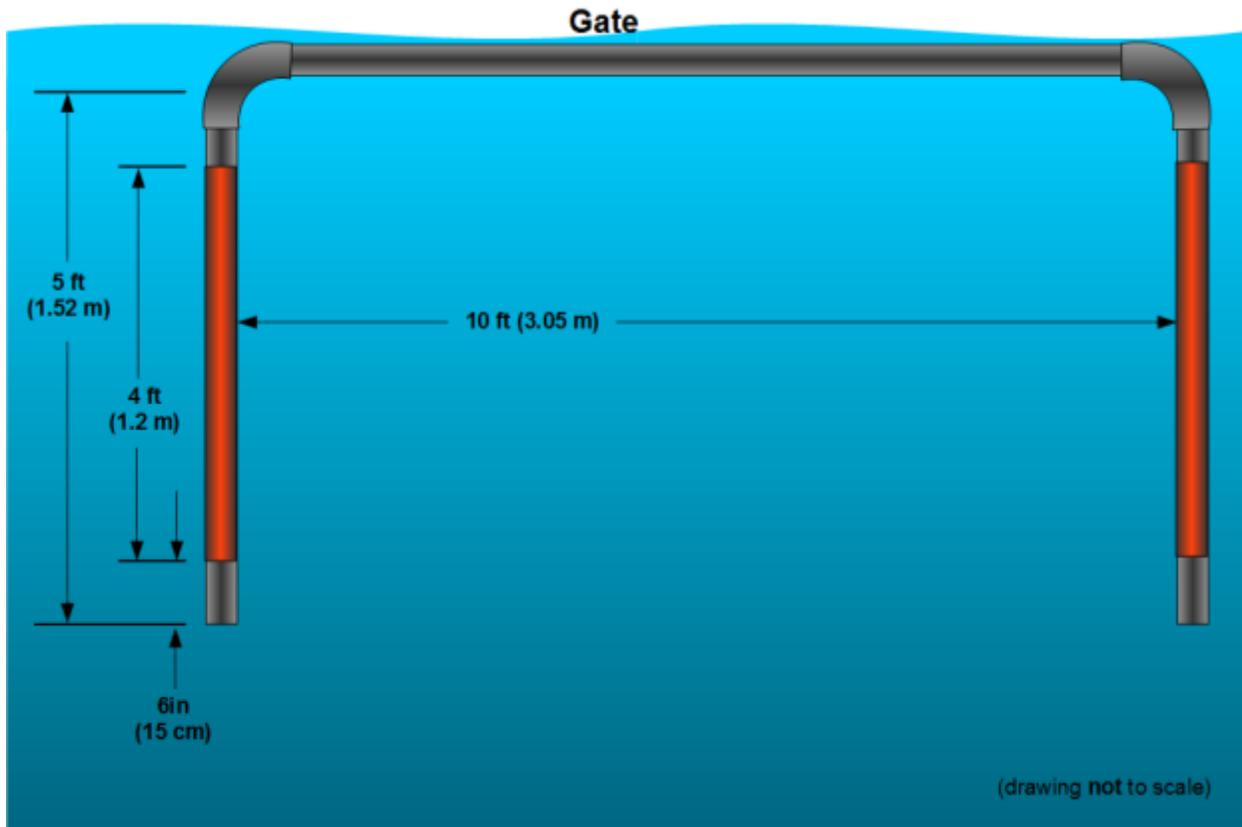


Figure 6: Validation gate.

