

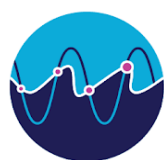
UNDERWATER ROBOTICS  
**CHALLENGES**  
MORE THAN A CHALLENGE...

# Underwater Robotics Challenges

## 2024 Rulebook



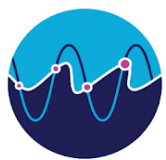
UNDERWATER ROBOTICS  
**CHALLENGES**  
MORE THAN A CHALLENGE...



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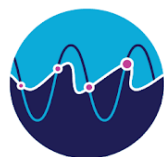
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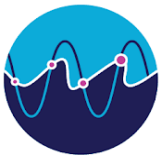
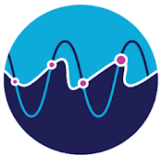


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## 1. About Underwater Robotics Challenges (UWR)

Underwater Robotics Challenges are a series of annual Underwater Robotics and Artificial Intelligence Challenges that occur in the MENA Region powered by the Underwater Robotics Research Center.

The UWR Challenges were launched to creatively address and develop innovative ideas that make a difference! With the technological development and the emergence of many problems that need to be solved by using the technology of robots, marine technology, and artificial intelligence, such as monitoring and following-up water and sea pollution. As well as entertainment and marine tourism and the pursuit of fish and coral reefs.

Underwater Robotics Challenges include a series of challenges held at the local, regional, and international levels, in each challenge we aim to encourage new features and opportunities to share your design and ideas with the ocean.

## 2. Challenges

### 2.1. ROV Challenge

Remotely Operated underwater Vehicle (ROV) Challenge is an underwater robotics challenge that aims to teach and creatively apply skills to solve real-world problems and strengthen critical thinking abilities, collaboration, entrepreneurship, and innovation in marine science by building Remotely Operated underwater Vehicles. The ROV Challenge has two main categories as follows:

#### a. Seniors Category

This category is for undergraduate and postgraduate students with no restrictions on age or technical and non-technical levels. In this category, ROV (Remotely Operated underwater Vehicle) is required to be built by the team members to make specified simulated tasks underwater with specific scientific and engineering concepts.

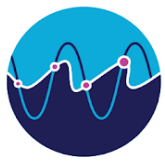
#### b. Juniors Category

This category is for high school students with no restrictions on age or technical and non-technical levels. In this category, ROV (Remotely Operated underwater Vehicle) is required to be built by the team members to make specified simulated tasks, with less complexity than the seniors' teams, underwater with specific scientific and engineering concepts.

### 2.2. AUV Challenge

Autonomous Underwater Vehicle (AUV) Challenge is an underwater robotics challenge that aims to push the applicants towards the latest technologies and develop their skills in underwater robotics by





applying them in real-life simulated missions to provide modern solutions for the marine field using Autonomous Underwater Vehicles. This challenge has one category as follows:

a. Seniors Category

This category is for undergraduate and postgraduate students with no restrictions on age or technical and non-technical levels. In this category, AUV (Autonomous Underwater Vehicle) is required to be built by the team members to make specified simulated tasks underwater with specific scientific and engineering concepts.

### 3. Rules and Guidelines

#### 3.1. Timeline

- **July 1st, 2024:** Registration Starts
- **July 25, 2024:** Registration Ends
- **August 24, 2024:** Submissions Deadline
- **1<sup>st</sup> week of October 2024:** Regional Finals
- **October 10 – October 14, 2024:** International Challenge

#### 3.2. Registration

- Registration will open from July 1, 2024 to July 25, 2024
- Seniors Category is for postgraduate and undergraduate students
- Juniors Category is open for high school students
- The team members cannot be less than 3 and not more than 20 including mentors or advisors
- All data should be written in English
- Email and phone number for each member must not be duplicated

- **Fees:**

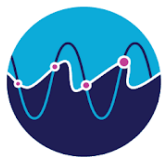
500\$ registration fees for Seniors Category teams in the regular registration period, for 10 team members in the team, 10\$ will be added per each extra member.

For more information, please visit the [website](#).

- **Registration steps:**

1. Choose your underwater robotics challenge and category.
2. Sign up to create your team account.
3. After signing up for the first time you will receive a confirmation link sent to your email, to verify your account.
4. After verification, go to the log in page, use your email and password to edit/complete your team data.





5. Fill and write the team data. You can save your progress and continue with the form later
6. Review for the last time and click submit.
7. You will be directed to payment page. Fees will be determined based on team category, number of participants and the challenge/s you have chosen.
8. After payment successfully completion, you will receive a confirmation mail which includes all the data you have written in the form.

Note: You may start working on your vehicle during the registration steps and do not wait to the registration deadline.

### 3.3. Challenges Phases

#### 3.3.1. Submissions

- **Proposal (15 points)**  
Each team must submit a proposal for their product before the competition to show how the product will be suitable for the Underwater Mission, check the criteria of the proposal from [Appendix A](#).
- **Cost Analysis (20 points)**  
Each team should prepare cost analysis and send it before the competition – 20 points, check the criteria of the cost analysis from Appendix B.
- **Technical Report (30 points)**  
Each team should prepare a technical report document and send it before the competition. Check the criteria of the technical report from [Appendix C](#).
- **Safety Document/Software Safety Check (15 points)**  
Each team will be asked to deliver a safety document prior the competition. All rules are mentioned in the [Safety section](#).

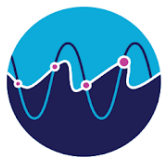
#### 3.3.2. Challenge Day

The challenge will be divided into three sections as following:

- **Safety Check (35 points)**  
Each team will perform the safety check according to the specifications described in the [Safety section](#), teams that cannot pass the check will not be allowed to compete in the Underwater Mission.
- **Underwater Mission (180 points)**  
Each team will have two trials for the Underwater Mission using their robot. The total time of each trial is 30 minutes. 5 minutes for setup, 20 minutes for performing the tasks, and 5 minutes for leaving the station. Check the Underwater Mission details [here](#).
- **Onsite Pitching (20 points)**







Each team will be required to perform a 5-minute pitch presenting their work, the pitch will be followed by 10 minutes of Q&A for evaluation by the judging panel. Check the pitching criteria from [Appendix D](#).

## 4. Playground and Stations Specifications

### 4.1. Playground Specifications

The Underwater Mission will be performed in a swimming pool, the necessary details for the pools are mentioned in the description of each task in the Underwater Mission section for each challenge and category ([ROV Seniors Category](#) - [ROV Juniors Category](#) - [AUV Seniors Category](#)). Additional details are included in [Appendix E](#).

### 4.2. Power Sources

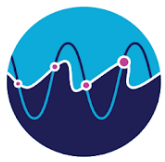
#### 4.2.1. AC Power Sources

One AC Hub with 220 volts will be provided for each team at each station.

#### 4.2.2. Main Power Source

- The competition will provide a power supply limited to 48-volts and 30-amps for all categories.
- Vehicles in Juniors category can be powered by power supply less than 48 volts but in Seniors; it is mandatory to be powered by 48 volts.
- Each vehicle should use a suitable fuse according to fuse calculations (which must be clearly detailed in the safety document), maximum fuse rating to be used is 30-amp.
- It is allowed for any team to use their own power supply, but it must pass from the safety check, and it is restricted to 48 volts maximum and 30 amperes maximum.
- The power supply should provide power to the vehicle through one input. No external power will be used.
- Each component in the vehicle should be powered through the main supply (motors, valves, cameras, and modules).
- No power conversion is allowed until the power reaches the vehicle.
- Batteries aren't allowed for the main power (except for AUVs)
- Each vehicle should be connected to the power supply via [Anderson Powerpole](#) connectors or via [XT60H](#) connectors, the team connectors should be the male side of XT60H.





*Figure 1: Red and black Anderson power-pole connectors*



*Figure 2: XT60H (XT60 upgrade) connectors*

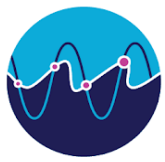
#### 4.2.3. Auxiliary Power Sources

- The competition will provide a power supply limited to 12V/10A for both categories.
- The device should have a maximum fuse of 10-amps or less.
- It is allowed for any team to use their own power supply, but it must pass from the safety check, and it is restricted to 12V/10A maximum, also the vehicle must have a suitable fuse for the maximum power used.
- Batteries are allowed as the auxiliary power, but not in the water, just on the station and with maximum 12V/12Ah.

### 4.3. Vehicles and Additional Devices Specifications

- For the Seniors Category, vehicles are restricted to 90 cm in diameter and 35 kg in weight, vehicles above these limits will not be allowed to compete in the Underwater Mission.
- For the Juniors Category, vehicles are restricted to 80 cm in diameter and to 30 kg in weight, vehicles above these limits will not be allowed to compete in the Underwater Mission.
- Any modifications on the vehicles after the size and weight measurements are not allowed.
- Pneumatics and hydraulics are permitted.
- Lasers are permitted.
- A camera is required in the main vehicle.
- It is not allowed to use multiple vehicles, but it is allowed to use any additional device to help the vehicle in performing the mission.



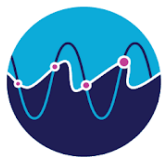


- The tether of additional devices should be hardly attached to the tether of the main vehicle.
- The additional devices and the tether will be considered in the size and weight check.
- Each team will be required to submit design documents for the main vehicle, additional devices, and their SIDs.

#### **4.4. Penalties and Disqualifications**

- Trying to cheat in any way leads to disqualification.
- Disrespecting the judges or the organizers leads to disqualification.
- Not passing the safety check leads to disqualification for the Underwater Mission.
- The vehicle that cannot pass the size and weight measurements will be disqualified for the Underwater Mission, but the team can still participate in the other challenge phases.
- Participation of mentors, instructors or any person who is not registered with the team in any activity (mission, safety or pitching) leads to a 5-points penalty.
- During the time of mission only four members are allowed on the station, any additional member will interfere leads to a 5-points penalty.
- Touching the playground by the vehicle or the tether leads to a 5-points penalty.
- Any debris left in the water results a 5-points penalty for each one.
- If the team exceeds their allowed time for leaving the station, a 3-points penalty will be deducted for each extra minute.
- Any late submission will be accepted but with only half the score in case no acceptable excuse is sent 5 days before the deadline.





## 5. Safety

Safety check will be divided into two checks, Software Safety Check and Hardware Safety Check.

### 5.1. Pre-inspection Safety

Each team must submit a safety document that will be added to the onsite safety score. The document should be in PDF format with max size 3 MB. It should be uploaded to Google Drive named as [2024\_ChallengeName\_ Category\_ TeamName\_ Software\_ Safety], and to be emailed to [info@uwrchallenges.org](mailto:info@uwrchallenges.org) before September 20, 2024.

Moreover, this document should demonstrate the procedures you followed to make your product safe.

The document should demonstrate:

- The IP rating of sealing and how the motors and control box are sealed
- How the motor propellers are shrouded in front and back
- The main fuse connection
- Fuse calculation

Example:

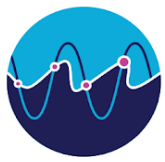
6	Motors	*	3	=	18	Amp
2	Servos	*	0.5	=	1	Amp
4	Cameras	*	0.25	=	1	Amp
2	Valves	*	0.5	=	1	Amp

Total rated current = 21 amp, the overcurrent =  $1.5 * \text{total rated current} = 31.5 \text{ amp}$ ; you should use a 30 amper fuse.

- Other fuses: you should protect the components in the low level
- Isolation of DC and AC components from each other and mark them with labels
- Electrical Diagram should demonstrate electrical connection, joints, and power. The diagram should have 2 sections (one for underwater system and one for the station)
- Fluid Diagram should demonstrate fluid connection, joints, and power. The diagram should have 2 sections (one for underwater system and one for the station)
- There are no exposed wires
- Strain reliefs used
- Any additional device(s) used to aid the Vehicle in the task
- No sharp edges in the vehicle

The document should also include some pictures of your vehicle to visualize the points mentioned above.





## 5.2. Onsite Safety Check

Prior to the Underwater Mission, each team must pass the onsite check. The safety judge(s) will decide whether the team is allowed to compete or not.

The judge(s) will evaluate your robot according to the following criteria:

- Motors shrouding
- Motors and control box sealing and strain reliefs
- The main fuse
- Exposed wires
- AC and DC labels
- Additional devices safety
- Sharp edges
- Fluid power and regulators

## 5.3. Safety Check Scoring

The score of the Pre-Inspection Safety Check will be added to the total score of the safety with maximum of **15 points**.

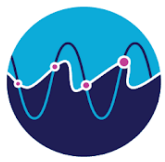
The total score of the Onsite Safety Check will be **35 points** divided as follows:

- Motors shrouding (**5 points**)
- Motors and control box sealing and strain reliefs (**5 points**)
- The main fuse (**5 points**)
- Exposed wires (**5 points**)
- AC and DC labels (**5 points**)
- Fluid power and regulators (**5 points**)
- Sharp edges (**5 points**)

## 5.4. Safety Check Rules

- Only **4 members** from each team will be allowed to attend the Onsite Safety Check.
- Each team will be asked to make a dry test to check the vehicle.
- If the team uses their own power supply, it must be tested.
- Each team that uses fluid power will be asked to test the fluid elements and their fluid power source





- Teams should take the comments of the judges in consideration and try to solve the problem within a maximum of 20 minutes. After these 20 minutes, if the problems are not solved, the team will not be allowed to do the Underwater Mission
- Teams will lose the Safety Check points for each part causing them not to pass the check. Teams still have to solve the problem to be allowed to participate in the Underwater Mission
- Teams that pass the safety check will receive a card showing their readiness for the Underwater Mission. The pool judge will collect and check this card from the team before starting the Underwater Mission.



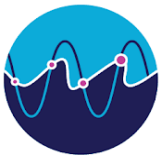
## 6. Context

Pollution in the Abu Dhabi Seaport poses a significant threat to its unique marine ecosystem. This semi-enclosed body of water, bordered by several countries, faces contamination from oil spills, industrial discharges, and plastic waste. Oil spills, often from shipping and oil extraction activities, can smother coral reefs, killing them and the diverse species that depend on them. Industrial discharges introduce heavy metals and chemicals, which accumulate in marine organisms, causing health issues and disrupting reproductive systems. Plastic waste entangles marine life and degrades into micro plastics, which are ingested by fish and other species, leading to injury or death. The cumulative effect of these pollutants not only diminishes biodiversity but also impacts local fisheries and tourism, crucial to the economies of bordering nations. Concerted efforts are needed to mitigate pollution and preserve the Arabian Gulf's vibrant marine life.

The Abu Dhabi Seaport is also facing the impact of increased tourism and coastal development. The rapid expansion of tourist infrastructure along the coast is leading to the destruction of natural habitats, such as mangrove forests and sea grass beds. Additionally, the influx of tourists and their activities is putting pressure on the local communities, disrupting their livelihoods and leading to social and economic problems.

*Figure 3: Abu Dhabi Seaport*





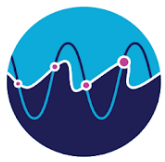
## 7. Theme

In this year's version of UWR Challenges, underwater robots will be tasked with assisting in the development, monitoring, and maintenance of Arabian Gulf. Utilizing marine technology in similar projects can result in achieving better outcomes with higher efficiency by relying on more accurate data and direct access to these water bodies.



*Figure 4: Cleaning the Abu Dhabi Seaport from plastic manually*

As per the growing demand for qualified scientists and engineers, UWR Challenges are developed to provide the new engineering generation with new challenges with this class of underwater technology and innovation for the science, inspection, and research world. Aligning these challenges with national problems is intended to create further opportunities and result in actual development for the marine technology sector in Abu Dhabi.



## 8. Mission Background

Each team will be required to use their robot to perform an Underwater Mission consisting of several tasks that mimic different operations needed to develop, maintain, or monitor the Abu Dhabi Seaport. These tasks are built to address the following areas.

### 8.1. Pollution

Pollution in the Abu Dhabi Seaport from plastic waste and oil spills is a growing environmental concern. Plastic waste, including discarded fishing nets and single-use plastics, often ends up in the sea, where it entangles marine animals such as turtles and dolphins, leading to injury or death. Over time, larger plastics break down into micro plastics, which are ingested by fish and other marine organisms, causing internal damage and disrupting the food chain. Oil spills, resulting from shipping activities and oil extraction, coat marine surfaces and smother coral reefs, which are vital to the Arabian Gulf's biodiversity. These spills also contaminate the water, affecting the health of fish and other marine life by impairing their respiratory functions and reproductive systems. The combined impact of plastic waste and oil spills reduces marine biodiversity, threatens the livelihoods of local fishing communities, and diminishes the region's appeal as a tourist destination. Addressing these issues requires international cooperation and stringent regulations to protect the Arabian Gulf's unique marine environment.

### 8.2. Marine life

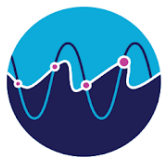
Overfishing has been identified as the most widespread global threat to fisheries in Arabian Gulf. It is a process that occurs when fishing activities lead to lower levels of fish stocks below the acceptable level. This process ultimately depletes fish resources and potentially extinct a number of fish varieties exposed to this process. The dramatic changes in ecosystems resulting from the overfishing process led to a loss of ecosystem balance and the emergence of other species of marine organisms, which may prevent the target species in the fishing process from re-emerging, known as the ecosystem transformation process. In this task, underwater robots will be used to monitor and report changes in fish populations in the sea.

