# HMS SeaBots: Scout Team

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**ROV *Discus***
Photo credit: M. Barrett


**HMS SeaBots: Team Photo**
Photo credit: M. Barrett

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## Abstract

We are the HMS SeaBots, a marine robotics company committed to developing remotely operated vehicles (ROVs) that protect and preserve the marine ecosystem. Our company is made up of 9 employees who specialize in mechanical, electrical, and software engineering. The global community has released a request for proposals (RFP) to design and build an ROV that will successfully tackle the real-world problems of plastics in our ocean. To address this RFP, we designed an ROV, *Discus*, that has special features including a servo motor-controlled manipulator arm and a waterproof camera. We have responded to the RFP by creating an ROV that will not only complete all of the given tasks but also surpass all expectations. *Discus* will replace the mesh catch bag in the Seabin, remove plastic and ghost nets from our ocean, test sediment samples for contamination, evaluate a mussel bed, and restore the eel population.

# Teamwork: Project Management

Our company divided labor amongst our members in three main categories: mechanical, electrical, and software. With each member working on aspects of ROV *Discus* such as building, wiring, and programming, our company  was able to complete a successful robot.

**Mechanical Engineers**

- Designed ROV on TinkerCAD
- Built ROV frame and added designed additional features
- Designed thruster guards for motors

**Electrical Engineers**

- Built ROV circuit board and connected wires
- Assisted in constructing the ROV
- Prepared tether for ROV

**Software Engineers**

- Programmed Arduino for the ROV manipulator arm
- Assisted in constructing the ROV
- Wired Arduino box with electrical engineers

**All Engineers**

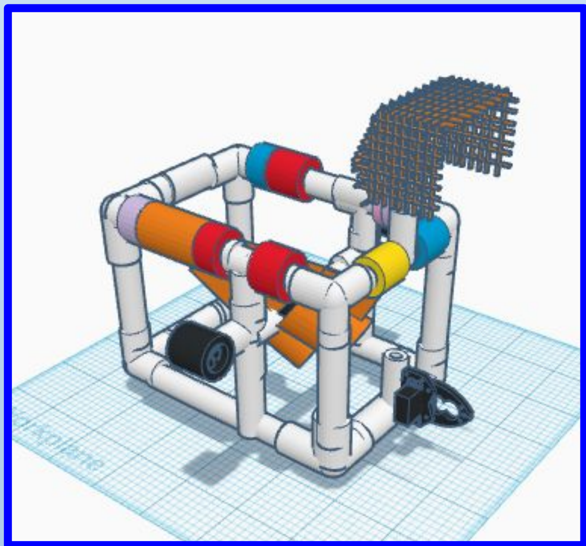
- Completed Documentations
- Brainstormed Ideas for ROV *Discus* and completed construction.

Our team kept to a schedule by meeting after school whenever possible for a few hours. All members of the company were on a Discord server to discuss project ideas and schedule additional meetings. If a team member was absent in meetings, we reached out to her/him/them via Discord or email. Our company split up the tasks evenly so everyone had a task to complete.

Our company used various materials to construct our ROV and documented the materials we used onto a Google spreadsheet. To find prices for materials, we searched online and on the MATE website. We also had a large variety of materials to use, such as the heat gun, heat shrinks, butt splicing, etc. To solve common problems in meetings, we brainstormed possible solutions and carried them out.

# Engineering Design Rationale

## *Mechanical*



3D design of ROV *Discus*

Photo Credit: Aanya Chanda

We designed ROV *Discus* by starting with a basic PVC frame and connector pieces. We built upon that design by adding a manipulator arm, pool noodles, motors, and other special features.

At first, we placed our manipulator arm near the top of the ROV but later moved it down to make it convenient for *Discus* to pick up various items on the pool floor. In addition, we decided to use a net to pick up the floating plastic debris for Task 1. We used PVC and tape to place a small fishing net on the back of the ROV to retrieve floating debris. The net was originally designed with a 90 degree angle, but we later made it around a 45 degree angle.

Initially, the width and length of our ROV was 27.94 cm x 27.94 cm to allow an extra amount of space for additional materials or features. However, this did not fit within the 48 cm size constraint, so we shrunk the size to 22.86 cm. The initial ROV was able to accommodate with more weight, but the new dimensions fit within the size constraints. This tradeoff was beneficial for extra points, and the weight capacity was minimally affected.

Mechanical engineers worked after school throughout the week to build ROV *Discus*, and, after the frame was built, helpful features and materials were added to enhance *Discus'* performance.

