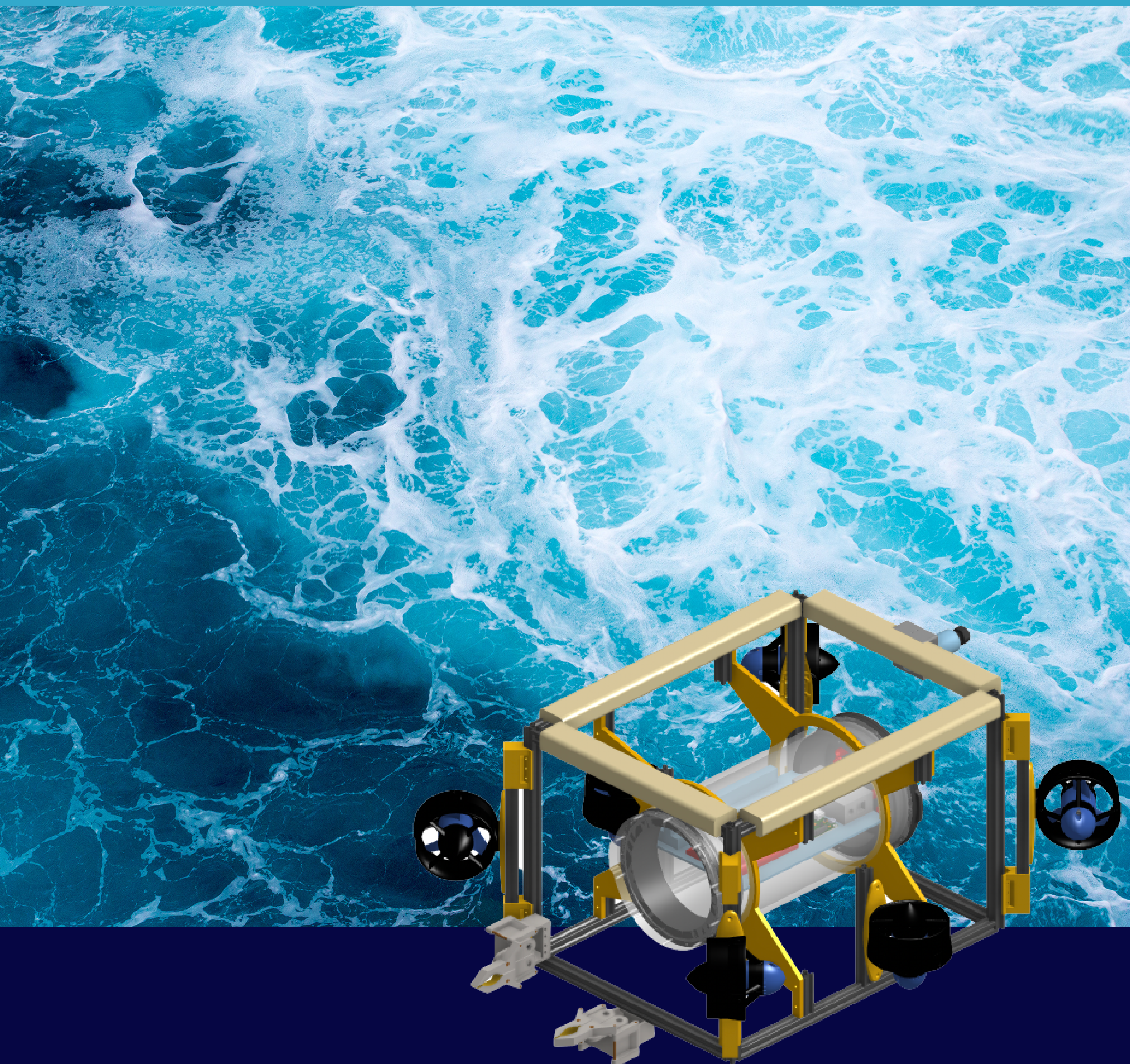
East Tennessee State University

ETSU BUCCANEERS

TECHNICAL REPORT



REMOTELY-OPERATED VEHICLE (ROV) KRAKEN

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INTRODUCTION

Abstract

Kraken is the ETSU Underwater Robotics Program's very first Remotely-Operated Vehicle (ROV). *Kraken* was designed to tackle the challenge of dealing with plastic pollution, monitoring and handling the effects of climate change on coral reefs, and maintaining healthy waterways. *Kraken* encompasses a versatile extruded aluminum frame, six thrusters, a low-light analog camera, two onboard electronics, and a custom control system.