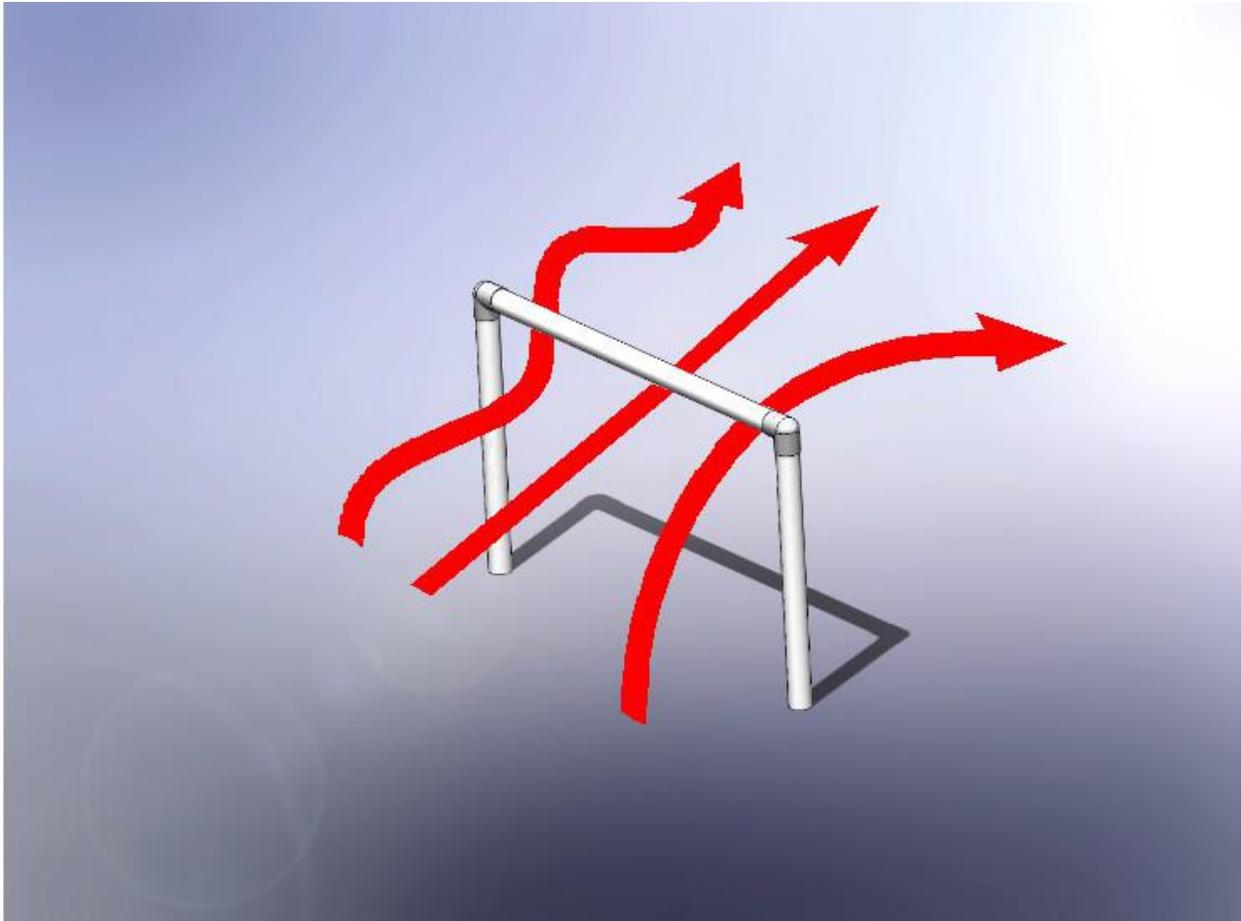


Figure 7: Valid ways to pass through the gate.

## 8.2 Path Marker

The path markers are 4 feet (1.2m) long by 6 inches (15cm) wide. The path will be covered in **BLAZE ORANGE** colored Duct Tape. Each path marker will be placed directly after the current task, and point to the next task. There will be one positioned at the gate that points to the Disable Ship (buoy) task. Positioned near the Disable Ship task, the next path segment will point to the Navigate Channel task. Those will be the only path segments which can be used to visually orient the vehicle.

## 8.3 Set Sail/Disable Ship (Buoy)

There will be two 9" (23 cm) diameter solid color Polyform A-0 buoys. One will be **Red**, the other will be **Green**. The third object will be a **YELLOW** buoy sized object (at least 9" – 23 cm diameter). All of the buoys will be moored to the floor. There is no set order for the color of the buoys. Points are awarded for touching any buoy. Additional points are awarded for touching the **Red** then **Green** buoy. Further points are also awarded for pushing the **YELLOW** buoy over an angle ( $\theta = \sim 10^\circ$  in any direction) to release a visual indication on the surface.

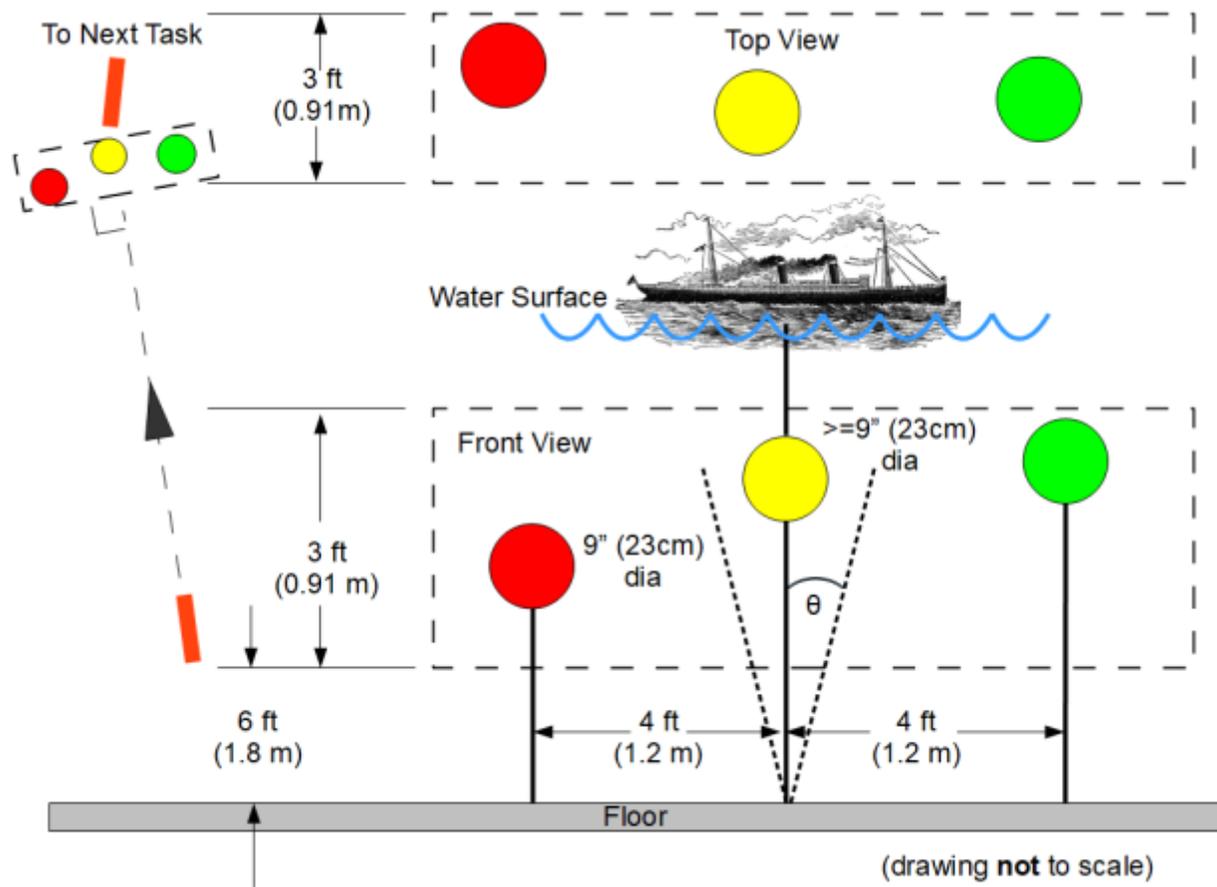


Figure 8: Set Sail/Disable Ship

### 8.4 Navigate Channel

A horizontal section of 2" PVC pipe, colored **YELLOW**, will be moored to the floor. Attached to this will be two **YELLOW** vertical sections. The vertical sections are tied to the horizontal PVC with rope. Points will be awarded for passing over the obstacle. More points will be awarded for navigating with "style" (sliding sideways, backward, upside down) through the channel.