### 8.3. Data collection

To understand the impacts of climate change on the Arabian Gulf, collecting data on sea level rise, water temperature changes, and ocean acidification is crucial. These indicators affect fish and coral life significantly. Monitoring temperature and pressure data from the sea helps predict the future viability of marine life in this region. Rising temperatures can lead to coral bleaching and disrupt fish habitats, while ocean acidification weakens coral skeletons and affects marine species' survival. By gathering this data, scientists can assess the resilience of marine ecosystems and develop strategies to protect them against climate change. This proactive approach is essential for maintaining the Arabian Gulf's biodiversity and the livelihoods dependent on it.







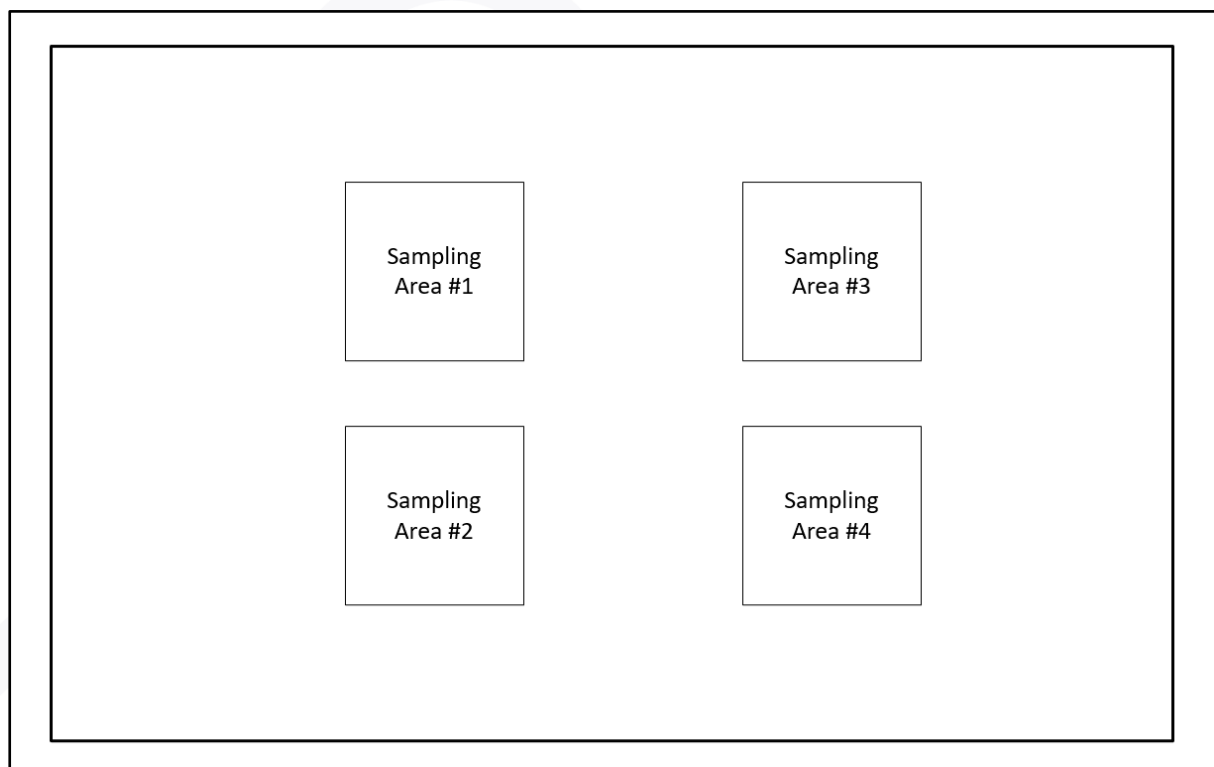
## 9. ROV Mission Brief—Seniors Category

### Task 1: Monitor the Abu Dhabi Seaport Against Pollution (60 points)

#### 9.1.1. Collect algae sample (20 points)

- Navigate your vehicle to the spots provided in the Sea map

The playground will be divided into multiple areas as shown in [Figure 5](#). Some area will be marked as sampling areas. Samples will be allocated in sampling areas. Teams will be provided with an information sheet by one of the judges at the beginning of the Underwater Mission's time. Teams should use this information to locate the spot where they should collect the algae samples and the sample type to collect from each spot. Algae samples will have three types and will be modeled using  $\frac{3}{4}$  inches PVC pipes shapes as shown in [Figure 6](#).

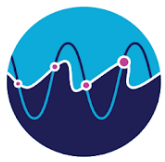


*Figure 5: ROV Playground Sampling Areas*

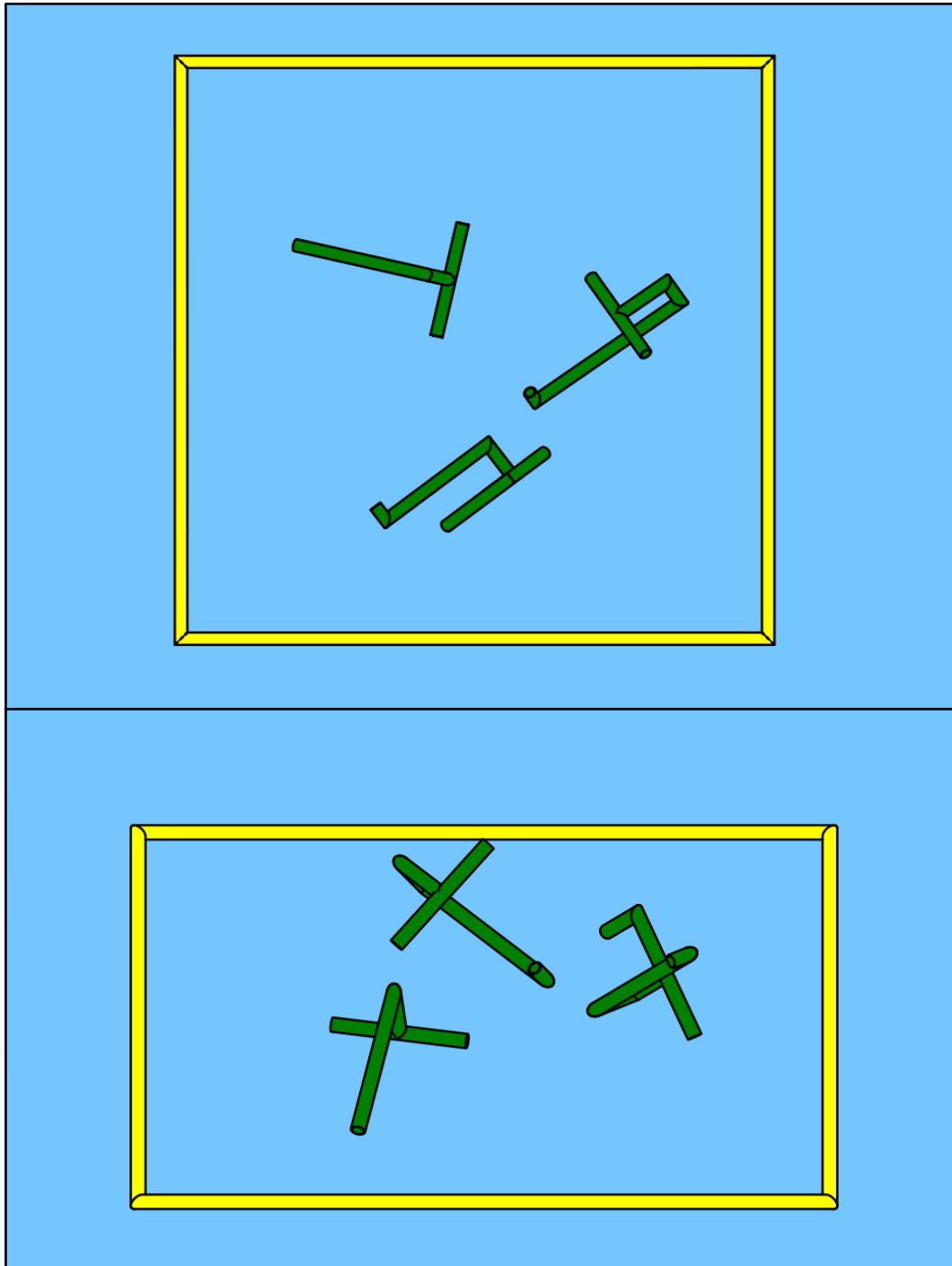
- Collect the required sample from each spot (15 points)

At each spot, there will be multiple samples with different types. Teams will be required to collect three samples as instructed in the information sheet. Teams will get **5 points** for successfully identifying each correct sample at its specified spot. Successfully identifying a correct sample is defined as informing the judge with the correct type of the sample on the



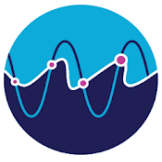


video stream from the correct spot. [Figure 6](#) shows an example for algae samples in a sampling area.



*Figure 6: Example for Algae Samples in a Sampling Area*

- Retrieve the collected samples to the surface **(5 points)**



Teams will get **5 points** for successfully retrieving algae samples to the surface. Successfully retrieving a sample is defined as handing the sample to the team member at the pool. Teams can retrieve multiple samples at ones and get full points. Teams who failed to identify the correct samples in the previous step can still get **2 points** for retrieving any 3 samples.

#### 9.1.2. Search for plastic samples (20 points)

- Find the samples and build a map marking their locations

Plastic can be located in different places in Sea. In this task, Plastic will be modeled using a randomly shaped piece of cement with specific dimensions constraints as follows:

*maximum length ( $l_m$ )  $\in [8, 15]$  cm,*

*maximum width ( $w_m$ )  $\in [4, 8]$  cm,*

*and maximum height ( $h_m$ )  $\in [3, 6]$  cm*

Similar to algae samples, Plastic will have three types. The types of the plastic samples will be identified by parallel lines visibly drawn across them where the number of lines on a sample indicates its type as illustrated in [Figure 7](#). Samples which is not plastic will have no lines. Plastic will be randomly allocated across the sampling areas. Teams will be required to find two plastic samples of specific types as instructed in the information sheet from any sampling area(s).

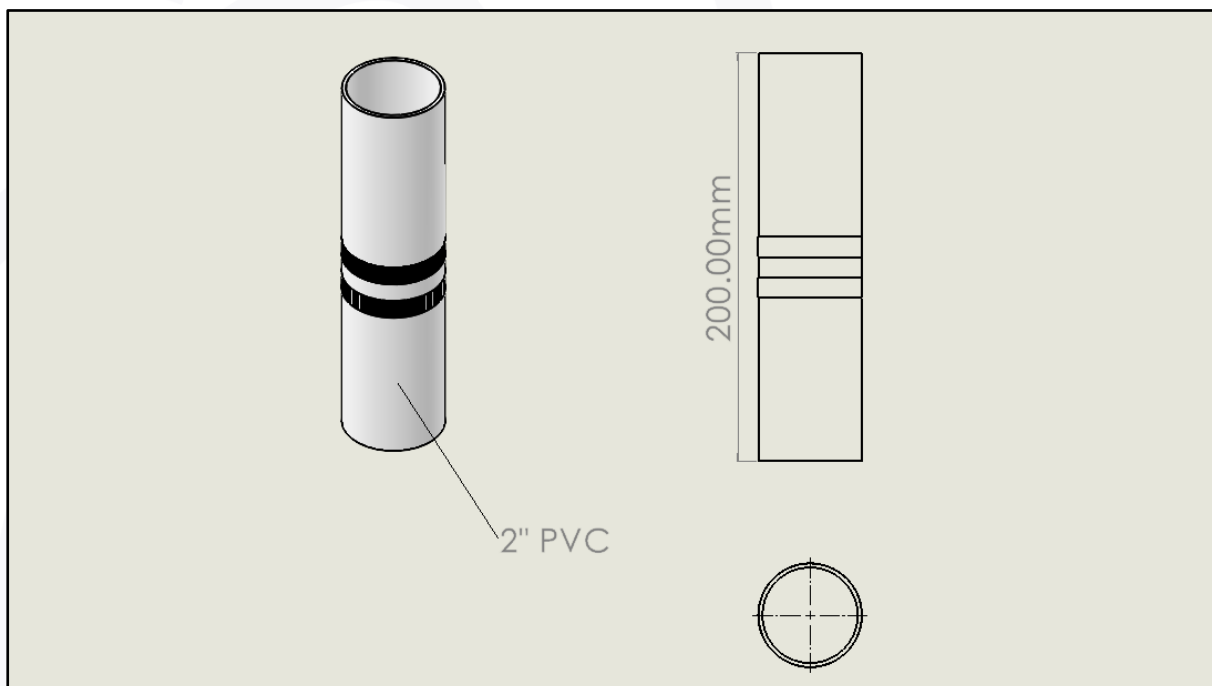
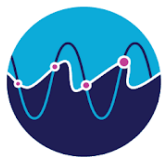


Figure 7: Example for a Plastic Sample of Type 2



- Collect and retrieve the samples to the surface

Team will get **10 points** for successfully retrieving the required samples to the surface. Successfully retrieving a sample is defined as handing the sample to the team member at the pool. Teams who failed to find the correct samples in the previous step can still get *half* the points for retrieving any 2 plastic samples.

### 9.1.3. Identify the pollutant (20 points)

- Scan and identify the unrecognizable plastic sample

A piece of A4-sized sheet will be located in one of the sampling areas. Teams are required to scan this sheet underwater to identify a pollutant. The sheet will have a number of symbols printed on it in a random pattern. Teams should *autonomously* calculate the score of the pattern by counting the number of each symbol and multiplying this number by the weight of its symbol and then sum the resulting values. The final score should be reported to the judge to get point. Teams should clearly show the judge that their system is able to extract the score without any manual processing from team members. Point will be given as follows:

- Exact value gets **20 points**
- Exact value  $\pm 10$  gets **15 points**
- Exact value  $\pm 15$  gets **10 points**
- Exact value  $\pm 20$  gets **5 points**
- Other values will get no points

The weight of the symbols are as follows:

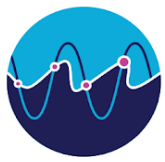
- Circle = 20
- Square = 15
- Triangle = 10
- Cross = 5

An example for the sheet is shown in [Figure 32](#). The number, type, and location of the symbols will vary from the provided example, but symbol will have the same size.

The exact value of the score for the provided example pattern should be calculated as follow:

$$9 \times 20 + 7 \times 15 + 9 \times 10 + 7 \times 5 = 725$$





## 9.2. Task 2: Save the Fish (70 points)

In this task, teams are required to assist in automating the process of fish species classification and size estimation. In a recent [work](#) (Garcia-d'Urso, 2022), a dataset was collected and labeled for 59 different fish species as part of a project called **DeepFish**. Check their published work for more information. This dataset will be used and referred to throughout this task to evaluate your work. The dataset files are published [here](#).



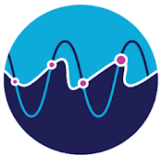


Figure 8: Examples from the mentioned work (<https://doi.org/10.1038/s41597-022-01416-0>)

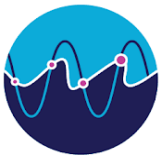
### 9.2.1. Estimate Fish Measurements (15 points)

- Measure the fish length

As part of collecting data for fish datasets is to label these data with true value that can further used to develop useful models, in this task, teams are required to measure the length of fish







in underwater conditions. A sample from the DeepFish dataset will be printed on a banner and placed vertically underwater on one side of the pool. Your task is to use your robot to

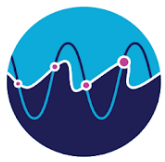
inspect this image and estimate the total length of the fish. For example, in [Figure 9](#), three fishes of Pagrus species are shown. In [Figure 10](#), the same image is shown after being labeled with different measurements (eye diameter, width at waist, length to tail, and total length). In this step, we are interested in measuring the total length only (labeled as the line between the fish mouth and the end of its tail).



Figure 9: Sample from DeepFish Dataset (7\_06\_21-B9.jpg)



Figure 10: Sample from DeepFish Dataset (7\_06\_21-B9.jpg) with Labels (7\_06\_21-B9\_\_labels.json) Visualized using Django Labeller Software



The printed image will be scaled up or down to vary from the available data. Teams will get **5 points** for each correct measurement within a 5% tolerance.

### 9.2.2. Estimate the length of the fish **(35 points)**

In this step, teams are required to estimate the length of the fish in a digital image. A digital image from the DeepFish dataset will be provided for the team by the judge. For this step we will only be using data for the Pagrus fish species (marked as “Pagrus pagrus” in the dataset). The data set provides you with the following data:

- Images of the fish in .jpg extension compressed in **fish\_tray\_images\_2021\_MM\_DD.zip** files.
- Labels for the images marking fish measurements (eye diameter, width at waist, length to tail, and total length) in .json format compressed in **fish\_tray\_json\_labels.zip**.
- Estimated total length for each label in **size\_estimation\_homography\_DeepFish.csv**

You should carefully review these files and find further instructions [here](#). You will need to extract the data for Pagrus pagrus species to use for this task. Teams are required to build a system that can autonomously (by taking the provided image as an input without any manual preprocessing) do the following:

- Estimate the total length of the fish in the provided image. **(10 points)**
- Label the total length of each fish on the provided image along with the estimated total length. **(10 points)**
- Provide a 3-page printed report detailing how this system was designed and tested—a digital version should also be submitted along with other submissions and following the same deadline. **(15 points)**

### 9.2.3. Check the fishing net for illegal sizing **(20 points)**

In this step, teams are required to inspect a fishing net to check for illegal sizing and disrupted sections. On one side of the pool, a white net will be placed with a red line showing the direction required to be followed, and the net will have four quadrants marked Q1, Q2, Q3, and Q4 as shown in [Figure 11](#). Not that the net spacing is not specified, the net color will be white, the line will be red, and the background structure will be made of white ¾ inch PVC.