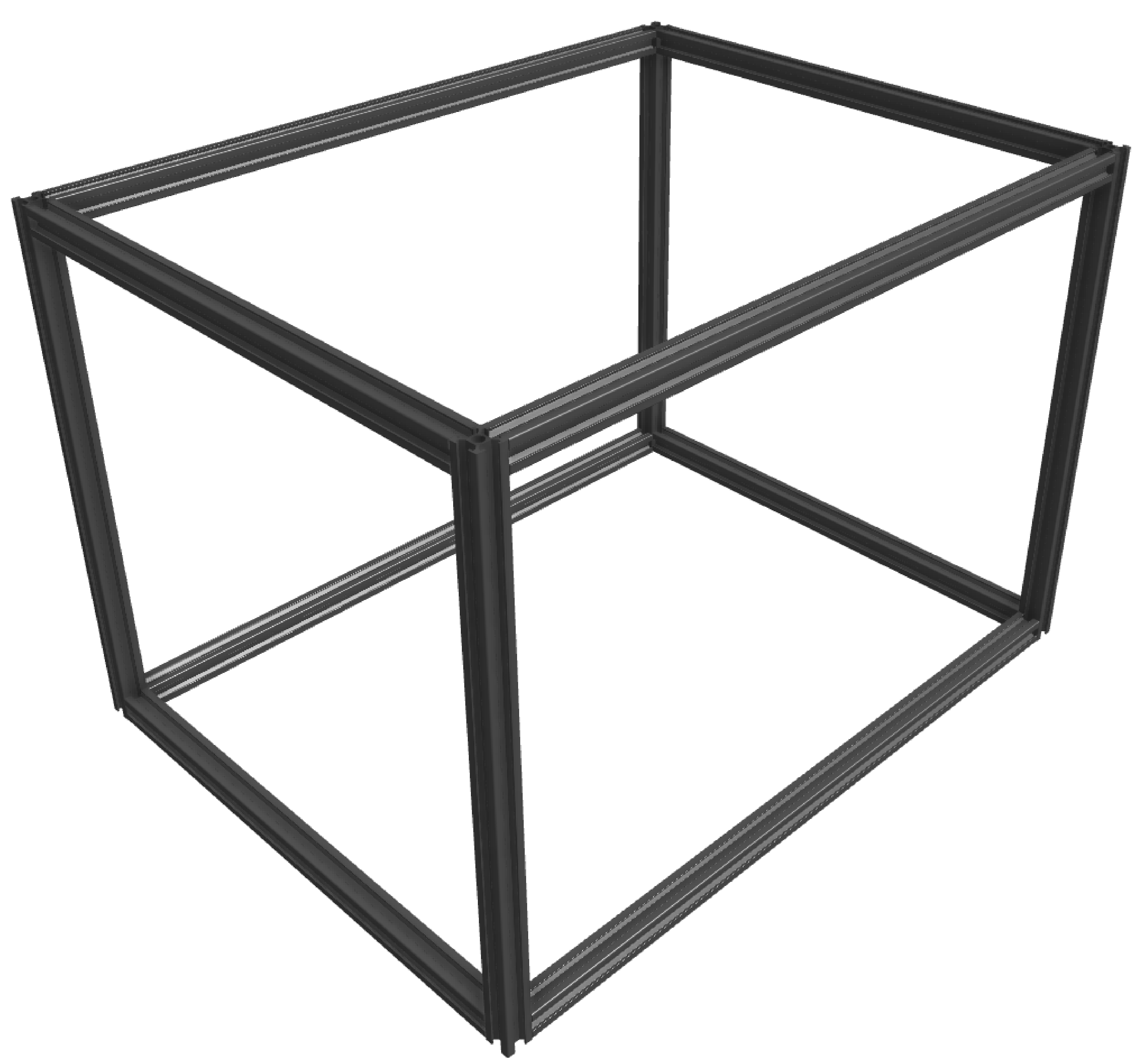
ETSU MATE Underwater Robotics Team

(Left to right: McKenzie