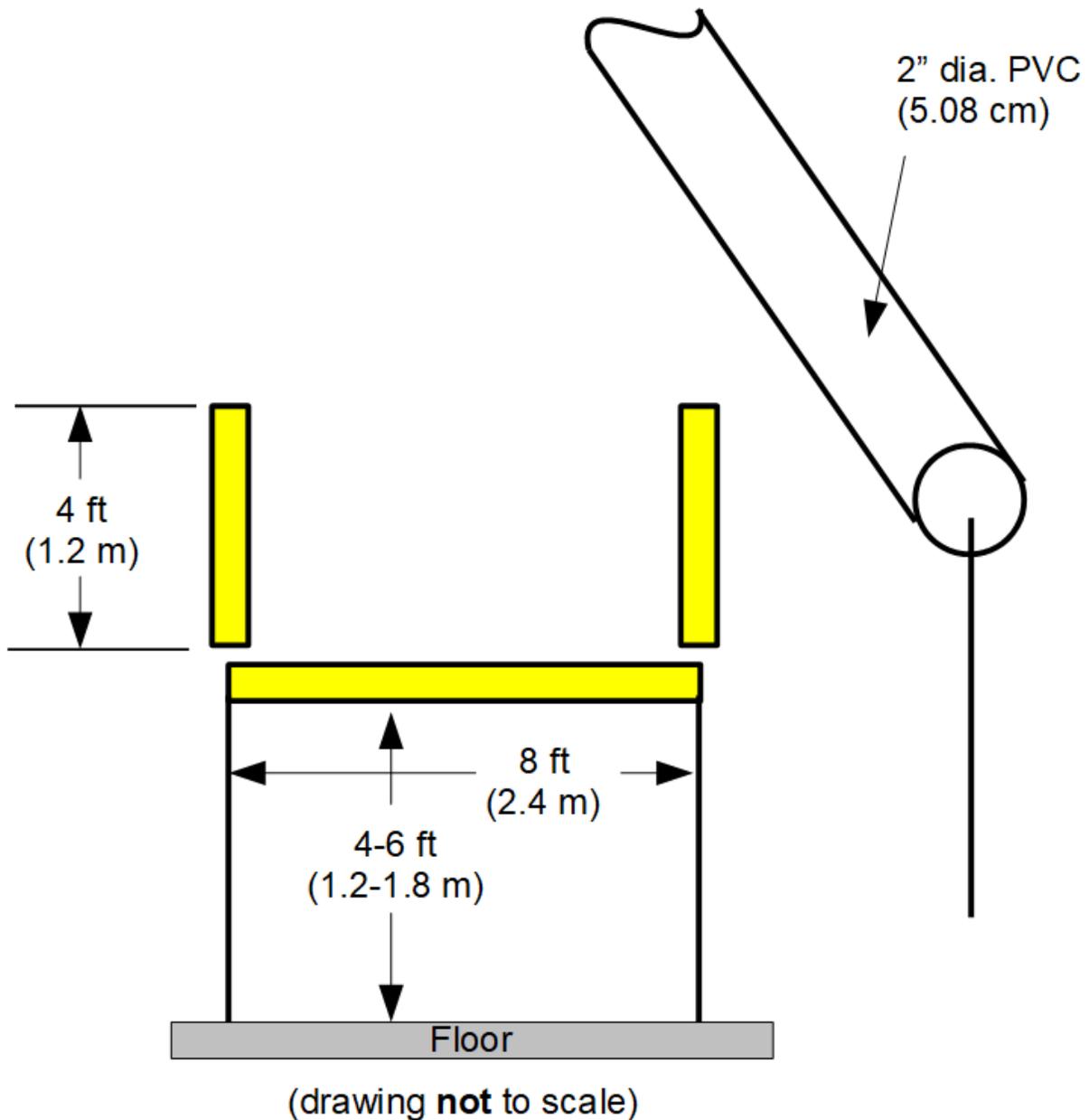


Figure 9: Navigate channel

### 8.5 Cultivate Pearls (Bins)

This task consists of two black bins. Each black bin will be surrounded by a 6" (15cm) white border. A total of two markers can be dropped from each vehicle. Inside each bin will be a saying (Pearls of Wisdom). One of the two bins will have a cover over the opening. The cover is **ORANGE**, while the handle is **PURPLE**. Points are awarded for dropping the markers in the open bin, or on the outer white edge. To obtain maximum points, the vehicle must remove the cover and drop both markers in the bin that was once covered.