## *Electrical*

The electrical engineers worked on building the circuit board by doing tasks such as soldering and wiring.

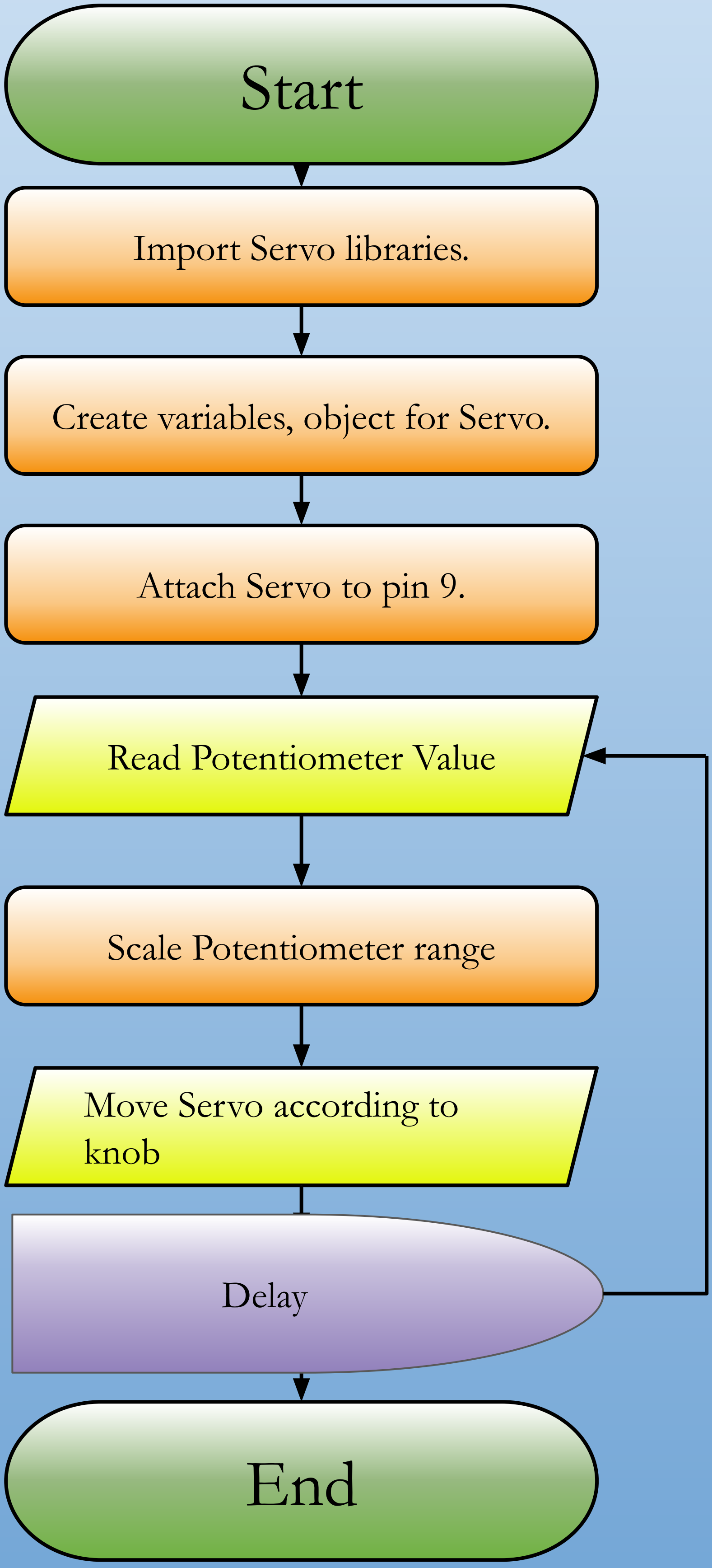
We met frequently to complete the Pufferfish circuit board. We attached the tether and did additional soldering for the manipulator arm (servo motor) along with waterproofing with heat shrink.

## *Software*

In an effort to create a manipulator arm capable of all tasks, we imported the *Servo motor* library, created two variables--*potpin* (potentiometer pin) and *val* (value)--and then used the *void loop* which is where all the action takes place. The *val* variable is set to reading the value of the variable *potpin*, the angle the potentiometer is rotated. The servo motor only takes inputs from 0-180, so our next step is setting the variable *val* to an applicable range. The servo then conducts the degree given. Finally, there is a delay of 15 milliseconds to wait for the motor. This is how our gripper functions.