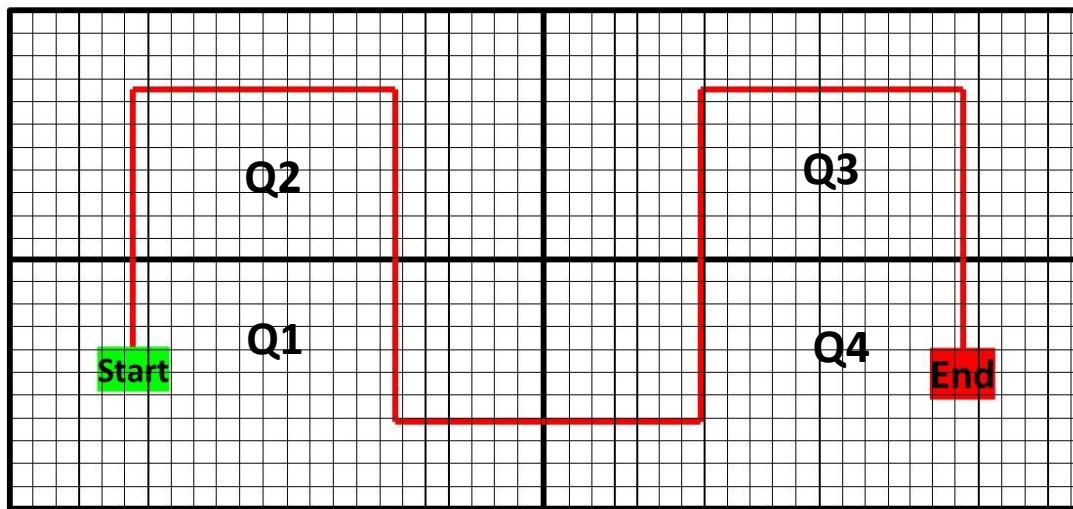
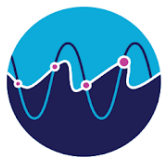


Figure 11: Illustration for the Fishing Net (showing the red line to be followed)

- Follow the colored line on the net

Follow the red line from the start point to the end point. This could be done manually or autonomously. Teams will get *double* the points in the next step if the line following is done autonomously.

- Count the number of illegally-sized and disrupted nets

An illegally-sized net is a section of the net which has a smaller square size as compared to the normal square size. A disrupted net is a section of the net which has a larger square size as compared to the normal square. Examples are shown in [Figure 12](#). Teams are required to report both the number and location of illegally-sized and disrupted nets while following the red line. The location should be identified as one of the four quadrants. Teams will get **15 points** when they successfully detect all nets. Successfully detecting all nets is defined as reporting their number, type, and location correctly.



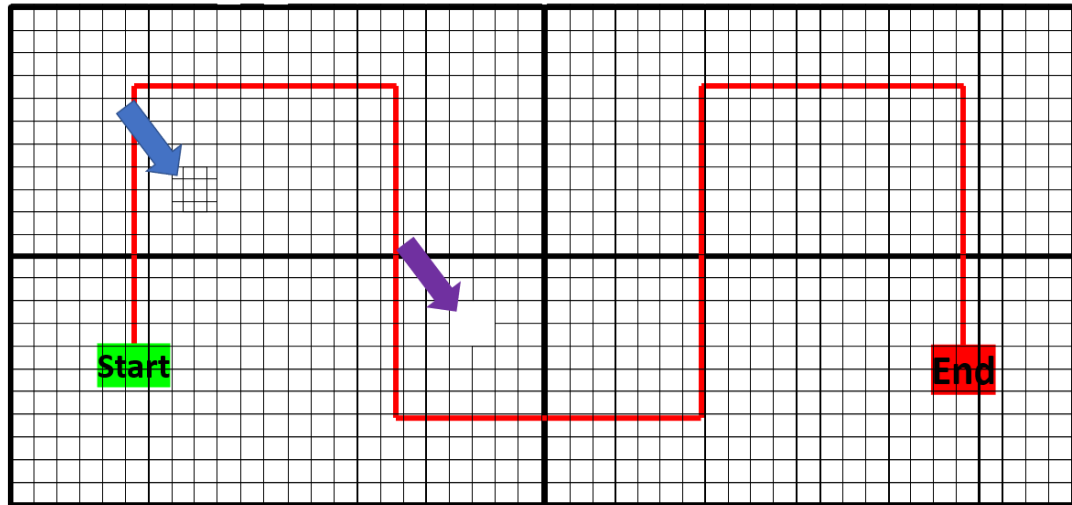
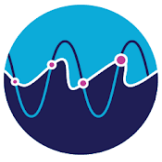


Figure 12: Illustration for the Fishing Net (showing an illegally-sized net section with blue arrow and a disrupted net section with purple arrow)

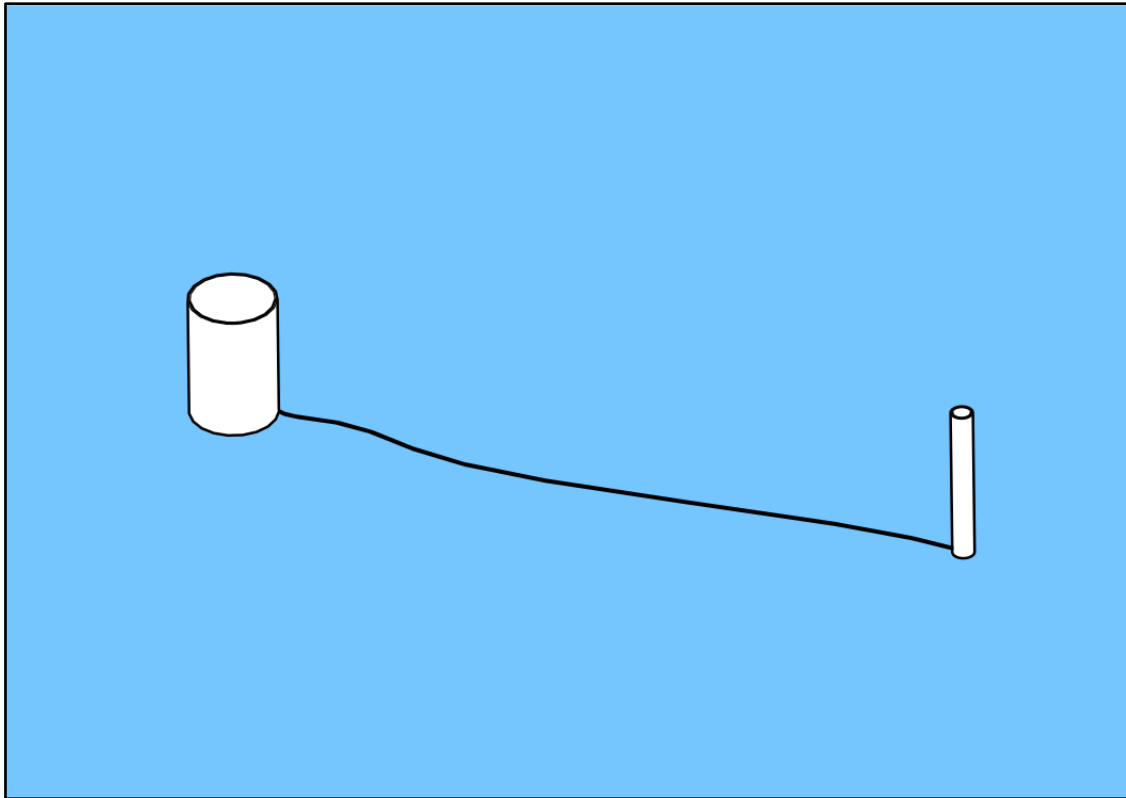
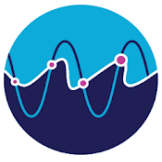
- Mark their locations on a map

Teams are required to produce a digital map showing the results from the previous step. Teams will get **5 points** for producing a correct map. A correct map is defined as having the locations of all illegally-sized nets marked with (X) mark and disrupted nets marked with (O) mark. It should be correct in terms of having all the nets shown with the corresponding mark and being in the correct location.

### 9.3. Task 3: Data collection (50 points)

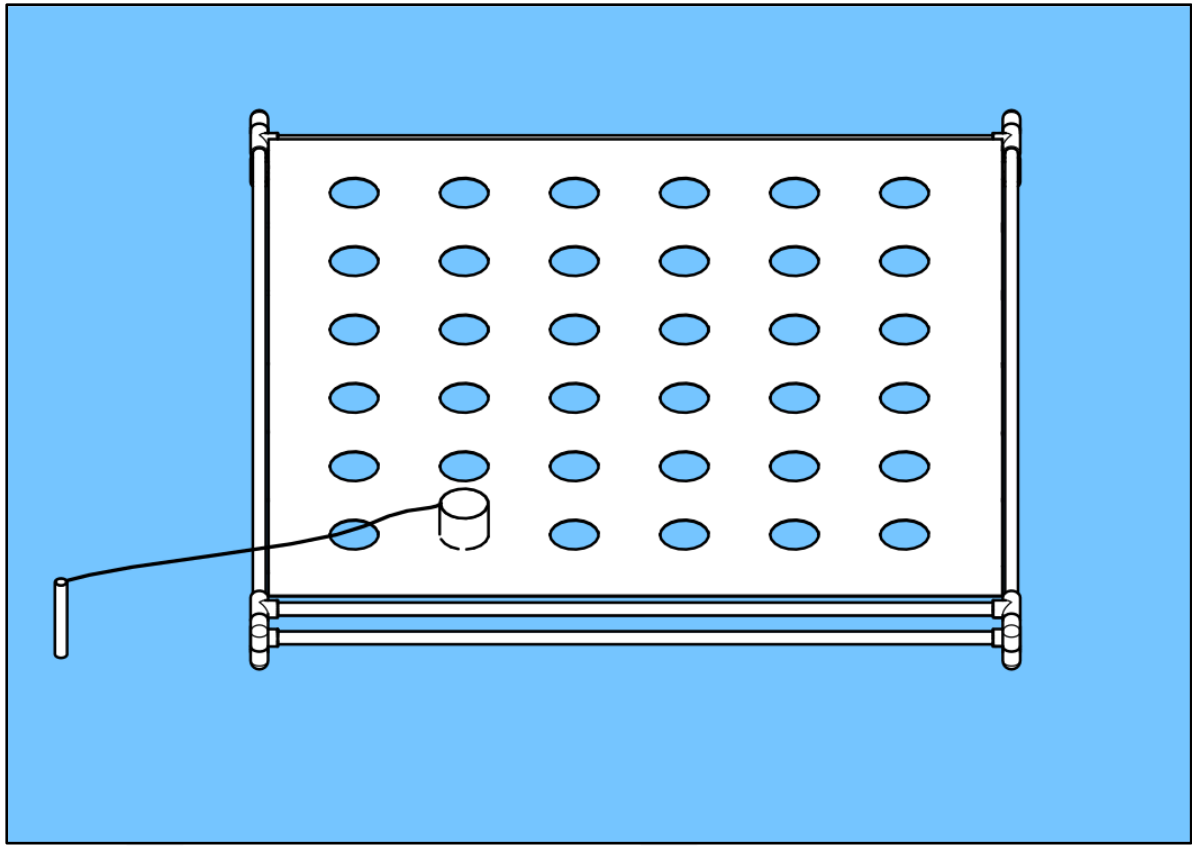
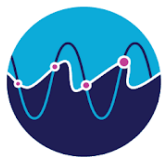
In this task, your robot will be used to inspect and install sensory equipment underwater. These pieces of equipment are beneficial in monitoring the environment of the sea and report any possible hazard such as pollution, shallowness, or unnormal fish population changes. Equipment will be modeled PCV pipes as shown in [Figure 13](#). Check for more details in [Figure 33](#).





*Figure 13: An Equipment (to the left) with its Connector (to the right)*

There will be two equipment areas, one for the operating equipment which area already installed but need inspection, and the other one for new equipment to be installed. Teams will be required to inspect the operating equipment and install new ones to target slot. An illustration for an equipment area is illustrated in [Figure 14](#). Each equipment area will have a number of slots. Each slot will have a unique code of four digits. An illustration for the slots codes is shown in [Figure 15](#).



*Figure 14: Illustration for an Equipment Area with One Equipment Inserted*



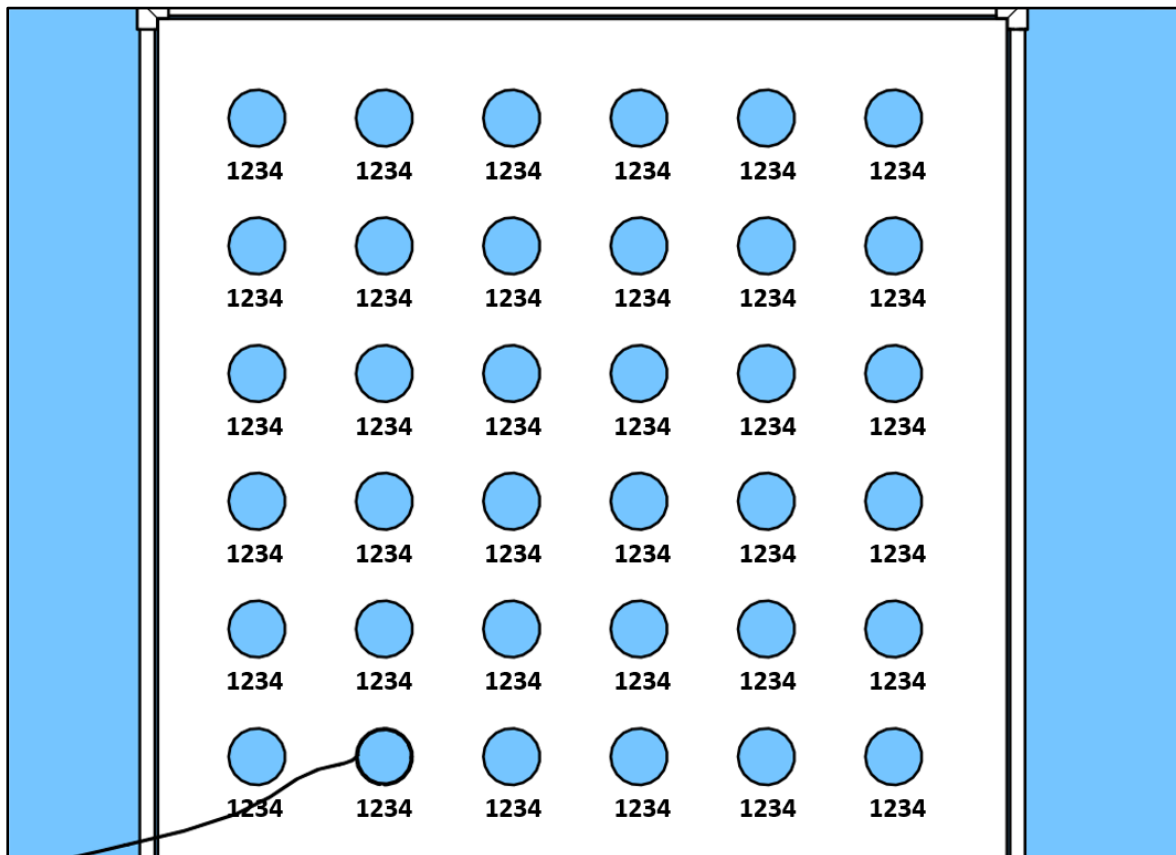
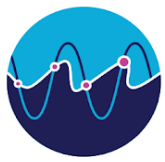


Figure 15: Example for Equipment Slots Codes

#### 9.3.1. Inspect the sensing equipment for damaged parts **(30 points)**

- Visually inspect the equipment and report damaged ones

Teams will be required to inspect the equipment installed in the operating equipment area. This area will have a number of equipment some of which will be broken. The broken equipment will be simulated by a physical crack in the PVC modeling the equipment. Team will be required to find the broken equipment and report the codes of their spots to get **15 points**.

- Carefully collect the broken ones and return them to the surface

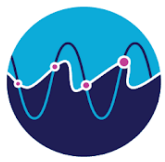
Teams will be required to retrieve the broken equipment to the surface to get **15 points**. Team who failed to correctly identify the broken equipment in the last step will not get points for this step.