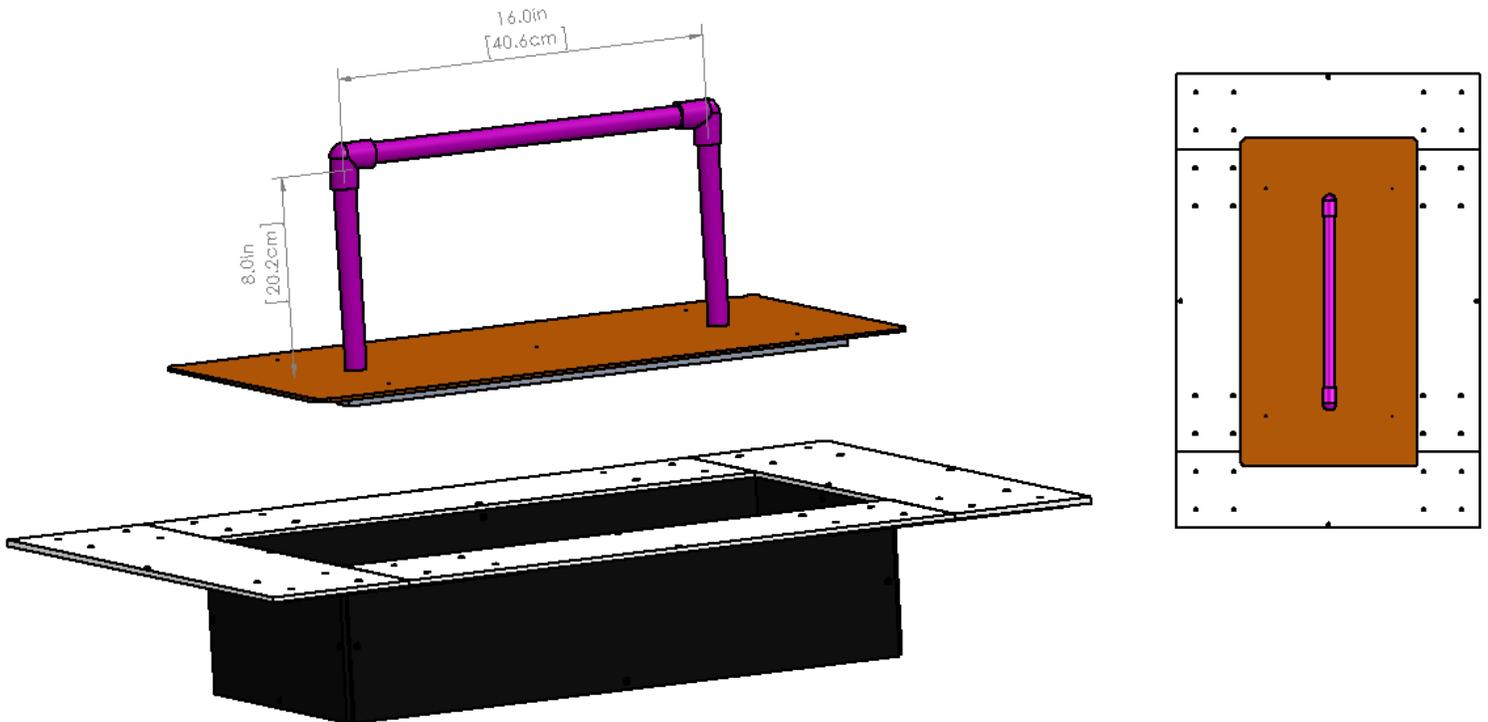


Figure 10: Bin with cover.

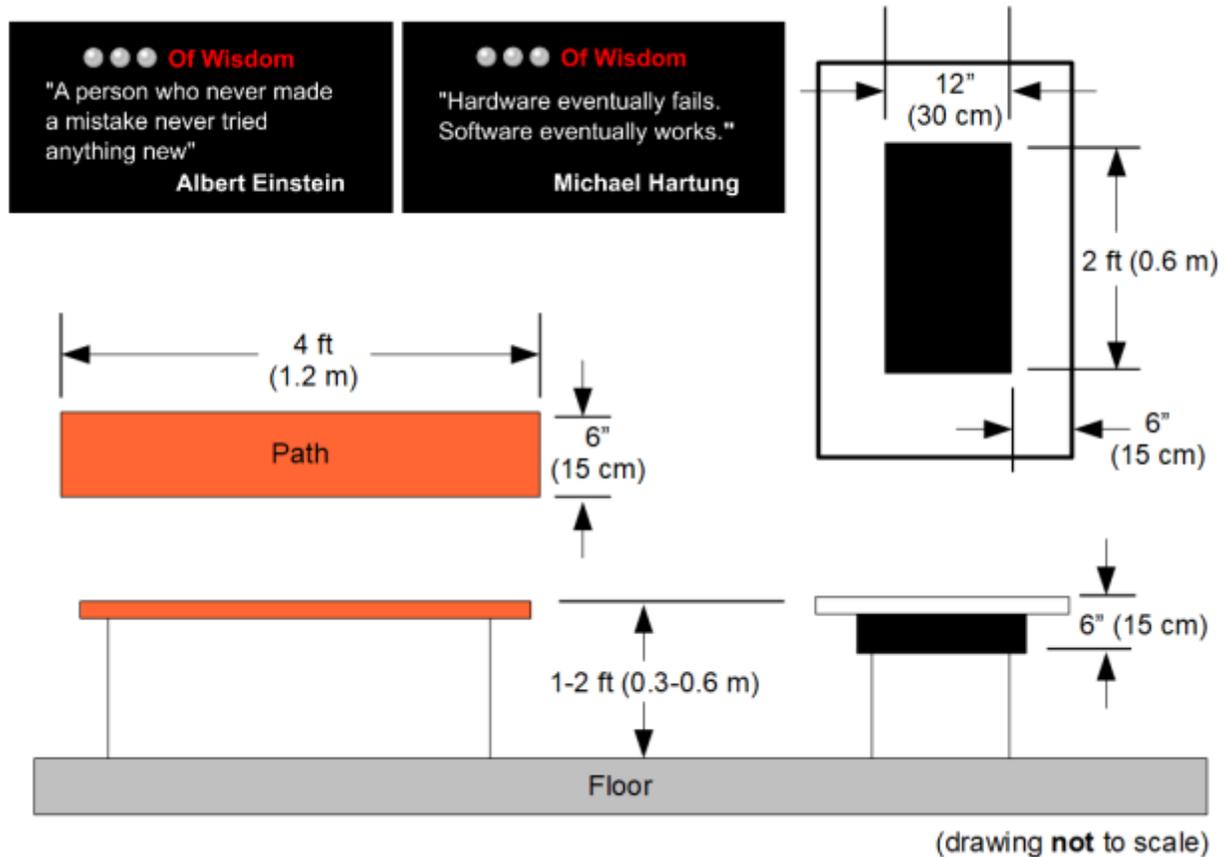
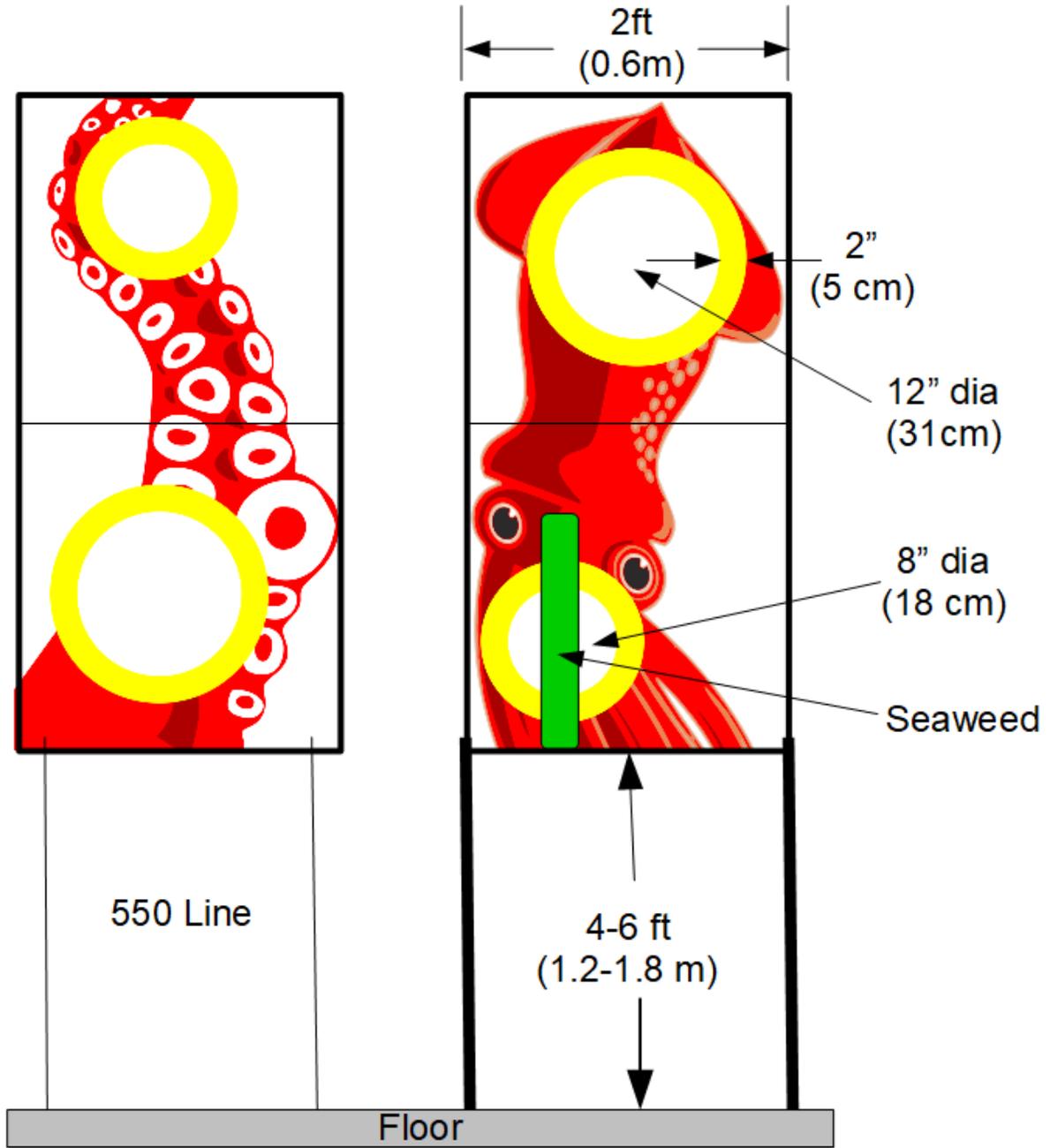