# Engineering Design Rationale

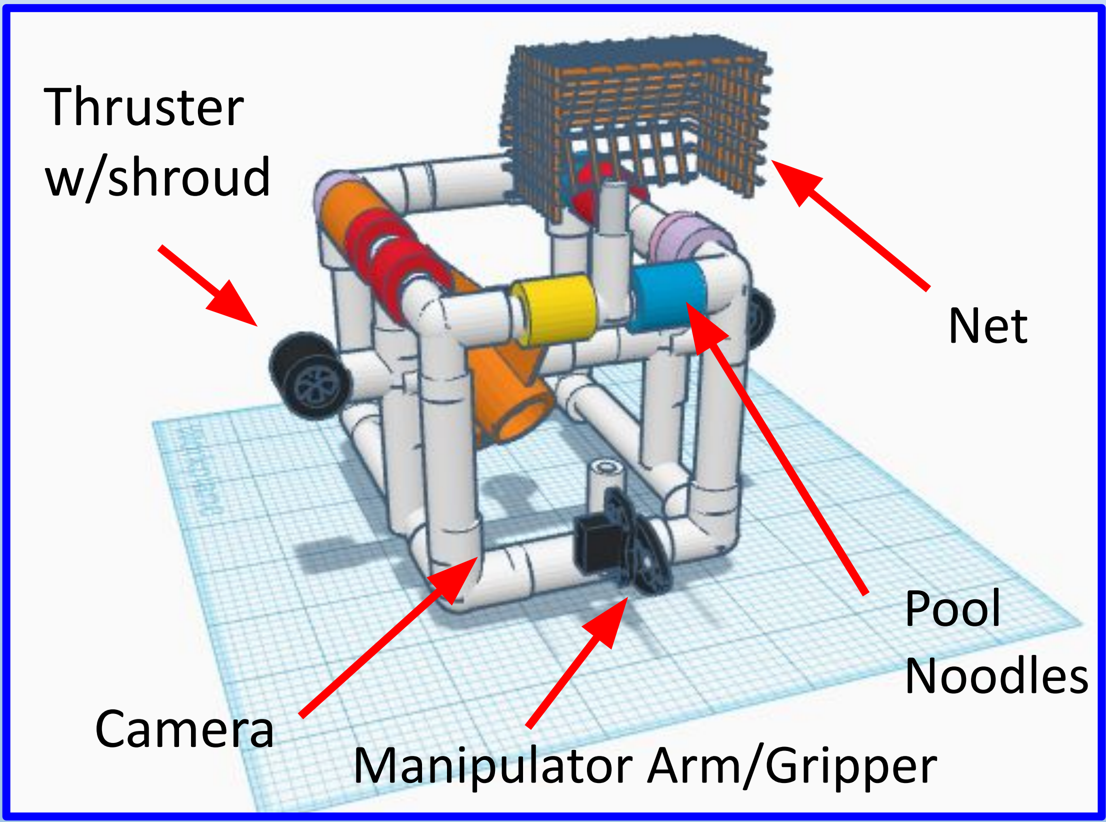
*Software (Cont.)*




```
#include <Servo.h>

Servo myservo;
int potpin = 0;
int val;

void setup() {
        myservo.attach(9);
}

void loop() {
        val = analogRead(potpin);
        val = map(val, 0, 1023, 0, 180);
        myservo.write(val);
        delay(15);
}
```

# Engineering Design Rationale

*Innovation/Special Features/Payload Tools/Problem Solving*




CAD design of ROV *Discus*
designed by Mechanical Engineers on TinkerCAD
Photo Credits: Aanya Chanda

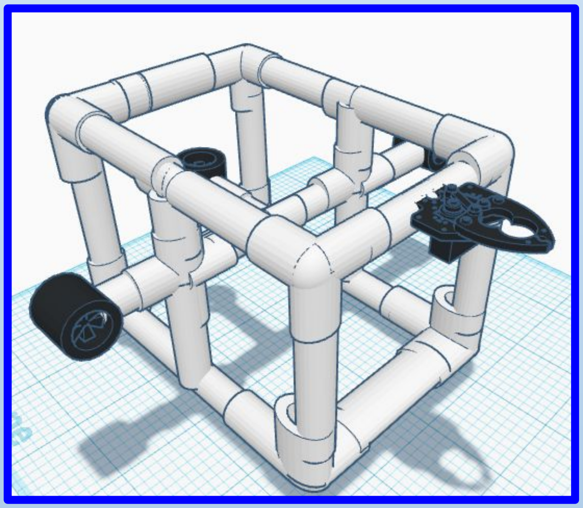
**Special Features:**

- The manipulator arm with a gripper to collect marine debris, sediment sample, eel traps, and other various items in tasks 1 and 3.
- The net will allow us to collect the surface marine debris in task 1.
- We also attached a camera for easier visibility in the water. The camera is located near the back, angled perfectly to see the manipulator arm of the ROV. The position of the camera gives us a wider field of view. This helps us see what is in front of the ROV at a closer angle.