#### 9.3.2. Install new sensing equipment to target spots **(20 points)**

- Collect and install new equipment from the surface

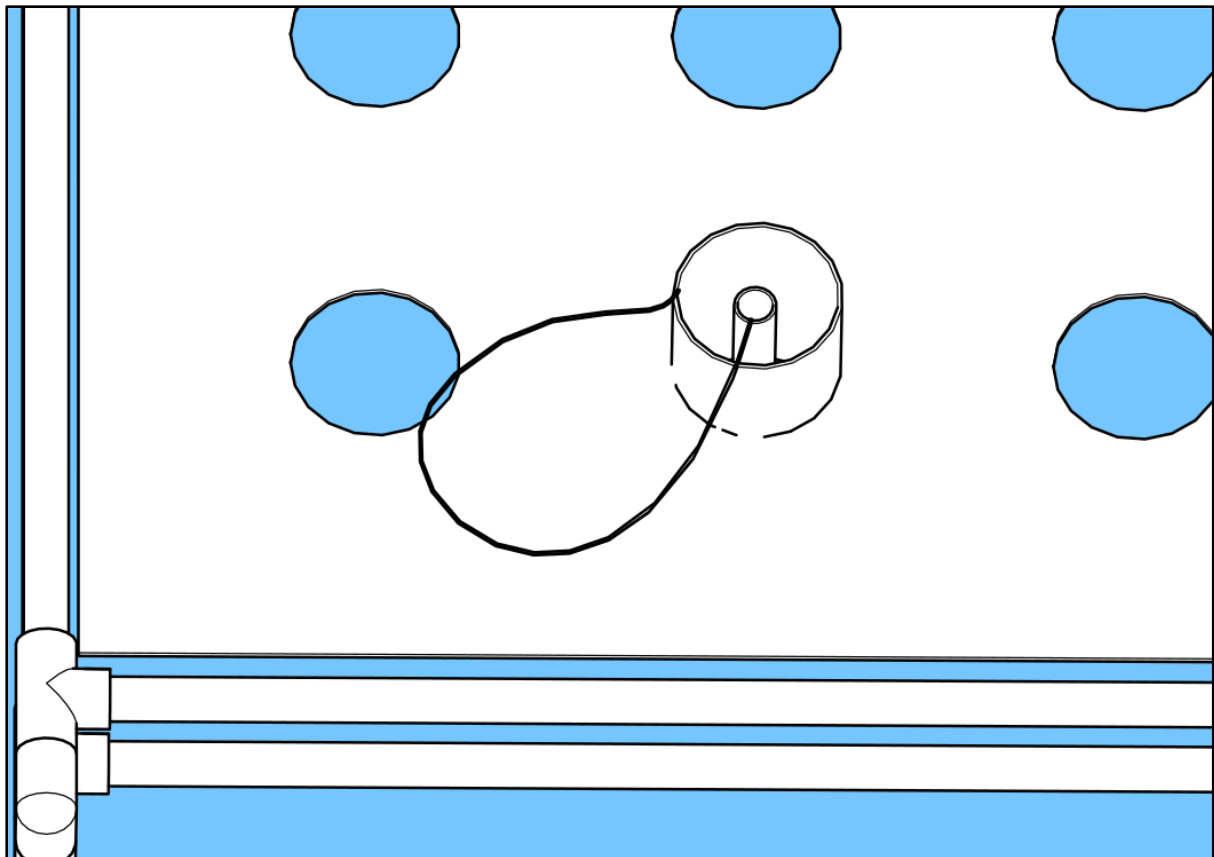
Teams will be provided with a list of codes for the slots where new equipment are required to be installed in the new equipment area. Team will get **20 points** for successfully installing all new



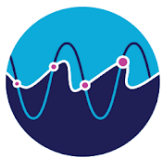


equipment in a correct spot from the list. Note the not all codes in the list will have corresponding spots in the new equipment area. Successfully installing an equipment is defined as inserting the

equipment in a correct spot (on that exists in the code list), and then inserting its connector inside the equipment itself, as illustrated in [Figure 16](#).



*Figure 16: Illustration for the An Equipment Correctly Installed*



## 10. ROV Mission Brief—Juniors Category

### 10.1. Task 1: Monitor the Sea Against Pollution (60 points)

#### 10.1.1. Collect algae sample (20 points)

- Navigate your vehicle to the spots provided in the lake map

The playground will be divided into multiple areas as shown in [Figure 17](#). Some area will be marked as sampling areas. Samples will be allocated in sampling areas. Teams will be provided with an information sheet by one of the judges at the beginning of the Underwater Mission's time. Teams should use this information to locate the spot where they should collect the algae samples and the sample type to collect from each spot. Algae samples will have three types and will be modeled using  $\frac{3}{4}$  inches PVC pipes shapes as shown in [Figure 18](#).

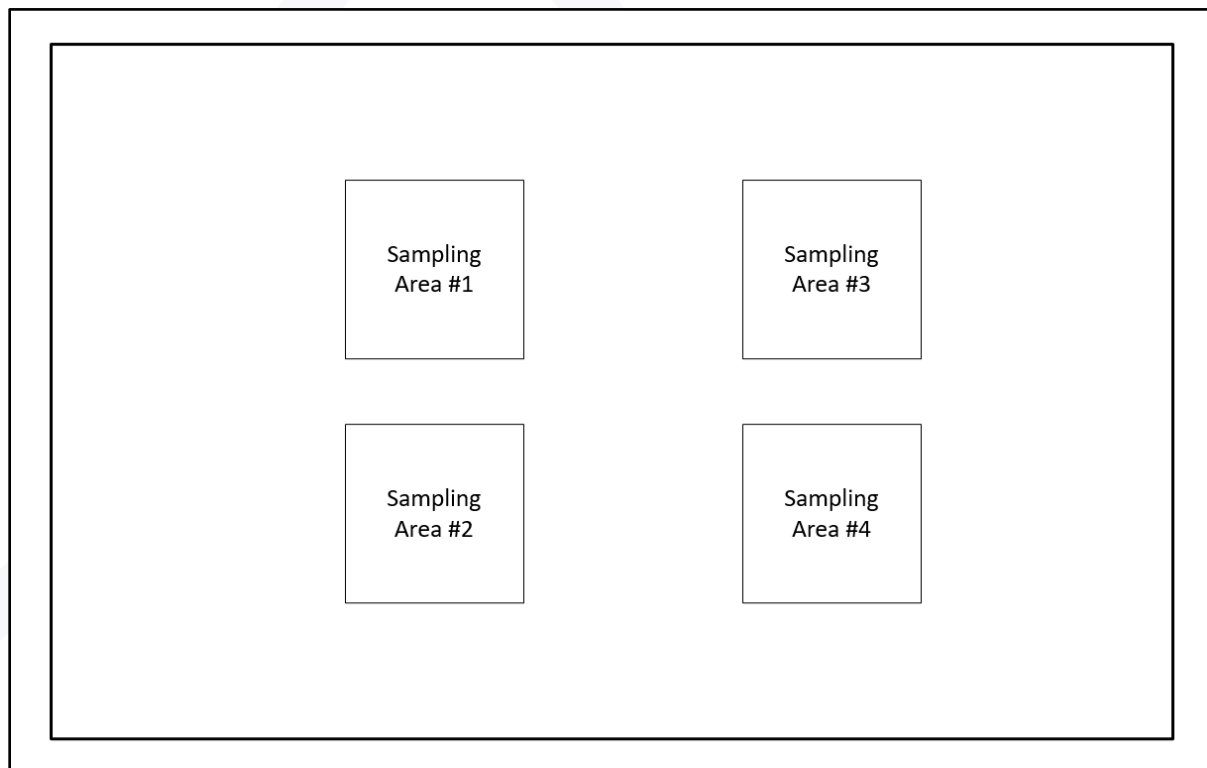
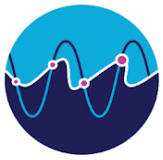


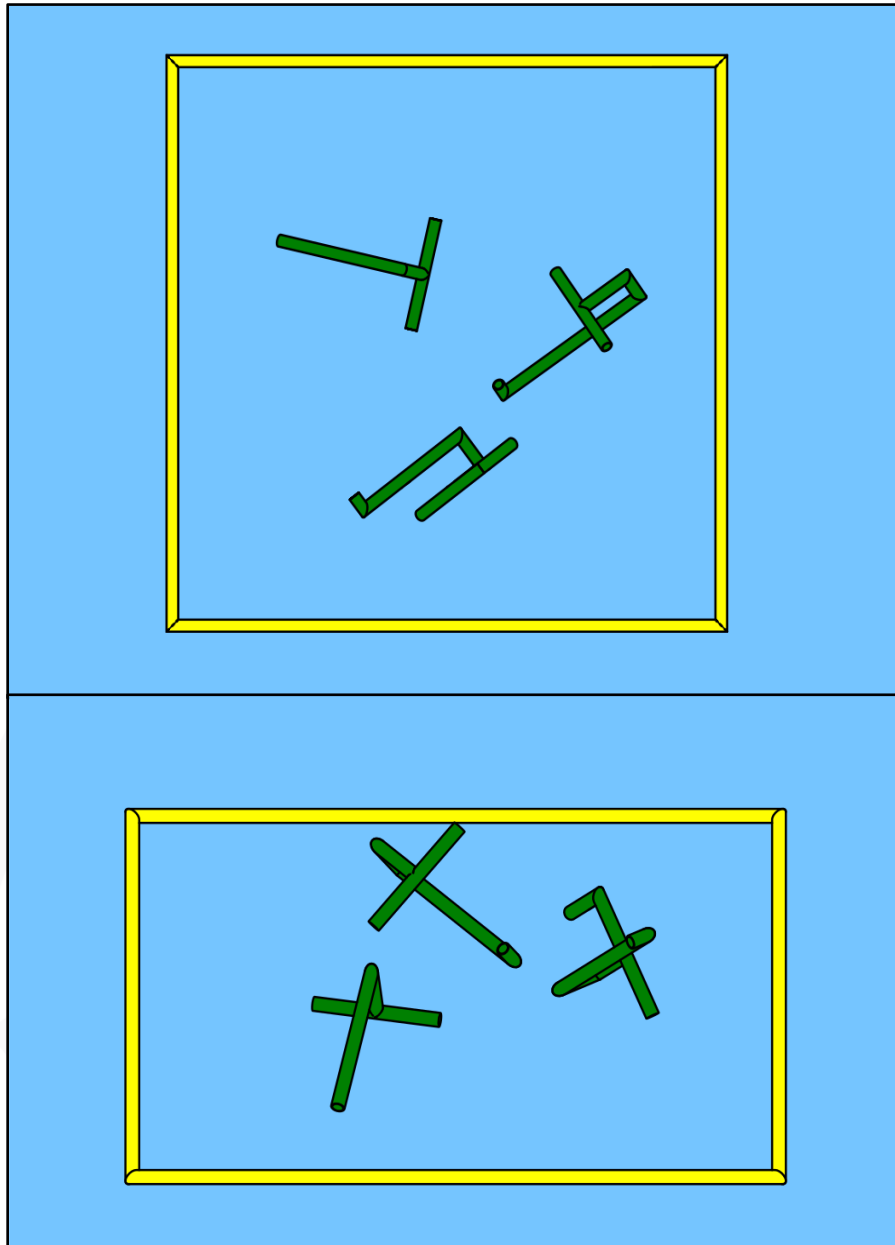
Figure 17: ROV Playground Sampling Areas



- Collect the required sample from each spot **(15points)**

At each spot, there will be multiple samples with different types. Teams will be required to collect three samples as instructed in the information sheet. Teams will get **5 points** for successfully identifying each correct sample at its specified spot. Successfully identifying a correct sample is defined as informing the judge with the correct type of the sample on the video stream from the correct spot. [Figure 18](#) shows an example for algae samples in a sampling area.

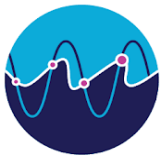




*Figure 18: Example for Algae Samples in a Sampling Area*

- Retrieve the collected samples to the surface **(5 points)**

Teams will get **5 points** for successfully retrieving algae samples to the surface. Successfully retrieving a sample is defined as handing the sample to the team member at the pool. Teams can retrieve multiple samples at ones and get full points. Teams who failed to identify the correct samples in the previous step can still get **2 points** for retrieving any 3 samples.

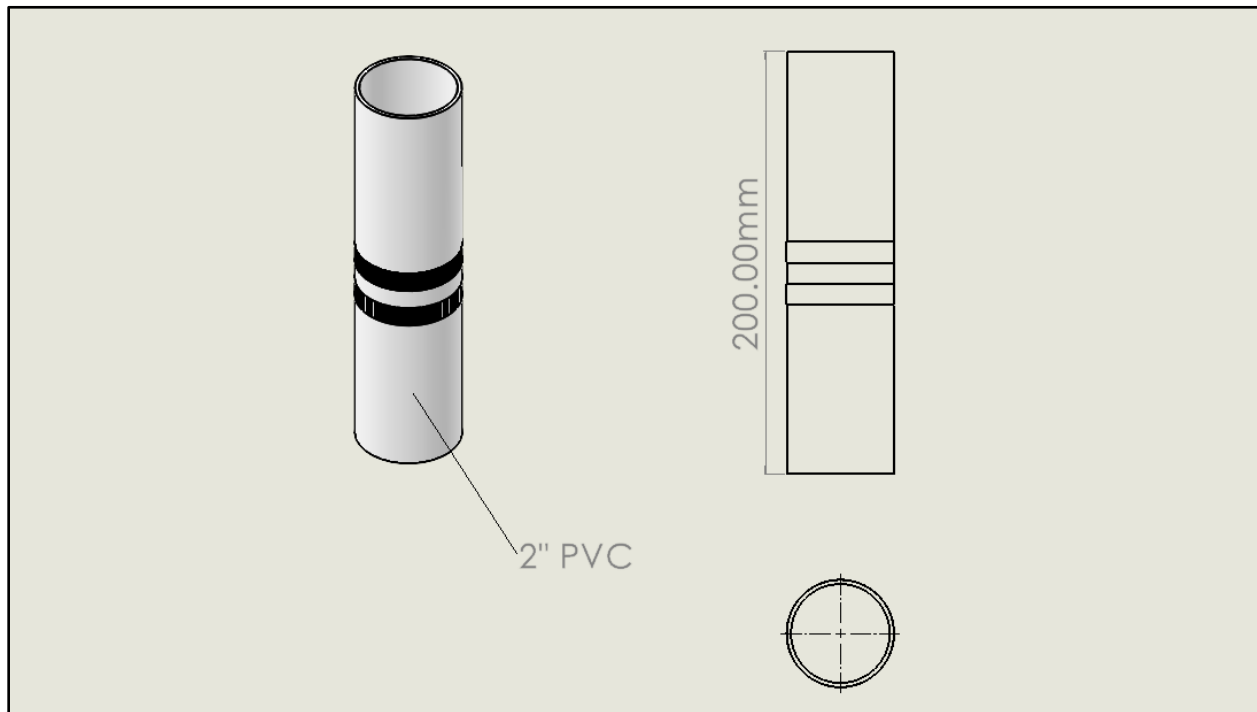


### 10.1.2. Search for plastic samples (20 points)

- Find the samples and build a map marking their locations

Plastic can be located in different places in a lake. In this task, Plastic will be modeled using 2 inches PVS pipe.

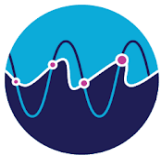
Similar to algae samples, Plastic will have three types. The types of the plastic samples will be identified by parallel lines visibly drawn across them where the number of lines on a sample indicates its type as illustrated in [Figure 19](#). Samples which is not plastic will have no lines. Plastic will be randomly allocated across the sampling areas. Teams will be required to find two Plastic samples of specific types as instructed in the information sheet from any sampling area(s).



*Figure 19: Example for a Plastic Sample of Type 2—Juniors*

- Collect and retrieve the samples to the surface

Teams will get **10 points** for successfully retrieving the required samples to the surface. Successfully retrieving a sample is defined as handing the sample to the team member at the pool.



Teams who failed to find the correct samples in the previous step can still get *half* the points for retrieving any 2 plastic samples.

### 10.1.3. Identify the pollutant (20 points)

- Scan and identify the unrecognizable plastic sample

A piece of A4-sized sheet will be located in one of the sampling areas. Teams are required to scan this sheet underwater to identify a pollutant. The sheet will have a number of symbols printed on it in a random pattern. Teams should *autonomously* calculate the score of the pattern by counting the number of each symbol and multiplying this number by the weight of its symbol and then sum the resulting values. The final score should be reported to the judge to get point. Teams should clearly show the judge that their system is able to extract the score without any manual processing from team members. Point will be given as follows:

- Exact value gets **20 points**
- Exact value  $\pm 10$  gets **15 points**
- Exact value  $\pm 15$  gets **10 points**
- Exact value  $\pm 20$  gets **5 points**
- Other values will get no points

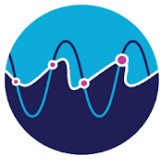
The weight of the symbols are as follows:

- Circle = 20
- Square = 15
- Triangle = 10
- Cross = 5

An example for the sheet is shown in [Figure 32](#). The number, type, and location of the symbols will vary from the provided example, but symbol will have the same size.