Templeton, Gavin Bentley, Quintin Folkner)

DESIGN RATIONALE

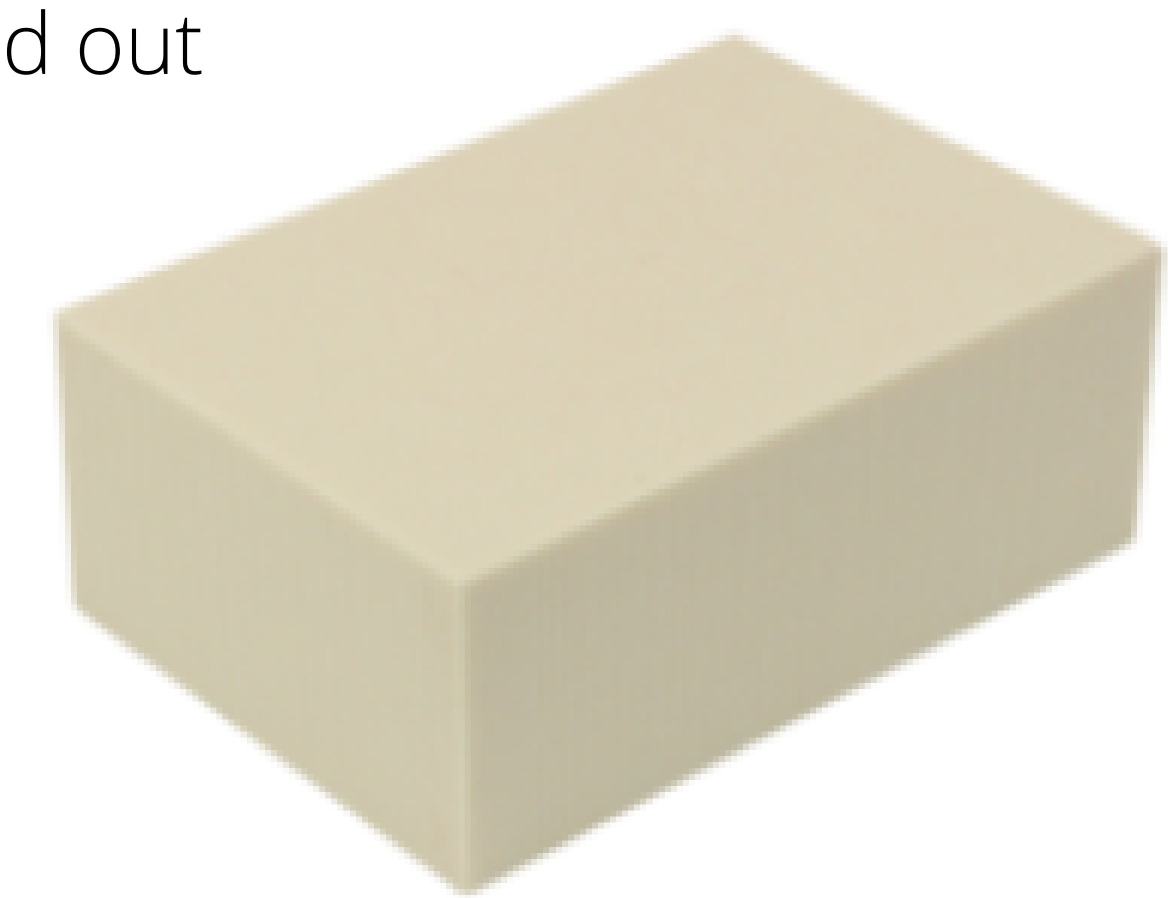
Frame:

Kraken has a rectangular frame consisting of 15mm by 15mm extruded aluminum. We choose extruded aluminum because of the modularity of the material. Since the material is made out of aluminum, it allows us to create a lightweight and sturdy ROV capable of completing our tasks. The team wanted to find a cost-effective material to construct our frame from, which led us to aluminum or PVC. Aluminum tensile strength is 310 MPa compared to PVCs tensile strength of 46 MPa (Moore, Bohm, & Jensen 2010). This was a motivating factor for choosing aluminum over PVC.



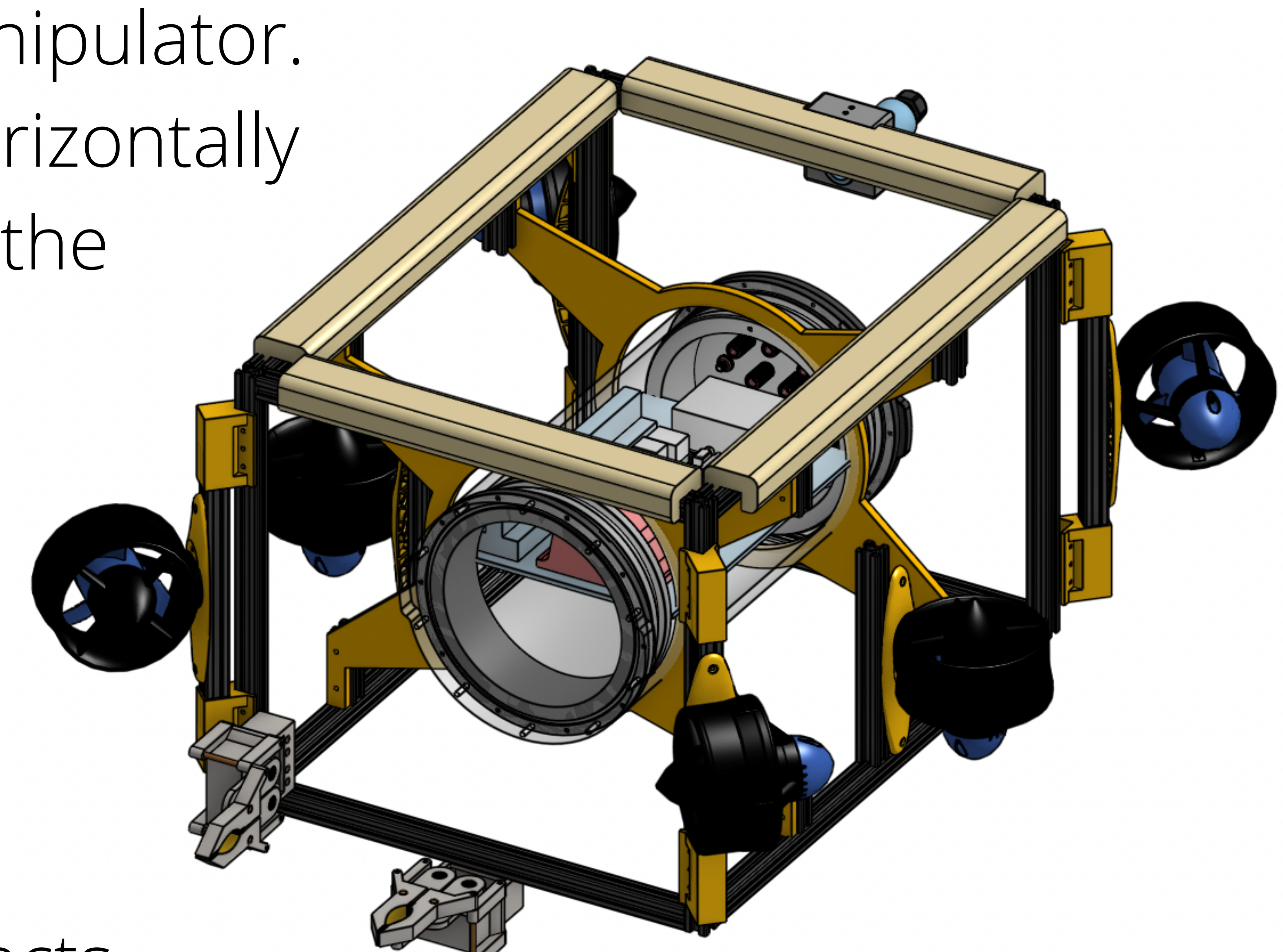
Buoyancy:

The Buccaneers used R3312 Subsea Buoyancy Foam. Purchased from Blue Robotics, the Subsea Buoyancy Foam is engineered out of Urethane allowing it to be better suited for underwater operations. The Urethane's closed-cell structure allows the foam to be more resistant to water. Unlike pool noodles, the depth rating for the Subsea Buoyancy foam is 91m, compared to 1.3m with the average pool noodle.



Manipulators:

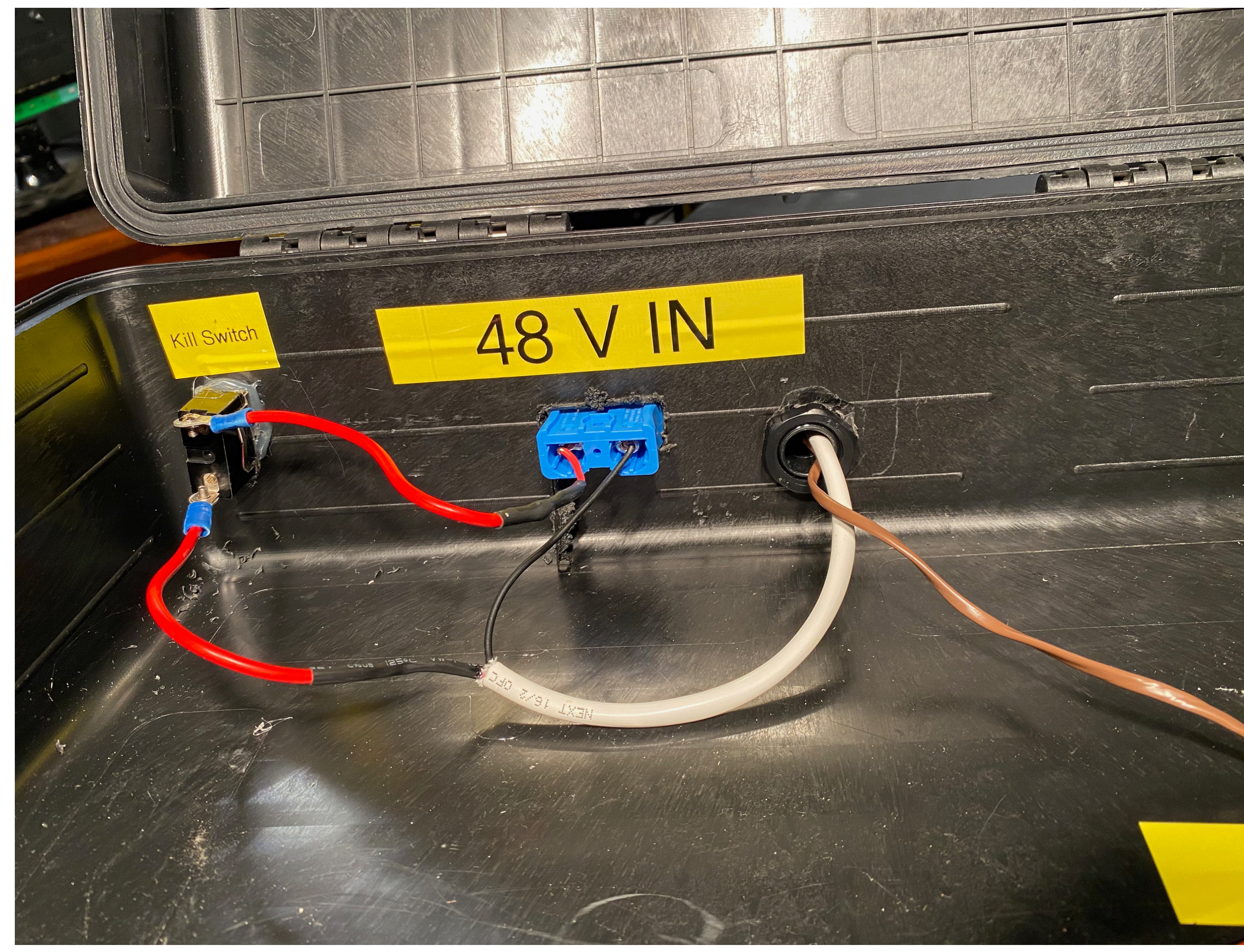
The Buccaneers chose to use two manipulators for the sake of versatility in regards to how a mission is executed. *Kraken* houses one vertically placed manipulator and one horizontally placed manipulator. The vertically placed manipulator handles horizontally positioned tasks such as the replacement of the seabin trash rack, while the horizontal manipulator manages vertically positioned tasks such as the sampling of the sea sponge. Bought from RobotShop.com, the Claws are controlled by a waterproof servo connected to the joints of the claw and the Arduino Nano. Our first claw can pick up objects 10.6cm in diameter and our second claw can pick up objects 7.1cm in diameter.