**Problem Solving:**
Payload - While testing ROV *Discus*, we found out that the original net, with a 0 degree angle, was unable to successfully catch any of the floating debris. Hence, we had to adjust the angle of the net from 0 degrees to roughly 90 degrees. This modification increased its effectiveness ten-fold.

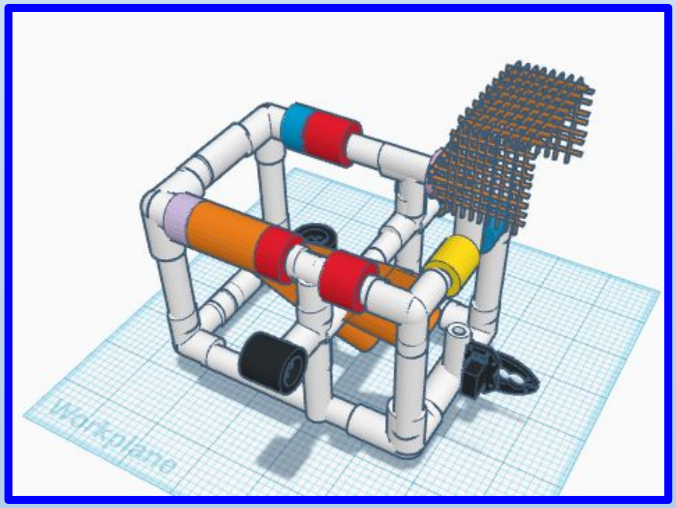
# Engineering Design Rationale

## *ROV Vehicle Systems & Design Iteration*



Preliminary design

Photo Credits: Aanya Chanda



Final design

Photo Credits: Aanya Chanda

ROV *Discus* started off as just a PVC frame, and was first equipped with three thrusters and a gripper. These are the main features of ROV *Discus,* but other parts improved its efficiency. ROV *Discus* evolved as it has many pool noodles attached to try to create neutral buoyancy, and a net to gather the marine debris.

ROV *Discus* features 3 thrusters to help move throughout the water. Two thrusters are located on the sides of ROV *Discus.* The blades of the thrusters are facing the back of ROV *Discus* to provide horizontal movement. The other thruster is located in the middle of the robot, attached to a piece of PVC. The blades of it face upward to help ROV *Discus* in vertical motion.

Thrusters
Photo credit: M. Barrett

Floats
Photo credit: M. Barrett

ROV *Discus* is neutrally buoyant, meaning it floats, however does not come up to the surface. The perks of ROV *Discus* being neutrally buoyant is that we can pilot the ROV to emerge from and submerge into the water without large amounts of pressure. If ROV *Discus* is negatively or positively buoyant, the robot would face severe difficulty to either submerge into the water or emerge from the water.

## *Build vs. Buy; New vs. Used*

Our ROV frame was built by our mechanical engineers. It includes new and reused PVC, and reused connector pieces. The motors, tether, and camera were all reused. The gripper and servo are both new purchases. Our floats and monitor were also reused, and we 3D-printed our thruster guards. As for our Pufferfish control box, we bought a new circuit board and soldered all the components because of its excellent performance in the past. Finally, we reused the software project box, but reprogrammed it on our own, since that box was exceptional years ago, and we inferred that the software box would provide similar benefits as it did years ago. We re programmed the box because the code changes every year, and it is best to utilize the code that is in tip-top shape.