The exact value of the score for the provided example pattern should be calculated as follow:

$$9 \times 20 + 7 \times 15 + 9 \times 10 + 7 \times 5 = 725$$



## 10.2. Task 2: Save the Fish (70 points)

In this task, teams are required to assist in automating the process of fish species classification and size estimation. In a recent [work](#) (Garcia-d'Urso, 2022), a dataset was collected and labeled for 59 different fish species as part of a project called **DeepFish**. Check their published work for more information. This dataset will be used and referred to throughout this task to evaluate your work. The dataset files are published [here](#).

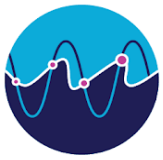


Figure 20: Examples from the mentioned work (<https://doi.org/10.1038/s41597-022-01416-0>)

### 10.2.1. Estimate Fish Measurements (15 points)

- Measure the fish length

As part of collecting data for fish datasets is to label these data with true value that can further used to develop useful models, in this task, teams are required to measure the length of fish in underwater conditions. A sample from the DeepFish dataset will be printed on a banner and



placed vertically underwater on one side of the pool. Your task is to use your robot to inspect this image and estimate the total length of the fish. For example, in



[Figure 21](#), three fishes of Pagrus species are shown. In [Figure 22](#), the same image is shown after being labeled with different measurements (eye diameter, width at waist, length to tail, and total length). In this step, we are interested in measuring the total length only (labeled as the line between the fish mouth and the end of its tail).



*Figure 21: Sample from DeepFish Dataset (7\_06\_21-B9.jpg)*





Figure 22: Sample from DeepFish Dataset (7\_06\_21-B9.jpg) Visualized using Django Labeller Software

The printed image will be scaled up or down to vary from the available data. Teams will get **5 points** for each correct measurement within a 5% tolerance.

#### 10.2.2. Label the length of the fish (35 points)

In this step, teams are required to Label the length of the fish in a digital image. A digital image from the DeepFish dataset will be provided for the team by the judge. For this step we will only be using data for the Pagrus fish species (marked as “Pagrus pagrus” in the dataset). The data set provides you with the following data:

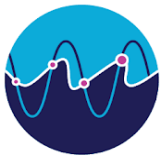
- Images of the fish in .jpg extension compressed in **fish\_tray\_images\_2021\_MM\_DD.zip** files.
- Labels for the images marking fish measurements (eye diameter, width at waist, length to tail, and total length) in .json format compressed in **fish\_tray\_json\_labels.zip**.
- Estimated total length for each label in **size\_estimation\_homography\_DeepFish.csv**

You should carefully review these files and find further instructions [here](#). You will need to extract the data for Pagrus pagrus species to use for this task. Teams are required to build a system (or use available ones) that can manually the following:

- Label the total length of each fish on the provided image along with the estimated total length. (35 points)

#### 10.2.3. Check the fishing net for illegal sizing (20 points)

In this step, teams are required to inspect a fishing net to check for illegal sizing and disrupted sections. On one side of the pool, a white net will be placed with a red line showing the direction required to be followed, and the net will have four quadrants marked Q1, Q2, Q3, and Q4 as shown in [Figure 23](#). Not that



the net spacing is not specified, the net color will be white, the line will be red, and the background structure will be made of white  $\frac{3}{4}$  inch PVC.

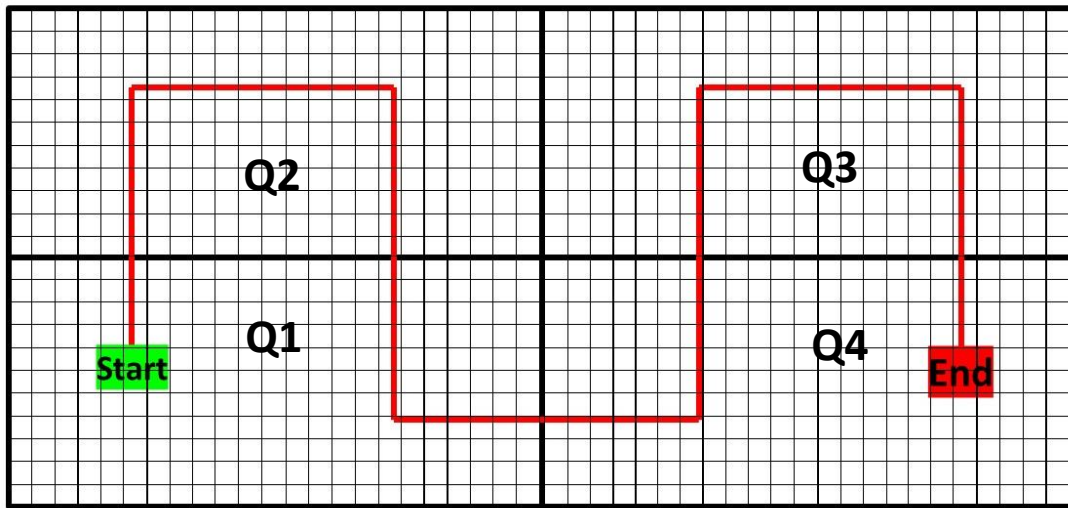


Figure 23: Illustration for the Fishing Net (showing the red line to be followed)

- Follow the colored line on the net

Follow the red line from the start point to the end point. This could be done manually or autonomously. Teams will get *double* the points in the next step if the line following is done autonomously.

- Count the number of illegally-sized and disrupted nets

An illegally-sized net is a section of the net which has a smaller square size as compared to the normal square size. A disrupted net is a section of the net which has a larger square size as compared to the normal square. Examples are shown in [Figure 24](#). Teams are required to report both the number and location of illegally-sized and disrupted nets while following the red line. The location should be identified as one of the four quadrants. Teams will get **15 points** when they successfully detect all nets. Successfully detecting all nets is defined as reporting their number, type, and location correctly.



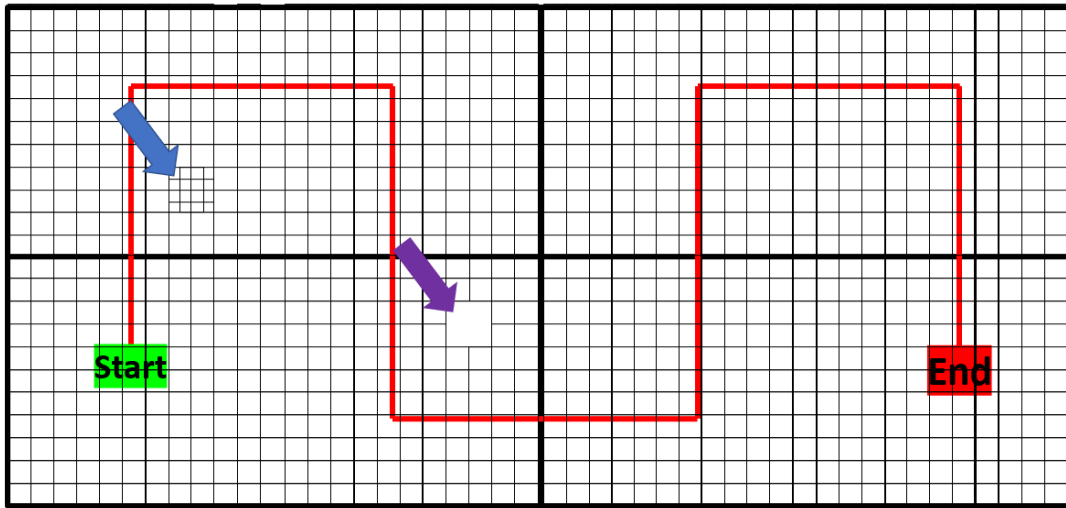


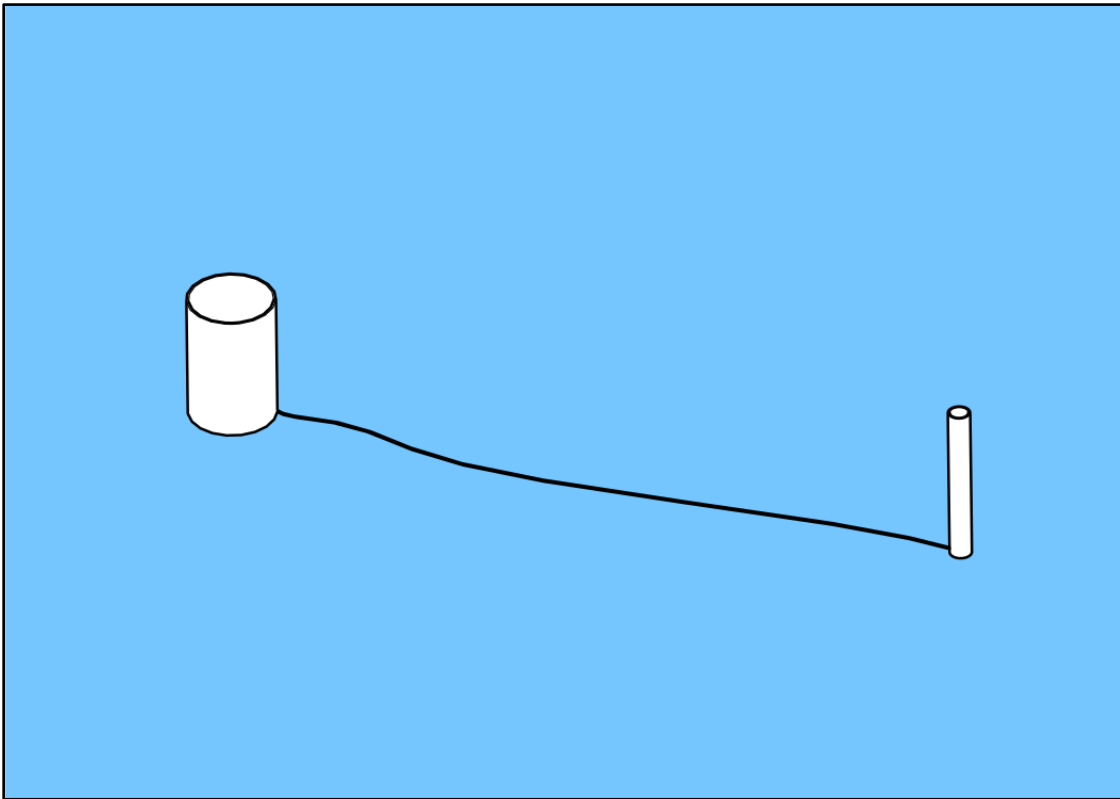
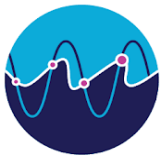
Figure 24: Illustration for the Fishing Net (showing an illegally-sized net section with blue arrow and a disrupted net section with purple arrow)

- Mark their locations on a map

Teams are required to produce a digital or handwritten map showing the results from the previous step. Teams will get **5 points** for producing a correct map. A correct map is defined as having the locations of all illegally-sized nets marked with (X) mark and disrupted nets marked with (O) mark. It should be correct in terms of having all the nets shown with the corresponding mark and being in the correct location.

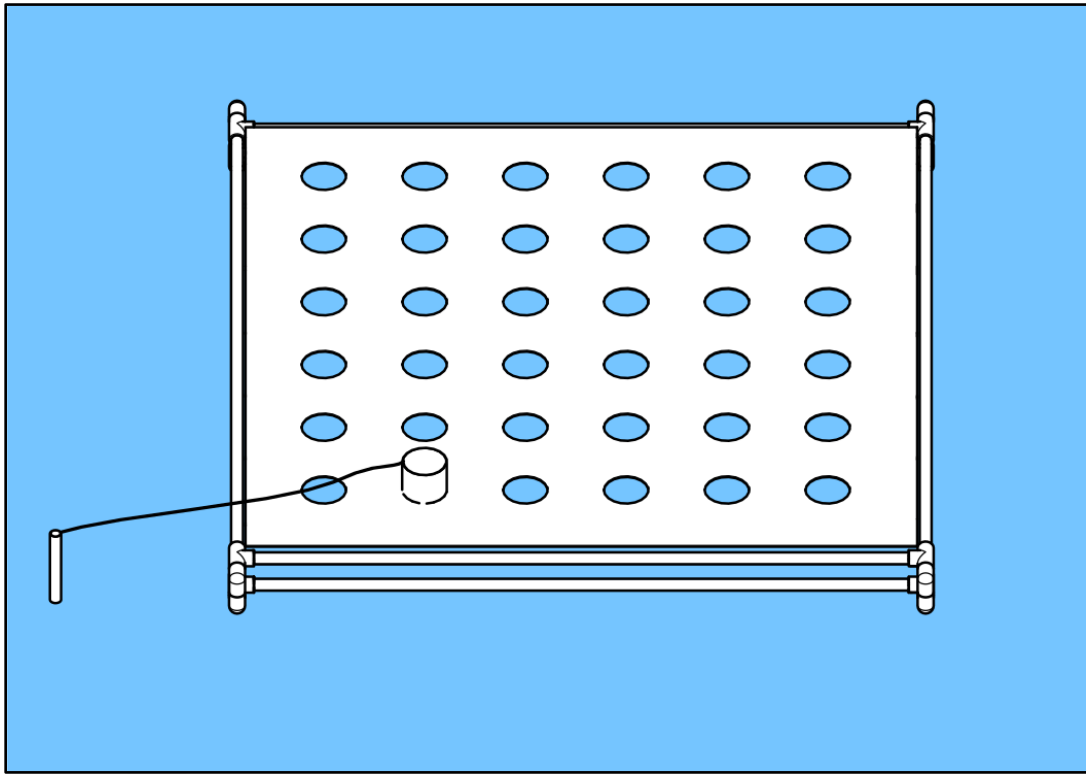
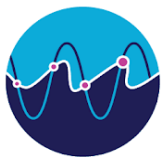
### 10.3. Task 3: Data collection (50 points)

In this task, your robot will be used to inspect and install sensory equipment underwater. These pieces of equipment are beneficial in monitoring the environment of the sea and report any possible hazard such as pollution, shallowness, or unnormal fish population changes. Equipment will be modeled PCV pipes as shown in [Figure 13](#). Check for more details in [Figure 33](#).



*Figure 25: An Equipment (to the left) with its Connector (to the right)*

There will be two equipment areas, one for the operating equipment which area already installed but need inspection, and the other one for new equipment to be installed. Teams will be required to inspect the operating equipment and install new ones to target slot. An illustration for an equipment area is illustrated in [Figure 26](#). Each equipment area will have a number of slots. Each slot will have a unique code of four digits. An illustration for the slots codes is shown in [Figure 27](#).



*Figure 26: Illustration for an Equipment Area with One Equipment Inserted*

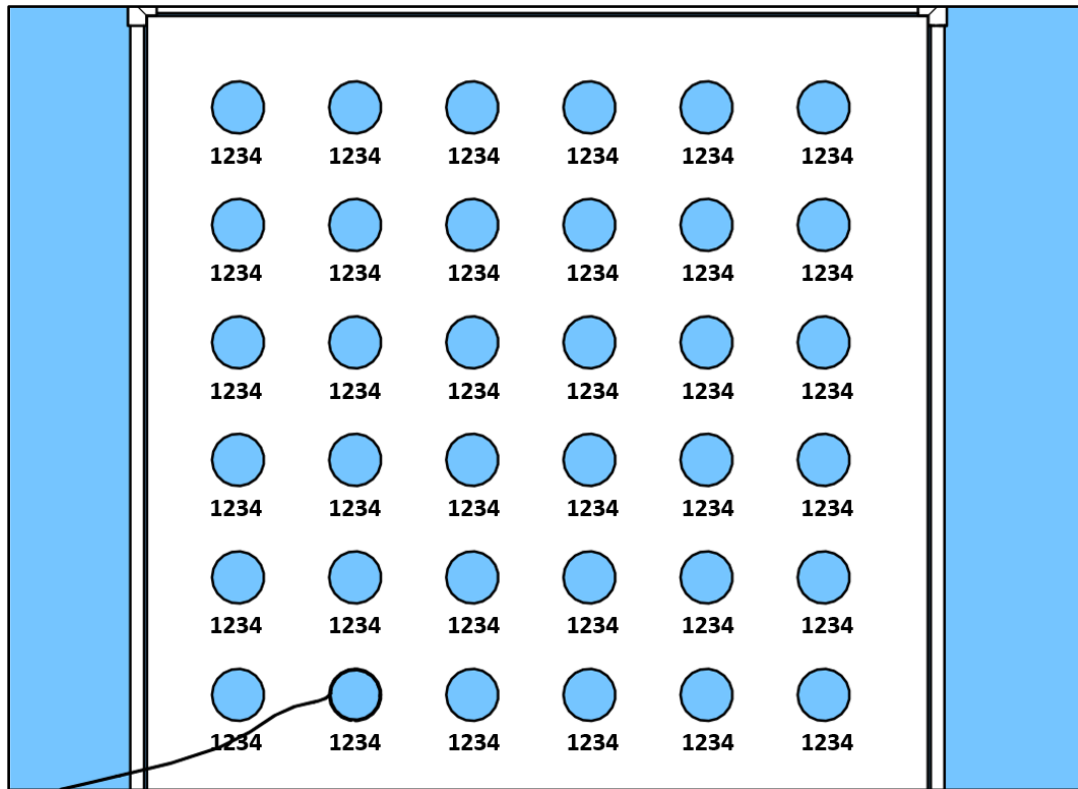
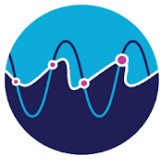


Figure 27: Example for Equipment Slots Codes

#### 10.3.1. Inspect the sensing equipment for damaged parts **(30 points)**

- Visually inspect the equipment and report damaged ones

Teams will be required to inspect the equipment installed in the operating equipment area. This area will have a number of equipment some of which will be broken. The broken equipment will be simulated by a physical crack in the PVC modeling the equipment. Team will be required to find the broken equipment and report the codes of their spots to get **15 points**.