Figure 11: Path marker, bin and inserts.

## 8.6 Battle a Squid

There is a pinger which can be used to guide the vehicle to this task. There will be two separate vertical rectangles moored to the floor, each with two different diameter openings. There will be two small openings and two large openings. One rectangle will be rigidly secured to the floor with PVC pipe (the squid). On this rectangle (the one with the squid), the small opening will be obscured with floating “seaweed”. The seaweed will be made from a green pool noodle. The seaweed will need to be pushed out of the way in order to get a clear shot through the small opening. The second rectangle (the tentacle) will be held in place with just 550 paracord line, and will be able to move and sway. A total of two torpedoes can be fired from each vehicle. Points will be awarded for firing a torpedo through any of the openings. Maximum points will be awarded for firing torpedoes through each of the small openings (one through the squid and one through the tentacle).



(drawing **not** to scale)

Figure 12: Battle a squid with seaweed

### 8.7 Collect & Classify Samples/Maelstrom

This task consists of an acoustic pinger located off the floor of the pool. Placed directly above the pinger, on a tower, are four different marine samples, one colored **RED**, one **GREEN**, one **ORANGE** and one **BLUE**. The **RED** and **GREEN** samples are longer than the **ORANGE** and **BLUE** samples. Floating above the pinger on the surface is an octagon representing the Maelstrom. Captured along the octagon are three 8" (20cm) balls representing the three shipmates to rescue (Ned Land, Pierre Arronax and Conseil) from the Maelstrom. Each ball is contained within a structure built into the octagon. In order to obtain full points for the rescue, the ball must be completely outside the octagon. In order to obtain full points for the octagon, the vehicle must surface completely inside the octagon.

Positioned next to the pinger/tower is the classification table (large flat horizontal surface). The table will be ~1ft (0.3m) off the floor. There are four corresponding ellipses on the table, one **RED**, one **GREEN**, one **ORANGE** and one **BLUE**. Points are awarded for picking up an object from the tower, surfacing with an object and placing the "sample" on the "table". Maximum points are awarded for placing the same colored sample on its corresponding colored ellipse.