# Safety

## Build and Pool Safety

All members, regardless of their engineering role, must follow the same fundamental safety precautions. However, each specified engineering role may have their own separate safety precautions.

| **Mechanical Engineers** | **Electrical Engineers** | **Software Engineers** | **Performance Team** | **New for 2021: COVID Safety Precautions (all team members)** |
|---|---|---|---|---|
| • Use safety goggles when cutting PVC<br>• Have two people handle cutting PVC<br>• Use safety goggles when drilling<br>• Tie hair back when drilling | • Use safety goggles when soldering and working with tools<br>• Do not make contact with battery terminals with conductive material.<br>• Stay away from water to avoid hazard | • Do not make contact with battery terminals with conductive material | • Stay off pool deck when testing is not in progress<br>• Walk on deck to avoid falling<br>• Watch feet for props and ROV on deck<br>• Wear rubber closed-toe shoes | • Wash hands before and after working<br>• Wear a mask when not in pool<br>• Social distance<br>• Wash hands frequently |

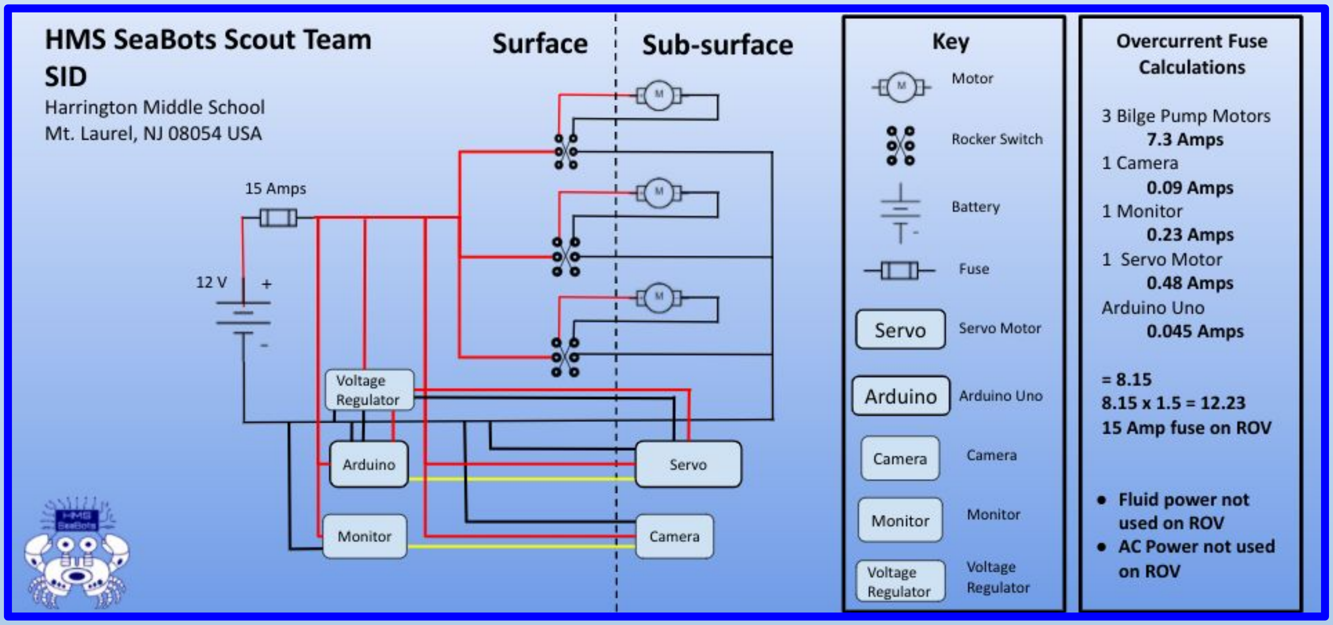
The shrouds included on our motors prevent company members from getting their fingers in it. The thruster guards included in our motors prevent any debris or stray material floating into the propellers.

Shrouds
Photo credit: M. Barrett

Two safety requirements implemented on ROV *Discus* are caution tape and our strain relief, used for wire management. We utilize caution tape on our thrusters to warn pilots, and people interacting with the ROV, that there are sharp objects near. We also have utilized strain reliefs to have proper wire management. Wire management is key since it would be dangerous if wires are tearing for the reason of wires tangled all around the ROV

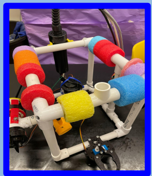
Thruster Guards
Photo credit: M. Barrett