- Carefully collect the broken ones and return them to the surface

Teams will be required to retrieve the broken equipment to the surface to get **15 points**. Team who failed to correctly identify the broken equipment in the last step will not get points for this step.

#### 10.3.2. Install new sensing equipment to target spots **(20 points)**

- Collect and install new equipment from the surface

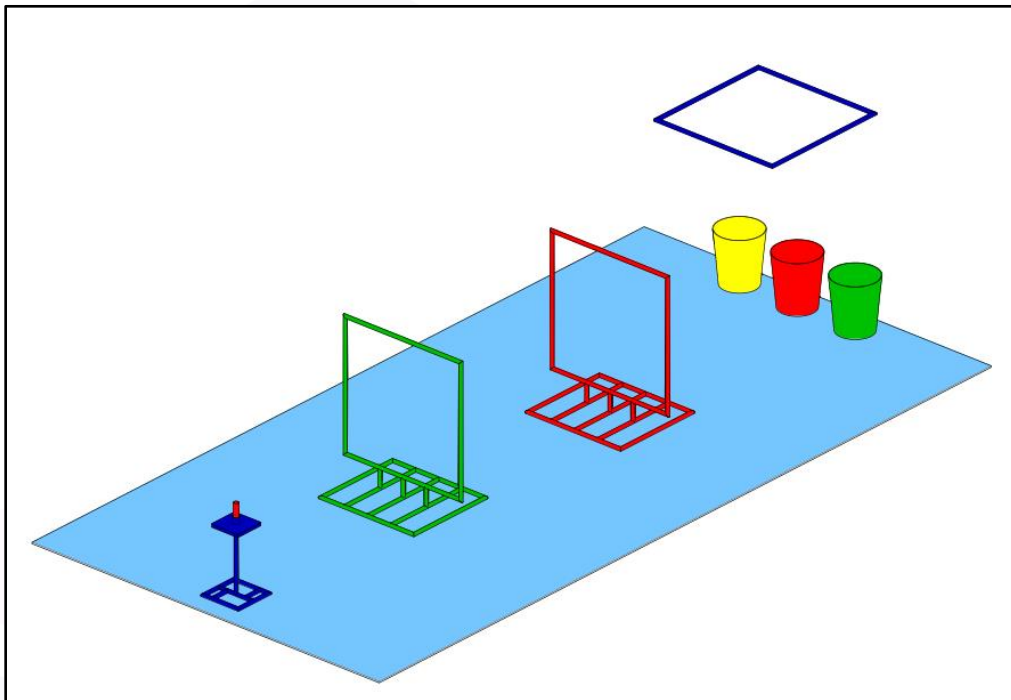
Teams will be provided with a list of codes for the slots where new equipment are required to be installed in the new equipment area. Team will get **20 points** for successfully installing all new equipment in a correct spot from the list. Note the not all codes in the list will have corresponding spots in the new



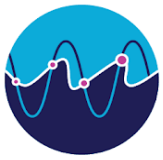
equipment area. Successfully installing an equipment is defined as inserting the equipment in a correct spot (on that exists in the code list), as illustrated in [Figure 26](#).

## 11. AUV Mission Brief—Seniors Category

In the AUV underwater mission, your robots will be required to autonomously collect a sample through a predetermined path. See [Figure 28](#) for the playground structure and check [Appendix E](#) for more illustrations.



*Figure 28: AUV Playground*



### **11.1. Task 1: Maneuver (40 points)**

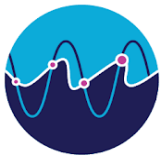
- **Maneuver through the path constructed by a series of square gates**

At the beginning of the mission, the robot must be launched into water through a blue square gate located horizontally at surface level next to the pool wall. The robot should be then initialized manually by the team without moving from the same position (just under the gate). This step could be beneficial for necessary calibration, if any. After initializing the robot, it must start the mission **autonomously**. In task 1, the robot is required to navigate through the red and green gates, respectively. The team will get **20 points** for successfully passing through each gate. Successfully passing through a gate is defined as the body of the robot completely exists in the other side of the gate. In case of failing to pass from one of the gates, the team can decide to position the robot to the beginning of next task and lose the points of Task 1. Alternatively, the team can decide to retry Task 1 from the beginning of the mission and for only half the points. No extra time will be granted in case of retrial. Each team can retry the task for one time only.

### **11.2. Task 2: Manipulate (50 points)**

- **Collect the correct sample from the end of the path**

After passing through the green gate, robot must collect the sample. The sample will be modeled be a 1.5-inch PVC red pipe. The sample will be inserted in a 2-inch blue PVC pipe on top of a blue stand. Teams will get **20 points** when the robot's gripper touches the sample. Teams will get **30 points** when the robot manages to detach the sample from the stand. Detaching the sample from the stand is defined as the sample being completely outside the blue pipe. In case of failure, the team can decide to skip the task and position the robot to the beginning of Task 3. The beginning of Task 3 is defined as the robot being positioned just next to the blue stand. Alternatively, the team can decide to retry Task 2 from its beginning for only half the points. No extra time will be granted in case of retrial. Each team can retry the task for one time only. In case of second failure, the robots must be initialized to begin the next task.



### 11.3. Task 3: Retrieve (40 points)

- Navigate back through the same path

In Task 3, the robot is required to navigate back through the green and red gates, respectively. Teams will get **20 points** for successfully passing through each gate. Successfully passing through a gate is defined as the body of the robot completely exists in the other side of the gate. In case of failing to pass from one of the gates, teams can decide to position the robot to the beginning of next task and lose the points of Task 3. Alternatively, teams can decide to retry Task 3 from its beginning for only half the points. No extra time will be granted in case of retrieval. Each team can retry the task for one time only.

### 11.4. Task 4: Handle (50 points)

- Drop the sample in the designated container

After passing back through the red gate, the robot will be required to insert the sample in one of the buckets. Teams will get **40 points** when the sample is successfully inserted in the bucket. Successfully inserting the sample in the bucket is defined as the sample is completely detached from the robot's body and be stable inside the bucket. In case of the team decided to skip or failed to accomplish Task 2, they will not be able to get points for the previous part of the task. In case of failing to insert the sample in the bucket, the team can decide to proceed directly to the next step of this task. Alternatively, the team can decide to retry Task 4 from its beginning for only half the points. No extra time will be granted in case of retrieval. Each team can retry the task for one time only. The robot will next be required to position itself under the blue gate. Teams will get **10 points** when the robot successfully positions itself under the blue gate for 10 seconds. This part cannot be retried. This is the end of the underwater mission.





## 12. Appendices

### 12.1. Appendix A

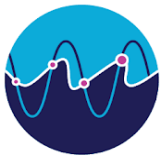
#### Proposal Criteria

Each team is required to submit a proposal for their product before the competition to show how the product, your robot, will be suitable for the Underwater Mission **(15 points)**.

Teams should upload the proposal in PDF format with max size 2 MB on Google drive naming it with [2023\_ChallengeName\_Category\_TeamName\_Proposat\_Submission] and email it to [info@uwrchallenges.org](mailto:info@uwrchallenges.org) before February 14, 2023.

The proposal should cover the following points:

- Identify the team
- Identify the problem
- Explain the solution
- Explain the product strategies created
- Indicate the costs (total expected budget)
- Specify the reasons for you to be chosen
- The benefits from your product



## 12.2. Appendix B

### Cost Analysis Criteria

The team should prepare and send a cost analysis of their vehicle with max score 20 points.

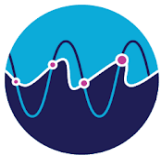
The team should upload the cost analysis in Excel sheet format with max size 2 MB on Google drive naming it with [2024\_ChallengeName\_ Category\_TeamName\_CostAnalysis\_Submission] and it send to [info@uwrchallenges.org](mailto:info@uwrchallenges.org) before February 14, 2023.

The sheet should contain the following:

#### 12.2.1. Product Costs

Product costs are the costs directly incurred from the manufacturing process. The three basic categories of product costs are detailed below:

- **Direct Material:** Direct material costs are the costs of raw materials or parts that go directly into producing products. For example, if Company A were a toy manufacturer, an example of a direct material cost would be the plastic used to make the toys.
- **Direct labours (if applicable):** Direct labour costs are the wages, benefits, and insurance that are paid to employees who are directly involved in manufacturing and producing the goods. For example, workers on the assembly line or those who use the machinery to make the products.
- **Manufacturing overhead:**
  - **Indirect materials:** Indirect materials are materials that are used in the production process but that are not directly traceable to the product. For example, glue, oil, tape, cleaning supplies, etc. are classified as indirect materials.
  - **Indirect labours (if exist):** Indirect labour is the labour of those who are not directly involved in the production of the products. An example would be security guards, supervisors, and quality assurance workers in the factory. Their wages and benefits would be classified as indirect labour costs.



### 12.2.2. Period Costs (if applicable)

Product costs are costs necessary to manufacture a product, while period costs are non-manufacturing costs that are expensed within an accounting period:

- Marketing costs
- Sales costs
- Rent of the working place

#### **Example:**

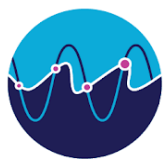
Company A is a manufacturer of tables. Its product costs may include:

- Direct material: The cost of wood used to create the tables
- Direct labour: The cost of wages and benefits for the carpenters to create the tables
- Manufacturing overhead (indirect material): The cost of nails used to hold the tables together
- Manufacturing overhead (indirect labour): The cost of wages and benefits for the security guards to overlook the manufacturing facility
- Manufacturing overhead (other): The cost of factory utilities.

Company A produced 1,000 tables. To produce 1,000 tables, the company incurred costs:

- \$12,000 on wood
- \$2,000 on wages for carpenters and \$500 on wages for security guards to overlook the manufacturing facility
- \$100 for a bag of nails to hold the tables together
- \$500 for factory rent and utilities

Total product costs: \$12,000 (direct material) + \$2,000 (direct labour) + \$100 (indirect material) + \$500 (indirect labour) + \$500 (other costs) = \$15,100. As this is the cost to produce 1,000 tables, the company has per unit cost of \$15.10 ( $\$15,100 / 1,000 = \$15.10$ ).



## 12.3. Appendix C

### Technical Report

Each team should prepare a technical-wise document and send it before the competition - 30 points.

The team should upload the their technical report on Google drive by naming it [2023\_ChallengeName\_ Category\_TeamName\_TechnicalReport\_Submission] in PDF format with max size 5 MB and send it to [info@uwrchallenges.org](mailto:info@uwrchallenges.org) before February 14, 2022.

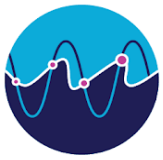
The team can use any required visuals to support your report

The document should demonstrate:

<b>1. Mechanical design</b>	<ul style="list-style-type: none"><li>• Vehicle materials</li><li>• Isolation</li><li>• Thrusters</li><li>• Stability</li><li>• Buoyancy</li><li>• Drag force calculations</li><li>• Mobility</li><li>• Equations of motion ... etc.</li></ul>
<b>2. Control Systems (Software)</b>	<ul style="list-style-type: none"><li>• Serial and parallel communications</li><li>• Movement techniques</li><li>• Stability techniques</li><li>• Autonomous system</li><li>• Image recognition techniques ... etc.</li></ul>
<b>3. Control systems (Hardware)</b>	<ul style="list-style-type: none"><li>• Vehicle components</li><li>• Station components ... etc.</li></ul>
<b>4. Electric power</b>	<ul style="list-style-type: none"><li>• Fuses</li><li>• Power conversions</li><li>• Power distribution ... etc.</li></ul>
<b>5. Fluid power</b>	<ul style="list-style-type: none"><li>• Software and hardware components ... etc.</li></ul>



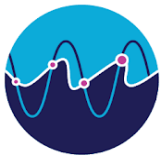
<b>6. Additional devices</b>	<ul style="list-style-type: none"><li>• Mechanical structure</li><li>• software and hardware components ... etc.</li></ul>
<b>7. SIDs: shows the power and signals diagram</b>	<ul style="list-style-type: none"><li>• Electrical SID</li><li>• Fluid SID</li><li>• Additional devices SID</li></ul>
<b>8. Events</b>	<ul style="list-style-type: none"><li>• If the team participated in any events before with the vehicle.</li></ul>
<b>9. Future plans</b>	<ul style="list-style-type: none"><li>• The plans that the team is seeking to do them.</li></ul>
<b>10. Acknowledgments</b>	<ul style="list-style-type: none"><li>• Acknowledgments for the team supporters.</li></ul>
<b>11. References</b>	<ul style="list-style-type: none"><li>• Show the references of presented info.</li></ul>



## 12.4. Appendix D

### Pitching Criteria

- Each team should prepare for the final pitching for the final evaluation. **(20 points)**
- The team will be asked to present a pitching to a judging panel.
- Each team has **5 minutes** to present, and the judges have 10 minutes for questions and evaluation.
- The competition will provide a data show for presenting.
- The team can use any software or hardware requirements to help them in the purpose of the pitching.
- It is preferred that a maximum of 3 team members to do the Onsite pitching, but other team members can join for Q&A
- The team may present in Arabic or English with no additional score.
- The team should cover some aspects:
  - **Problem/ opportunity:** in which the team describes the problems that they solve in the RFP
  - **Your solution description:** in which the team gives an overall description of your solution; describing the best value proposition you give to the customer
  - **Solution features:** in which the team shows their vehicle features to solve the problem and how the solution is special
  - **Competition and market landscape:** in which the team shows the competition that they will face in the market and how to stack up with them
  - **Progress status:** in which the team shows the progress of their solution, vehicle,
  - **Future plan:** in which the team give a brief on where they are going to forward in the development of the solution
  - **The team:** by showing the team members, their field of experience and their roles in the team