Electronics:

Control Box:

The ETSU Buccaneers used onboard electronics, so on the surface side, we do not have many components in our control box. Inside our control box, we have a monitor to broadcast video feed from our ROV underwater. Also inside the control box is a USB to Ethernet extender and a 12V to 5V power converter. The power converter is required to power the USB to Ethernet converter.



Tether:

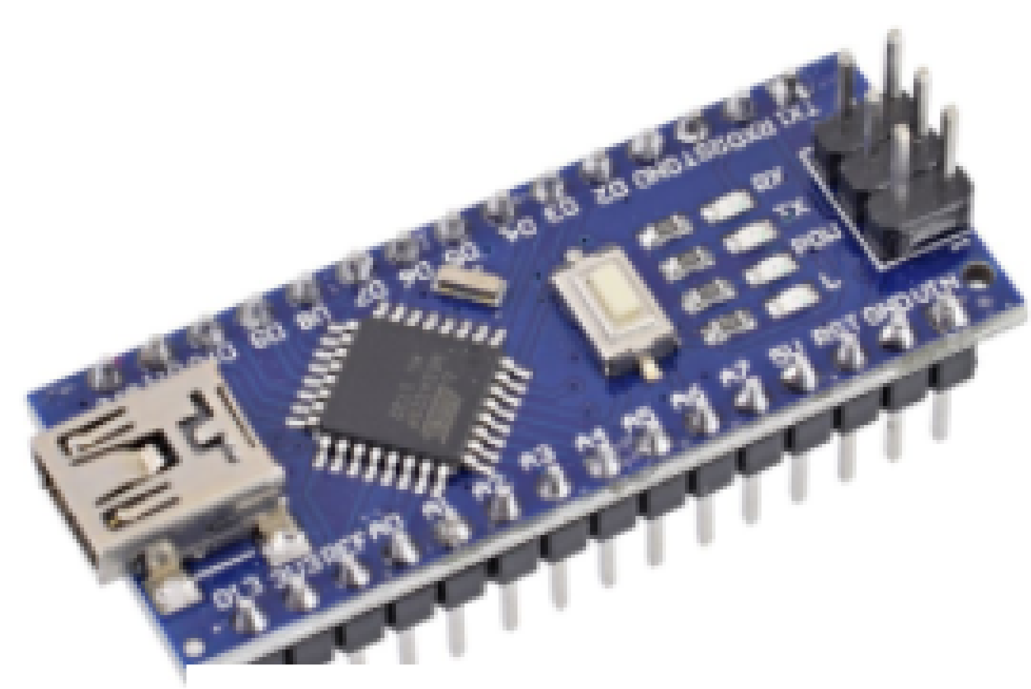
Kraken has a very minimalistic tether. The tether consists of our power cable, which is a 16-gauge 2 wire speaker cable in a white jacket to protect the wires, an ethernet cable to communicate with the controller and the USB breakout board onboard the ROV, and another power cable to run power back to our control box. The tether has strain relief on both ends of the wires.