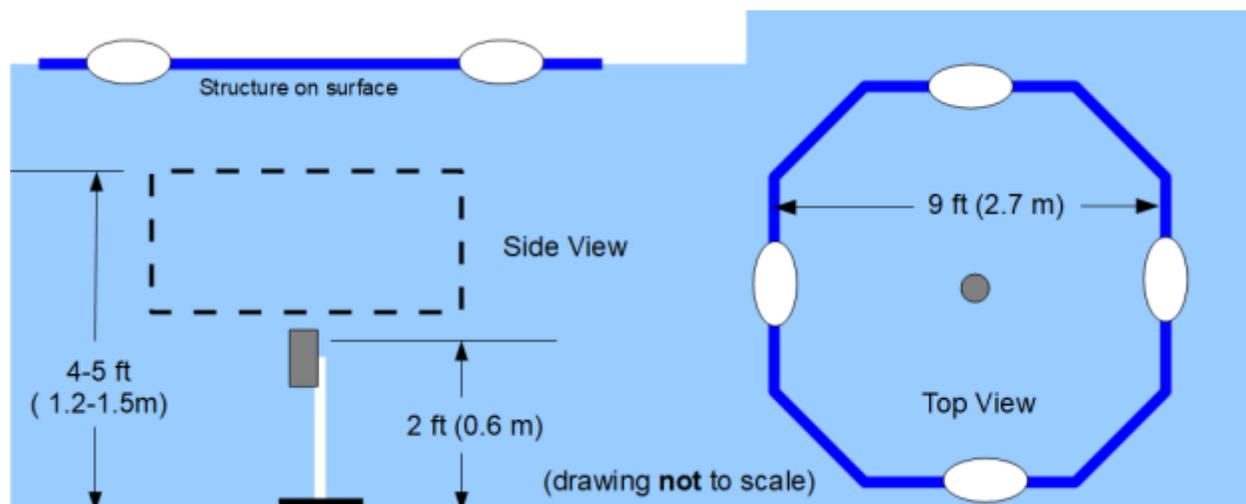


Figure 13: Collection point and Maelstrom

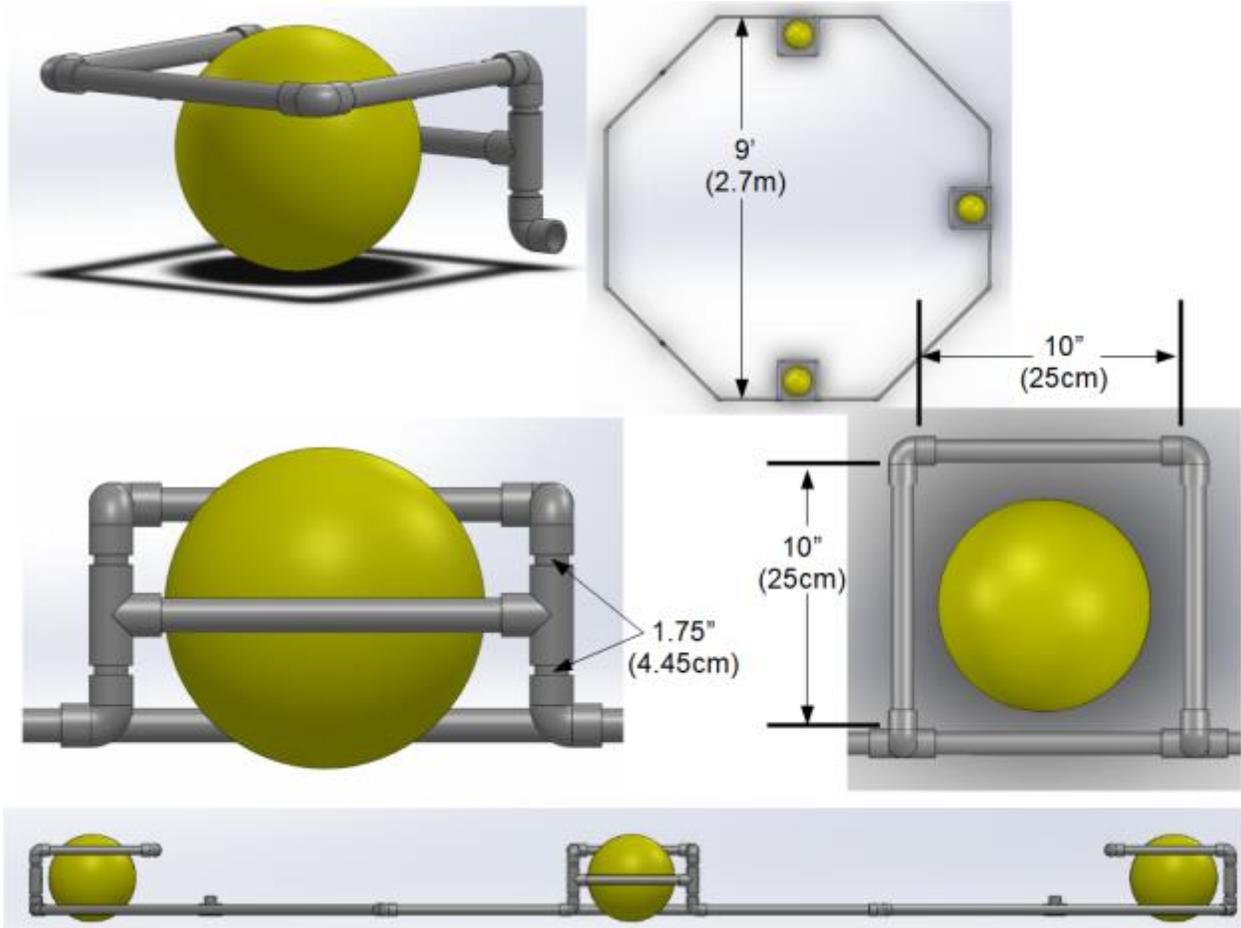


Figure 14: Maelstrom and crew rescue

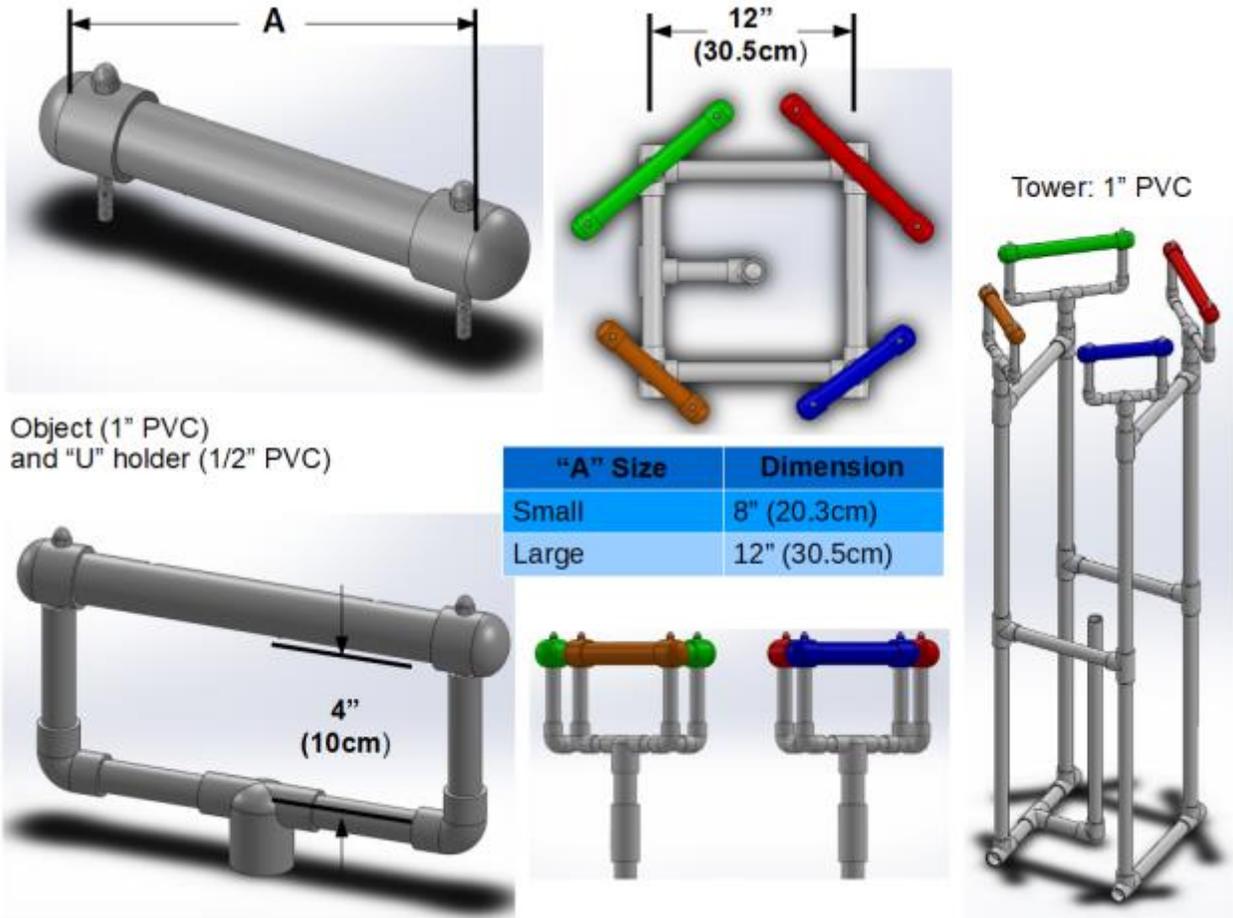


Figure 15: Tower holding the collection samples

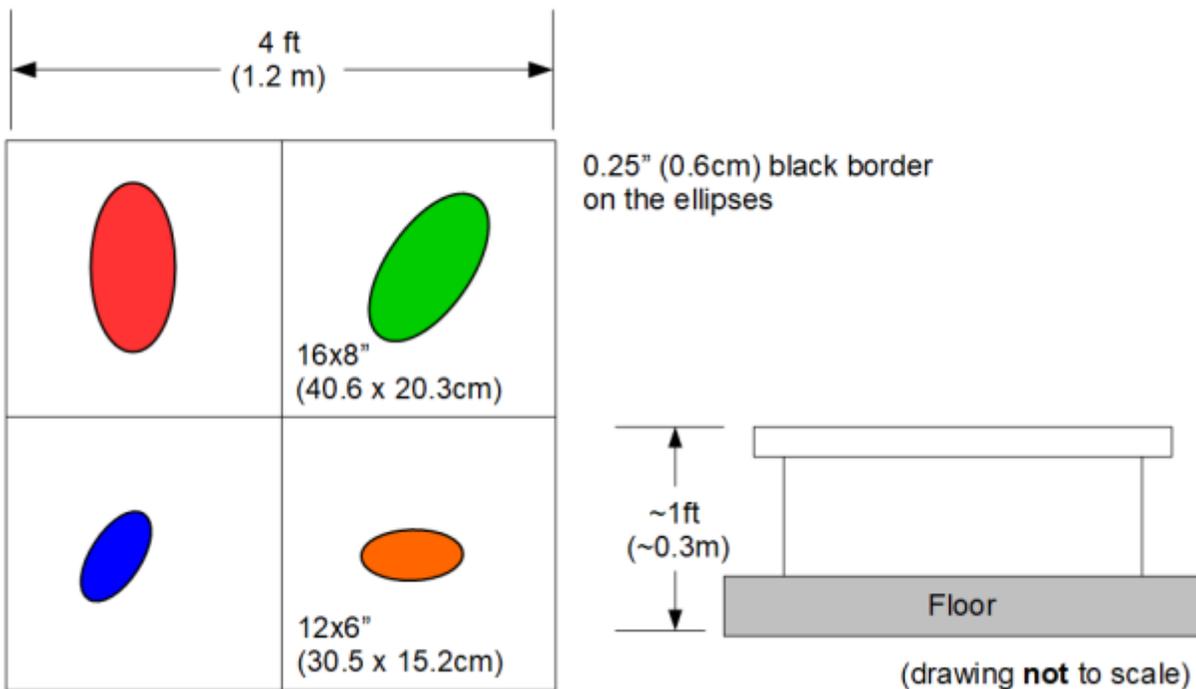


Figure 16: Classification table

## 9 SCORING

Each of the tasks has a point value associated with it. The tasks can be completed in any order by one or more vehicles. If multiple vehicles are deployed, points will only be awarded for the first time a task is completed by any vehicle. Subsequent accomplishment of the same task in the same run will not count for points. The recovered object must be attached to the vehicle when the vehicle is on the surface to obtain maximum points for “surfacing with object”.

The team captain 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. 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.

**NEW!** 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.

Cultivate Pearls / Battle a Squid and Collect and Classify 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 the Cultivate Pearls / Battle a Squid, or pinger near the Collect and Classify). However, additional points will be awarded if the team requests a random pinger.

A vehicle can accomplish tasks within each of the sections marked with a pinger, at the start of any run, a team 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 point after the vehicle has obtained points from the task(s) associated with the random pinger, the captain may request 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 captain 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 can be attained.