## 12.5. Appendix E

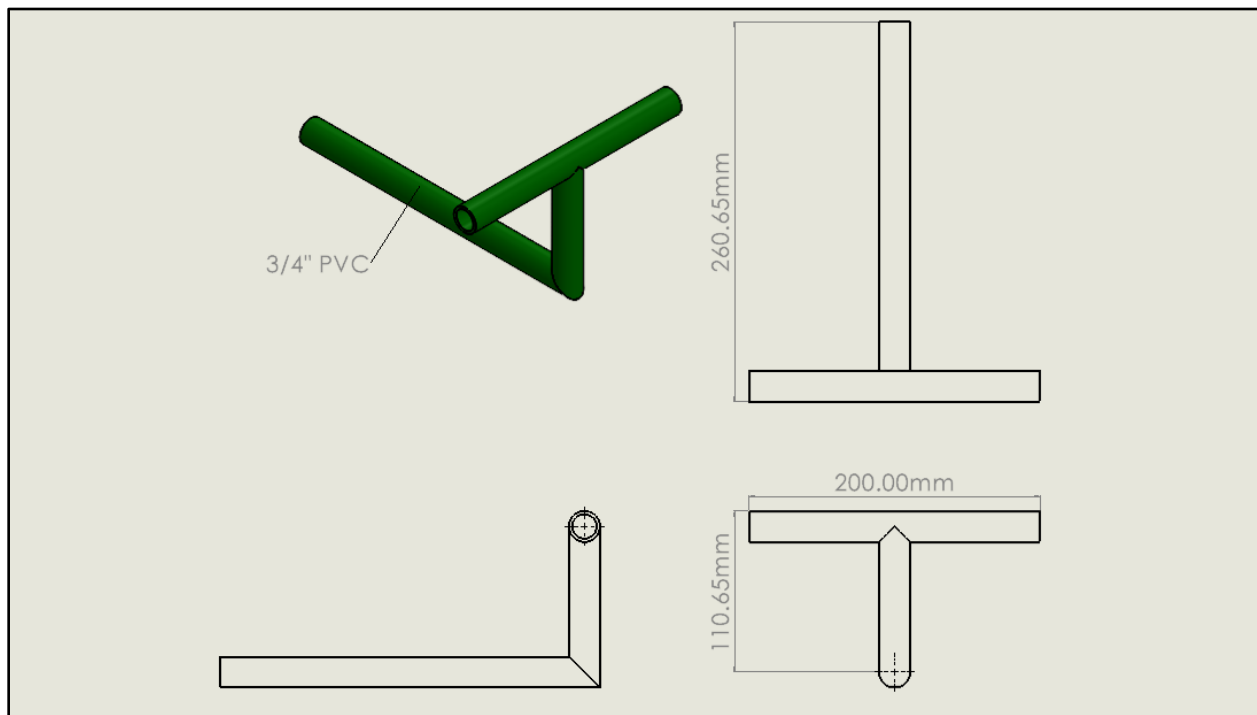


Figure 29: Algae Sample Type 1



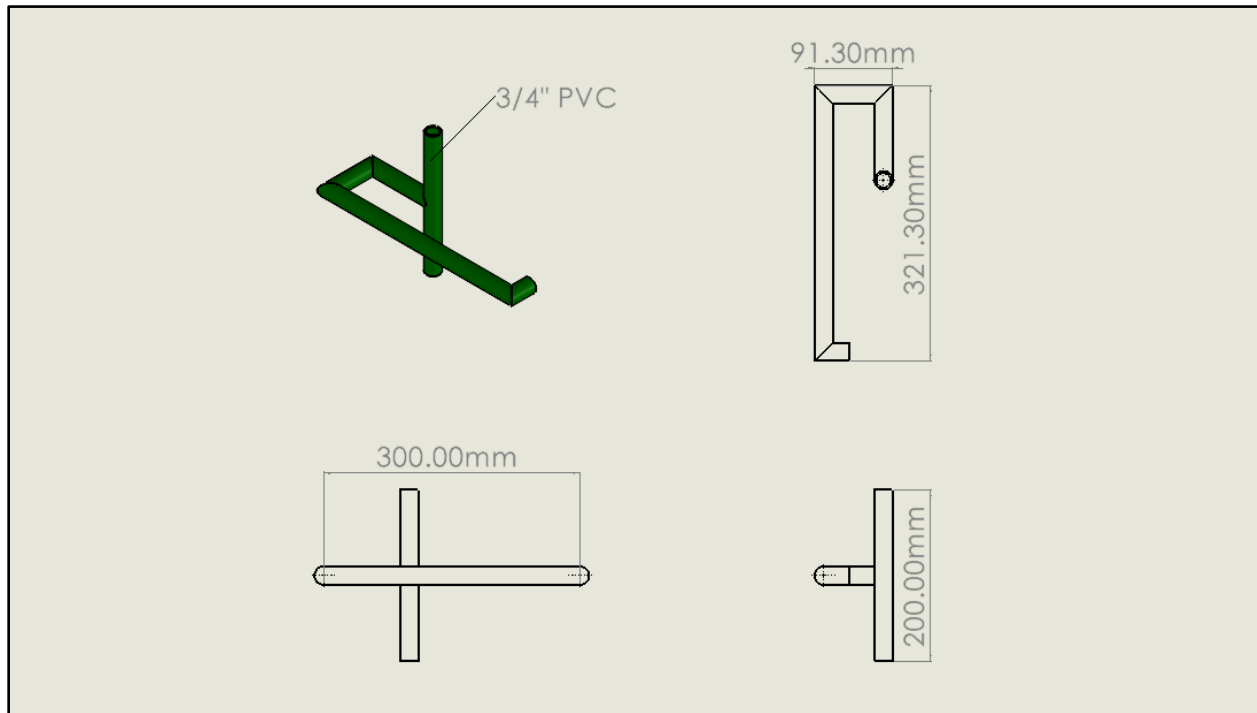


Figure 30: Algae Sample Type 2

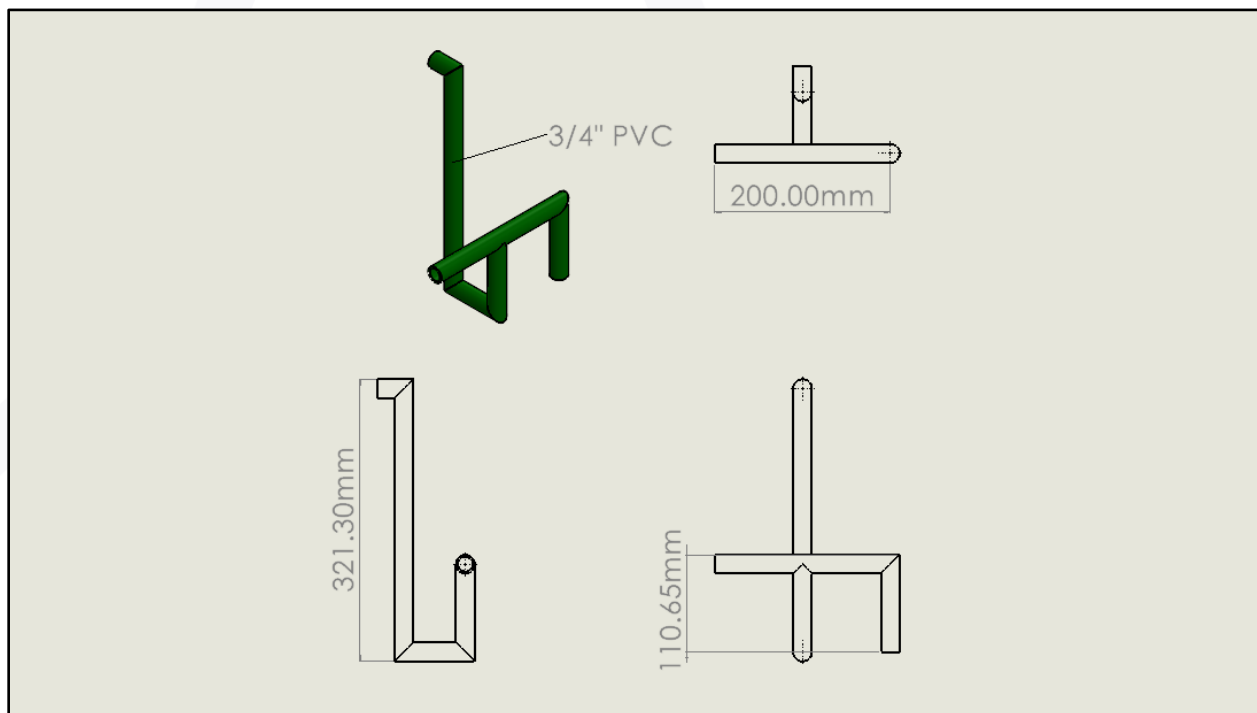
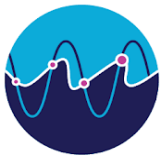


Figure 31: Algae Sample Type 3



A

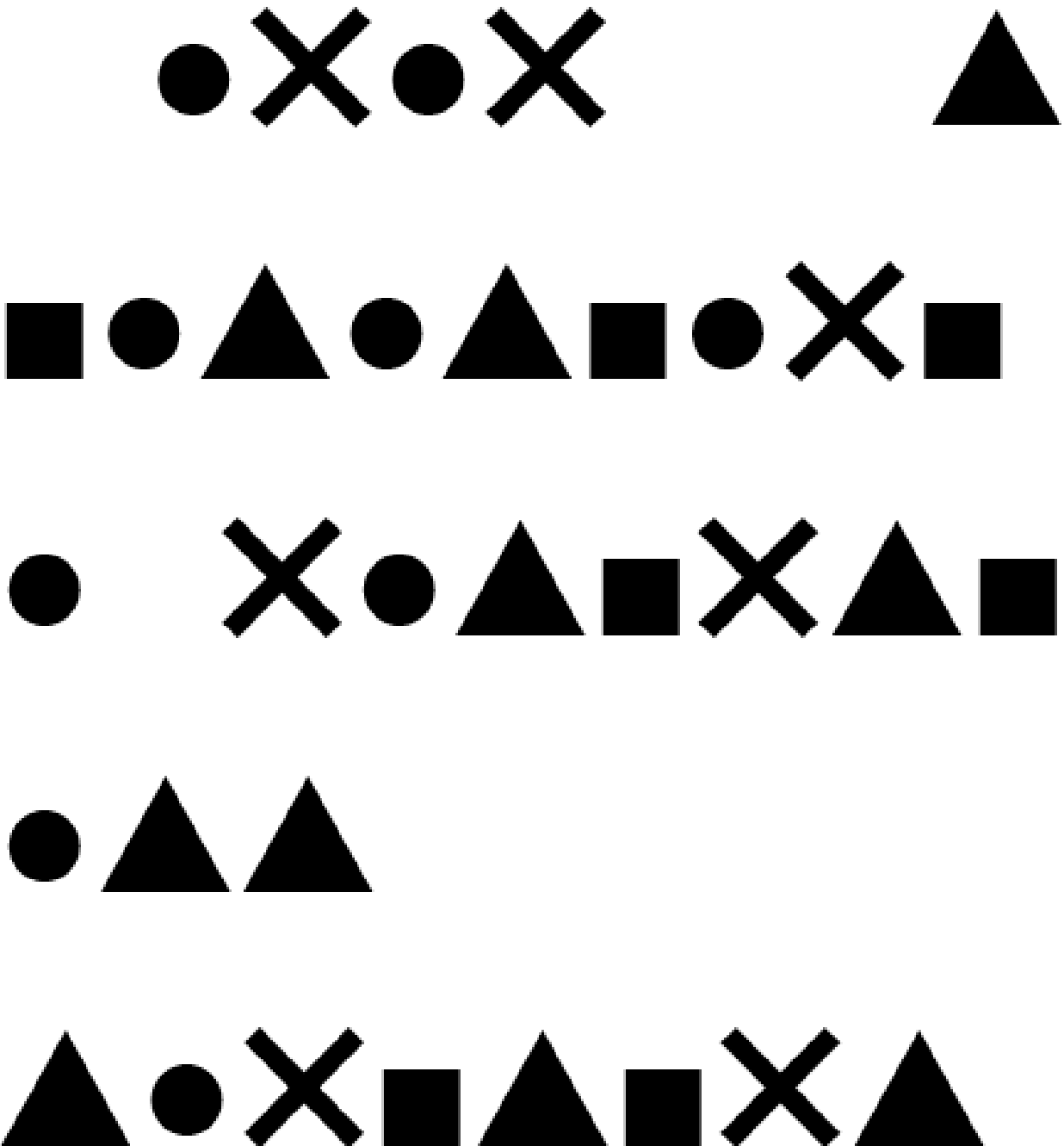


Figure 32: Sample Pattern

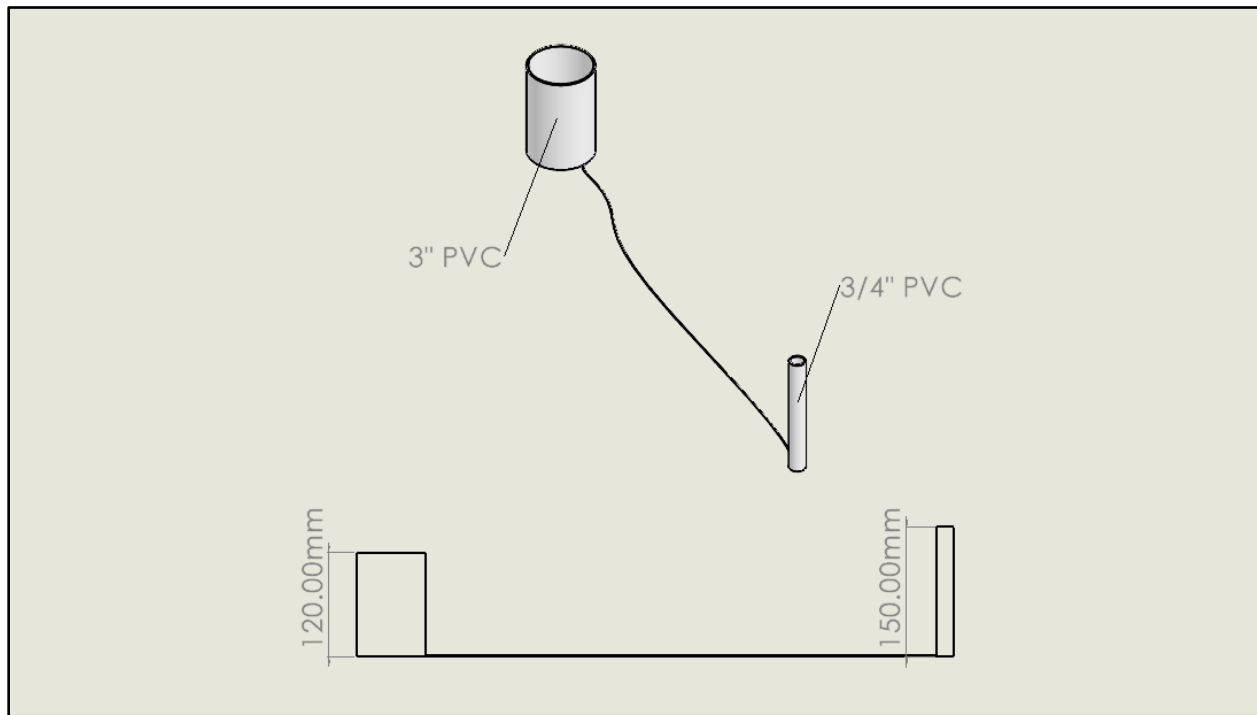
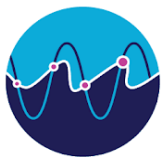


Figure 33: Equipment Dimensions

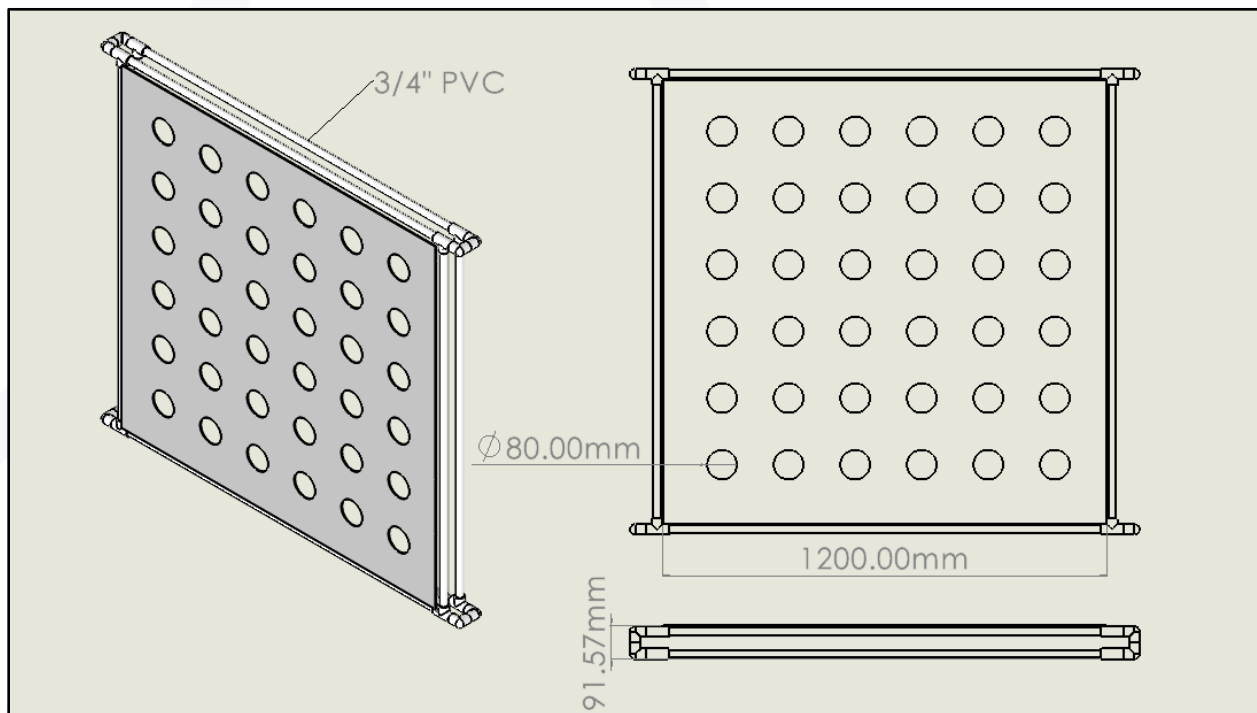


Figure 34: Equipment Area Dimensions

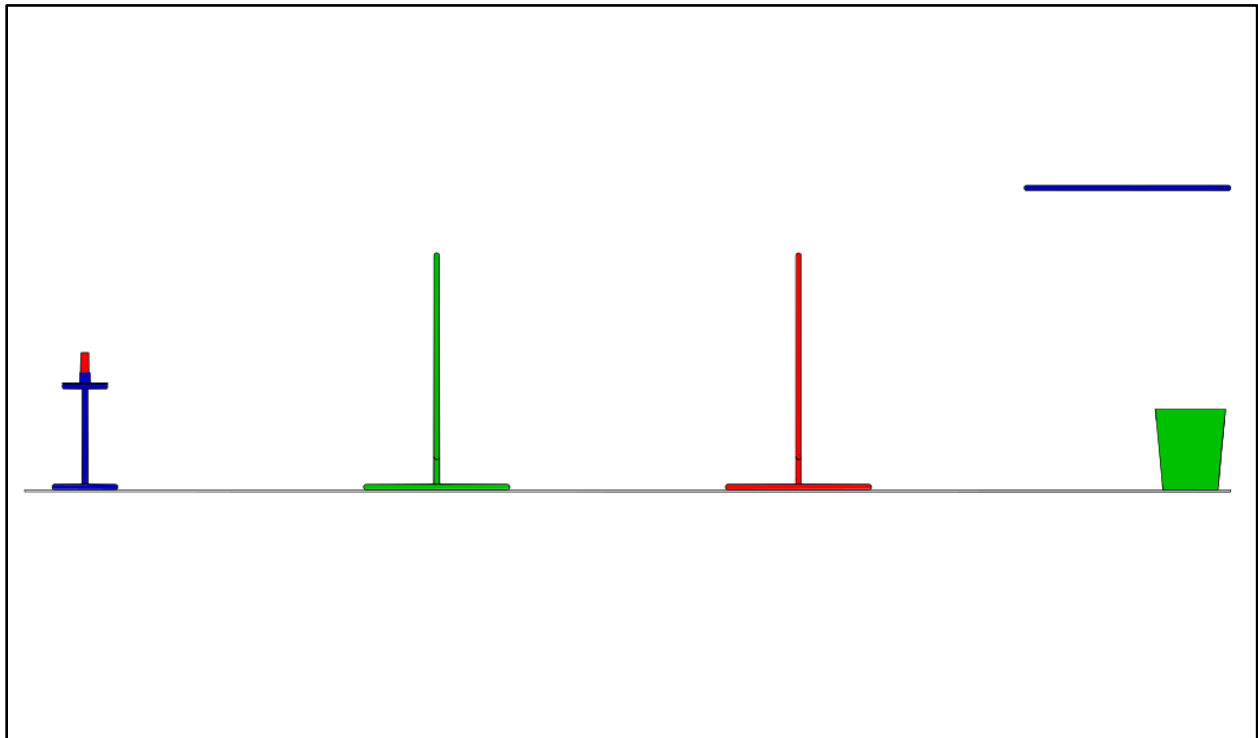
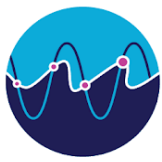