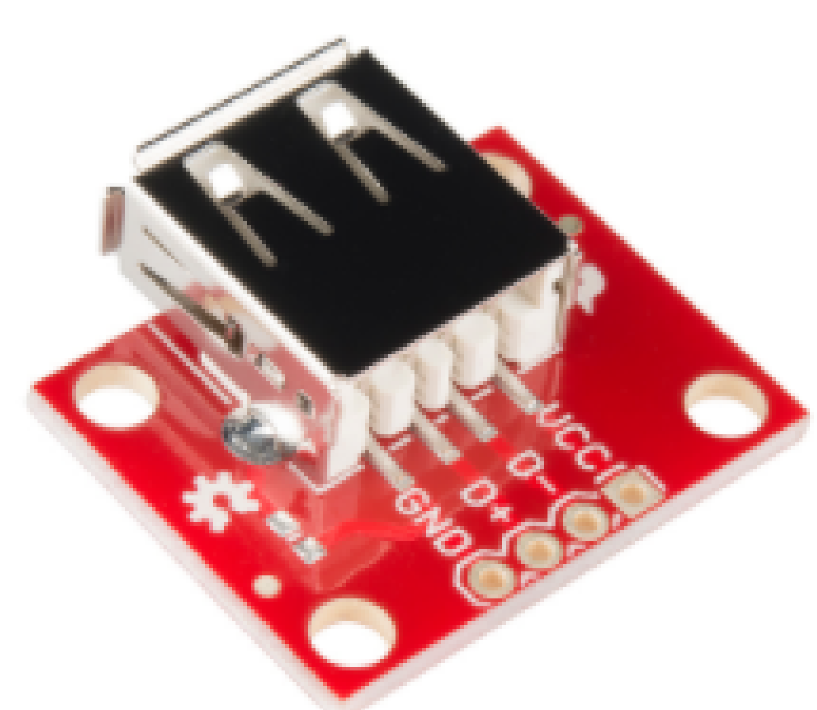
Power:

Kraken runs off of 48V provided by a power supply on the surface. Throughout our system, there are three power converters to send various voltages across our ROV. There is one 48V to 12V power converter and two 12V to 5V power converters. The 12Vs are needed to power our ESC's, T200 Thrusters, and a Blue Robotics Camera. The 5Vs are needed to power the Arduino Nano and our USB to Ethernet converter.

Arduino Nano:

Our ROV, *Kraken*, is controlled by one Arduino Nano. The Arduino Nano is smaller than most Arduinios allowing us to have more room to equipped other electronics in the watertight enclosure. With the Arduino Nano, we are able to control *Kraken* via Xbox 360 controllers, which allows us to have more control of our ROV. At first we were going to use the Raspberry Pi, but after some trial and error, we found that the Arduino Nano works the best for what we need it to do.