### 9.1 Time

Each vehicle is expected to have 15 minutes to complete the entire mission (with an additional 5 minutes of dock preparation time). Any vehicle that touches a buoy, passes over the obstacle, places at least one marker in the bin or on the lip (or fires a least one torpedo through the opening) and surfaces within the octagon will receive bonus points proportional to the unused time. Each vehicle must begin the run by passing under a validation gate. At any time during the run, if a vehicle breaches the surface, the run is terminated (See the section “Breaching” for the exception, *‘cause there’s always one*).

### 9.2 Breaching

When completing a sequence of tasks, a team may choose to complete the surfacing task (surface within the octagon) at any time. In this case (and only this case) a vehicle may breach the surface and then submerge again to complete the remaining tasks without risking disqualification. For a vehicle to continue after breaching, it must surface inside of, or touching the octagon. A breach outside of the octagon 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 that 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.

### 9.3 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 launching platform and start another new run. If a new run is begun, all points from the previous run are forfeit.

## 9.4 Point Breakdown

Subjective Measures	Maximum Points
Utility of team website	50
Technical Merit (from journal paper)	50
Written Style (from journal paper)	50
Technical Accomplishments (from static judging)	75
Craftsmanship (from static judging)	75
Team Uniform (from static judging)	10
Team Video	50
Discretionary static points (awarded after static judging)	40
<b>Total</b>	<b>400</b>

Performance Measure	Maximum Points
Weight	See Table 1 / Vehicle
Marker/Torpedo exceeding weight or dimensional specifications by <10%	-500 / maker
Pass through the Validation Gate	100
Maintain a fixed heading through gate	150
Follow the "Path" (2 total)	100 / segment
Set Sail (Buoy: Any, Red than Green)	400, 600
Disable Ship (Buoy: Yellow, push)	600
Navigate Channel (>1/2 above, <1/2 below) Straight through // w/ Style	400, 600 // +100 / style points (max of 8x)
Cultivate Pearls: remove cover	500
Cultivate Pearls: uncovered/covered (2 total)	500, 1000 / marker
Battle Squid: fixed lg,sm // sway lg,sm (2 total)	500, 800 // 600, 1000 / torpedo
Battle Squid: Bonus for both small openings	400
Surface within the Octagon	1000
Surface with the object	500 / object
Drop the object	200 / object
Object on Classification Table	500 / object
Correct Classification (Table) lg,sm	1000, 1500 / object
Rescue crew	500 / ball
Random Pinger first task	500
Random Pinger second task	1500
Inter-vehicle Communication	1000
Finish the mission with T minutes (whole + fractional)	Tx100

### 9.4.1 Subjective Measures description

**Technical accomplishments and craftsmanship:** These considerations will exclude any components of the design that are or could be (in the opinion of the judges) commercially

available or do not include a significant contribution by team members. In other words, if you use a well-built, well-designed off-the-shelf component, your team does not get points for the component's good technical design. You will get points for selecting a component that is, in the opinion of the judges, well suited to the engineering needs of the vehicle (system engineering).

#### 9.4.2 Performance Measures description

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

**Maintain a fixed heading through the gate:** Did the sub travel in a "straight line" 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 compensate for the vehicle's uncompensated yaw drift. For example, a vehicle that has a slight sinusoidal motion due to PID tuning, but on average is maintaining a heading has traveled straight through the gate. Or a vehicle that is searching for the gate, finds it and heads through it has traveled straight through the gate. A vehicle that is pointed away from the gate to compensate for un-tuned motors and yaw drift has not traveled straight through the gate.

**Follow the "Path":** How well did the vehicle find and follow the segment?

**Set Sail / Disable Ship (Buoy):** Partial points are awarded if you track the buoy(s) but you brush by instead of a deliberate bump. Full points to touching the Red then Green buoy without touching the Yellow in-between. Full points for tilting the yellow buoy at least 10°, partial points are awarded for not fully tilting the buoy. Manipulation of only the rope holding the buoys/ship will not count for points.

**Navigate Channel:** Did the vehicle pass over the PVC without touching it? What percentage of the vehicle passed over the top of the object?

"Style" is broken into 90° increments. For every 90° change in orientation, a bonus is added. The channel starts ~10 ft (3m) before the PVC structure and continues ~10 ft (3m) after the structure. For example:

- If a vehicle changes its heading by 90°, and passes through the structure, then 1\*(bonus points) are added to the base score.
- If a vehicle passed through the structure backwards (180° change), then 2\*(bonus points) are added to the base score.
- If a vehicle is able to complete a full barrel roll (360° rotation), then 4\*(bonus points) are added to the base score (and 8\* for a 720°!).

**Cultivate Pearls:** The covered bin is worth more points than the uncovered bin. Two markers in any bin will count twice. Partial points may be awarded if the marker lands near or on the lip of the bin.

**Battle a Squid:** A torpedo must pass through the opening for full points. Bonus points for passing one torpedo through each of the small openings. Partial points may be awarded if the torpedo touches the yellow border without passing through.

**Surface within the Octagon:** The sub must fully surface within the octagon to obtain full point value. Partial points will be awarded based on how much the sub is outside the octagon.

**Grabbing the Object:** The structure must be captured and constrained by the vehicle to obtain full points. Partial points may be awarded for a partial capture.

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

**Object on Classification table:** The object must remain on the table to obtain full points. Partial points may be awarded if the objects lands near or falls off the table.

**Object near ellipse:** The object must be completely within the correct color ellipse to obtain full points. Partial points will be awarded based on how much the object is outside the ellipse.

**Saving Shipmates:** The ball must be completely outside the octagon to obtain full points. Partial points will be awarded for a ball that is released but is still inside the octagon.

**NEW! 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. The level of the communication and the complexity of the behaviors derived by the communication are what determination the level of points awarded.

**Time Bonus:** At a minimum, a sub must touch a buoy, pass over the Navigate Channel task, drop at least one marker in the bin (or fire one torpedo through the cutout), and fully surface within the octagon to obtain a time bonus. These tasks can be completed in any order.

The time bonus is 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).