# SID




SID created in Google Draw by Coco Serenbetz and Jessica Yao

# Testing and Troubleshooting

| Problems During Testing | Troubleshooting Procedures |
|---|---|
| Buoyancy check: The first time we put Discus in the water, it sank to the pool floor. That means it was negatively buoyant. This would make it hard for the ROV to propel itself up and float to the surface. It makes the work of the pilot harder. This is not beneficial because when objects obtain negative buoyancy, it is difficult for the ROV to successfully emerged from the water. | The performance team attached floats, one by one, testing the buoyancy after each floats was attached. We finally reached a point where *Discus* hovered in the middle of the water column, obtaining neutral buoyancy.  Altered floats<br>Photo credit: M. Barrett |
| While conducting pool tests with *Discus*, we realized that we could not collect the floating debris (ping pong balls) in task 1.2 with our net. Gravity wouldn't allow the net to scoop up the balls and submerge into the water without the balls falling out, which makes it impossible to complete this task. This is not beneficial since the net is critical, while attempting to obtain the floating debris. Without it, we will not be able to catch the floating debris. | The performance team bent the net to roughly a 45 degree angle, which assisted us in getting the ping-pong balls much easier.  Altered net<br>Photo credit: M. Barrett |

# Budget

| Item Category | Amount | New/Reused/Donated/Discounted/On Sale | Amount Spent ($) | Market Value ($) |
|---|---|---|---|---|
| *Power and Control* | | | **$221.44** | **$231.44** |
| MATE Pufferfish Control Box | 1 | New | $80.00 | $80.00 |
| 15 Amp Blade Fuse | 2 | New | $6.44 | $6.44 |
| Pufferfish Video System (one camera) | 1 | New | $135.00 | $135.00 |
| 25 ft Tether 18 AWG | 1 | Reused | $ -- | $10.00 |
| *Manipulator Arm* | | | **$99.65** | **$143.13** |
| Standard Grippper Kit A | 1 | New | $9.95 | $9.95 |
| Hi-Tec D646WP 32-bit Waterproof Servo | 1 | New | $56.00 | $56.00 |
| Arduino Uno | 1 | New | $22.00 | $22.00 |
| Potentiometer with Knob | 1 | Reused | $ -- | $1.49 |
| Drok Current and Volt Regulator with Buttons | 1 | New | $7.70 | $7.70 |
| Liquid Electrical Tape | 1 | New | $1.00 | $1.00 |
| Pelican Project Box | 1 | Reused | $ -- | $20.00 |
| Black Nylon Hex Nut Spacers | 1 box | Reused | $ -- | $8.99 |
| On/off Power Switch | 1 | Reused | $ -- | $2.00 |
| Power Cord 16 AWG | 1 | New | $3.00 | $3.00 |
| Cat.5 24 AWG Cable | 1 | Reused | $ -- | $5.00 |
| In-line 15 AMP Fuse | 1 | Reused | $ -- | $6.00 |
| *ROV Frame* | | | **$5.16** | **$203.80** |
| 1/2 inch PVC Pipe | 13ft | New | $3.88 | $3.88 |
| PVC 3 Way Corner Connectors | 8 | Reused | $ -- | $21.16 |
| PVC Tees | 5 | Reused | $ -- | $2.80 |
| PVC Crosses | 2 | Reused | $ -- | $4.02 |
| 1 1/4 x 1 1/4 x 1/2 inch PVC Tee | 2 | Reused | $ -- | $10.44 |
| Johnson Bilge Pump Motors 1250 GPH | 3 | Reused | $ -- | $152.97 |
| 3 inch PVC Coupling | 3 | Reused | $ -- | $5.25 |
| Wire Ties | 6 | New | $1.28 | $1.28 |
| 3D Printed Custom Shroud Braces | 6 | Reused | $ -- | $2.00 |
| *Mission Tools* | | | **$9.79** | **$25.59** |
| Fishing Net | 1 | Reused | $ -- | $6.99 |
| Polyproplyene Rope | 1 roll | Reused | $ -- | $8.81 |
| Zipties | 62 | New | $9.79 | $9.79 |
| *Thrusters* | | | **$1.00** | **$100.00** |
| Thrusters | 3 | Reused | $ -- | $99.00 |
| 3D Printed Thruster Guards | 3 | New | $1.00 | $1.00 |
| | | New | | |
| **Total Cost** | | | **$326.25** | **$578.37** |

# Acknowledgments

Our company would like to thank the MATE organization for giving our team, as a whole, the ability to compete at such a high level, and truly discover our passion. Our whole team has learned many lessons throughout this last month. We would also like to thank our mentors, Ms. Maureen Barrett and Ms. Marieve Patterson. Even though we do not know the true winner of this competition, our team considers this a win, in our terms, for being able to learn amazing things, and make ROV *Discus* in just a month's time.

# References

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