Figure 35: AUV Playground—Side view

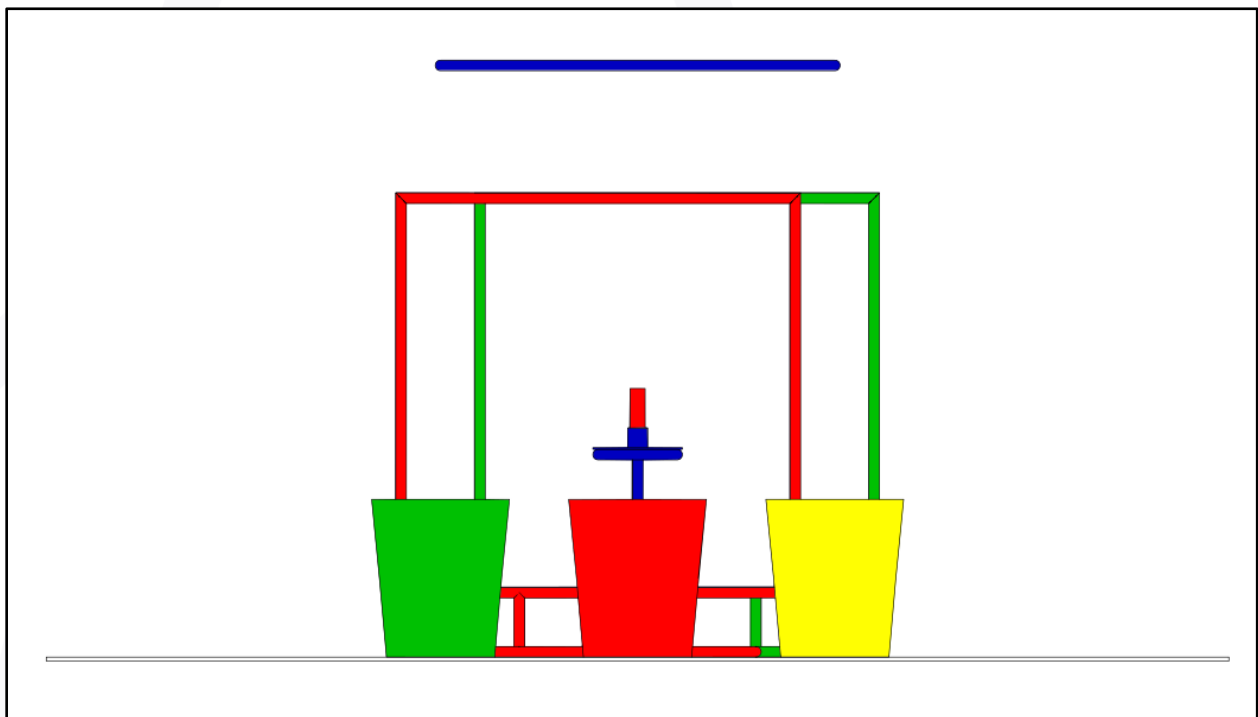
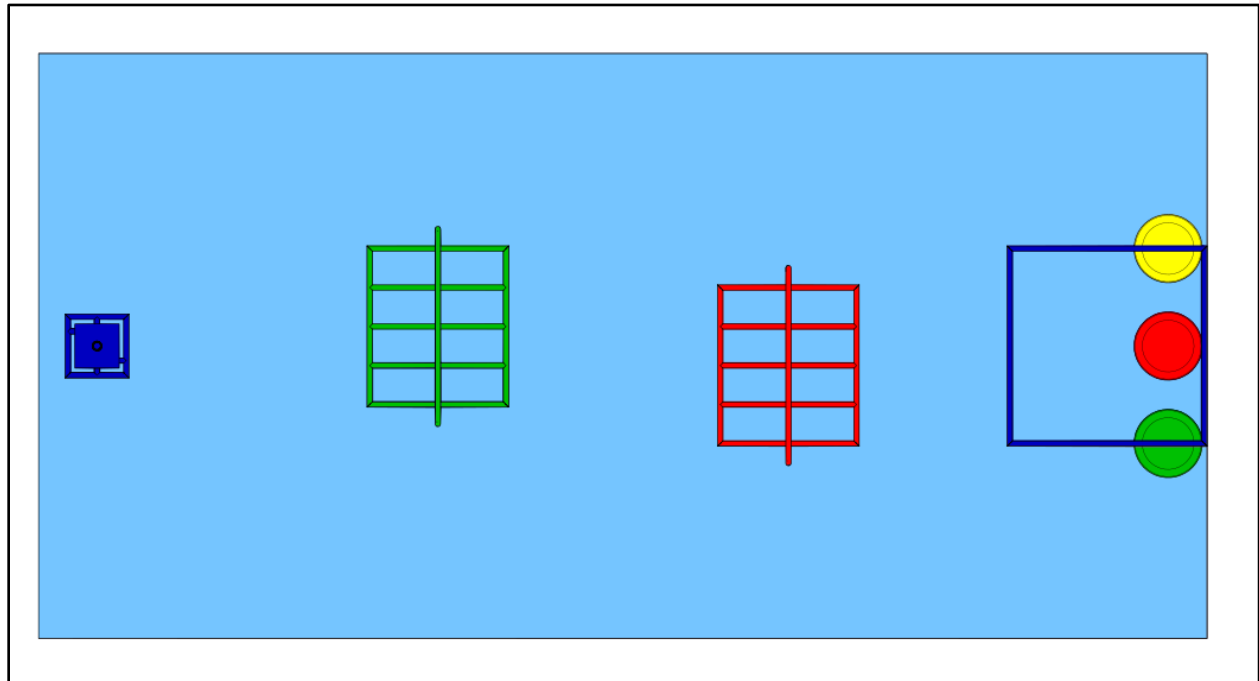
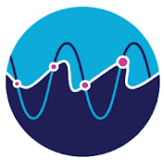
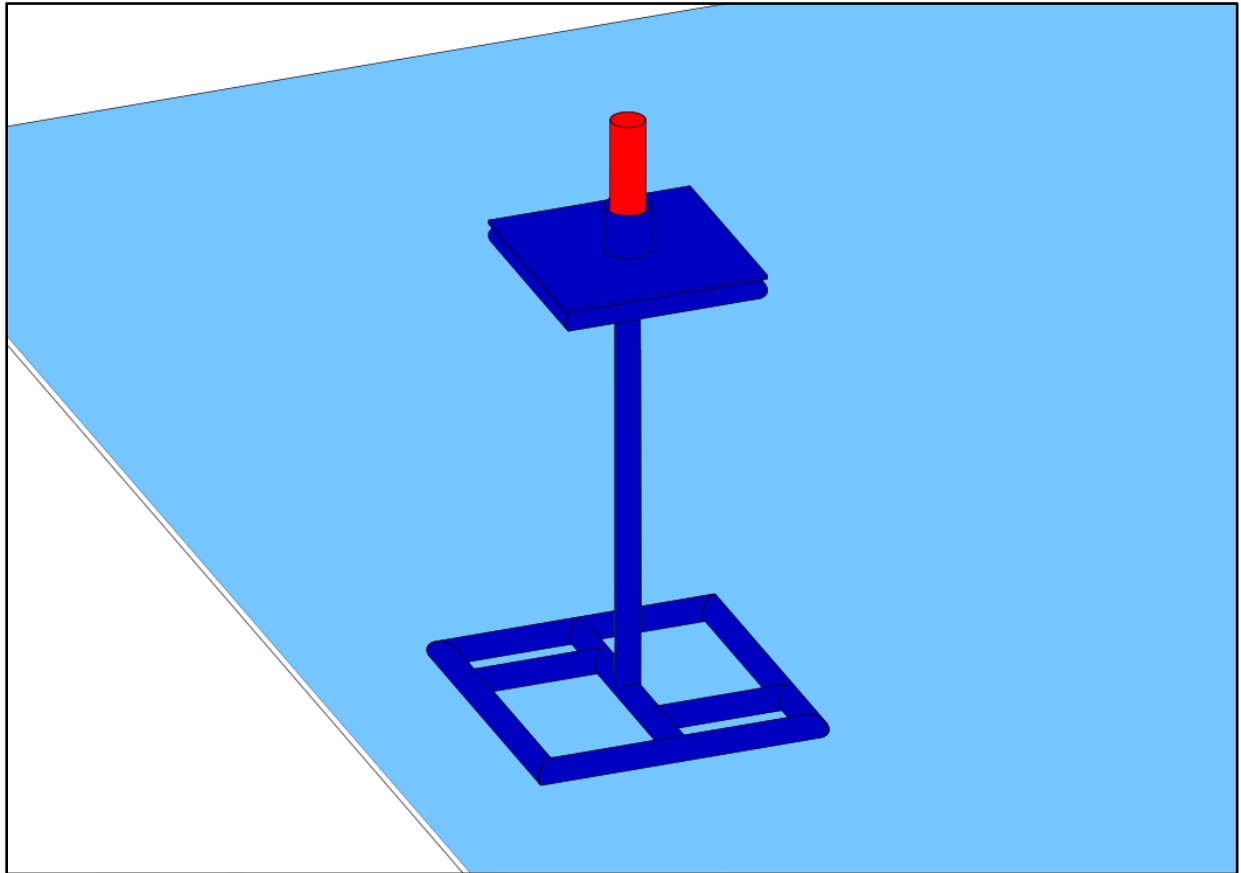
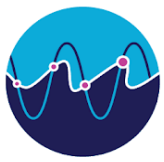


Figure 36: AUV Playground—Front view



*Figure 37: AUV Playground—Top view*



*Figure 38: AUV Sample*

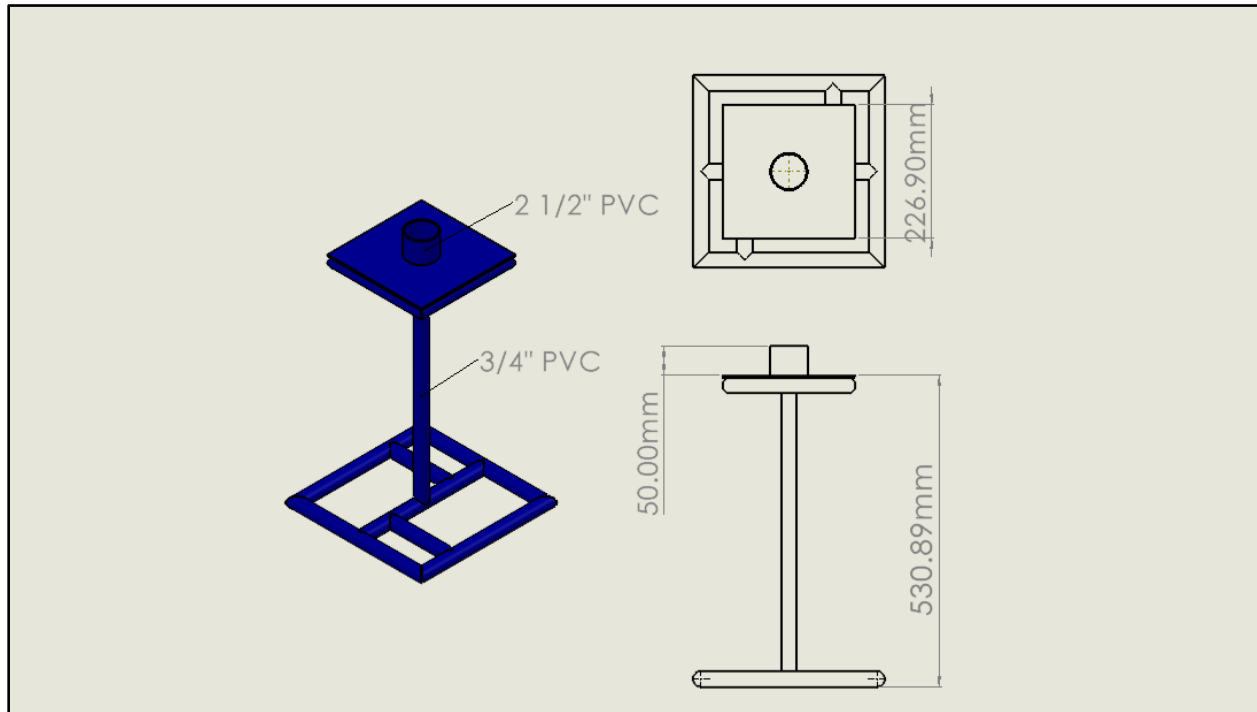
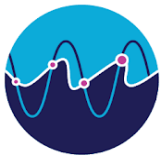
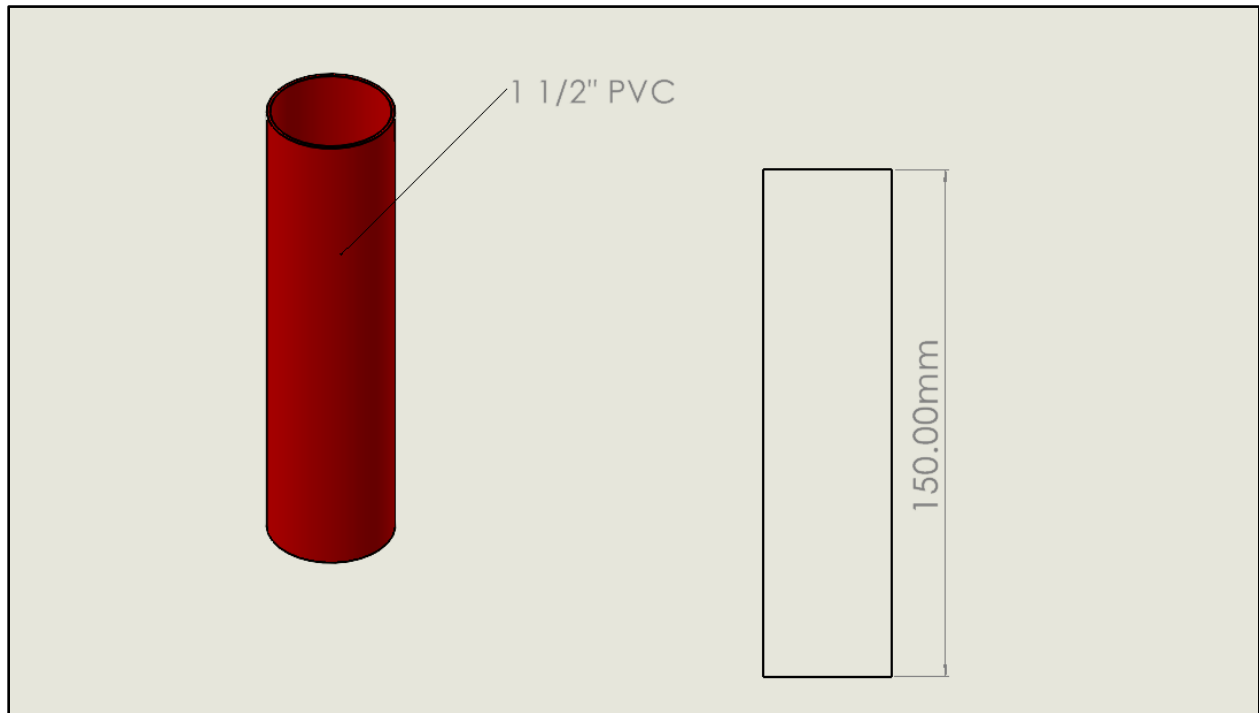
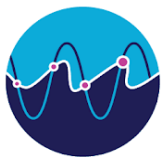
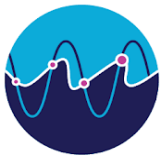


Figure 39: AUV Sample Stand Dimensions





*Figure 40: AUV Sample Dimensions*



## 13. References

Garcia-d'Urso, N. G.-C.-S. (2022). The DeepFish computer vision dataset for fish instance segmentation, classification, and size estimation. *Sci Data* 9, 287.  
doi:<https://doi.org/10.1038/s41597-022-01416-0>