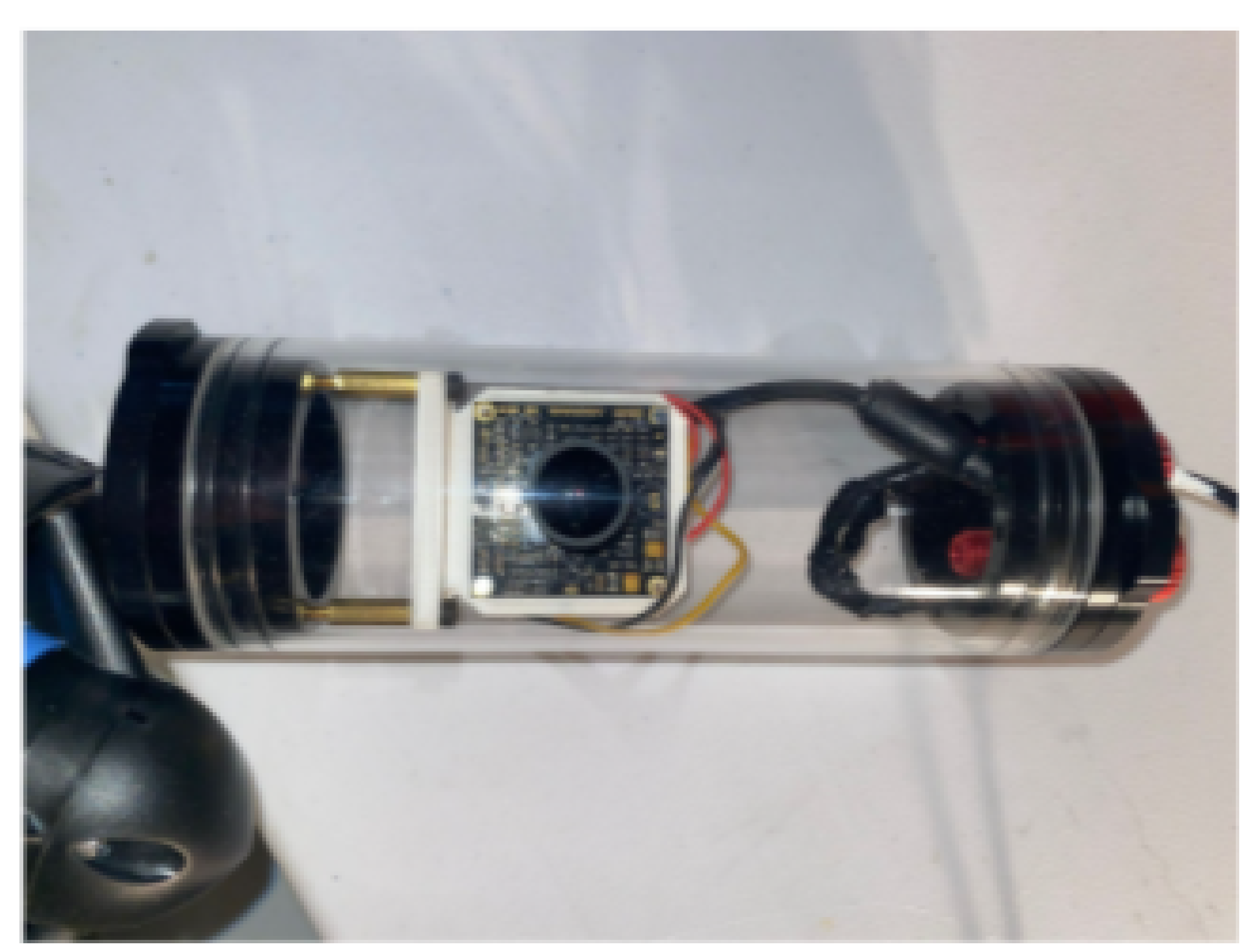


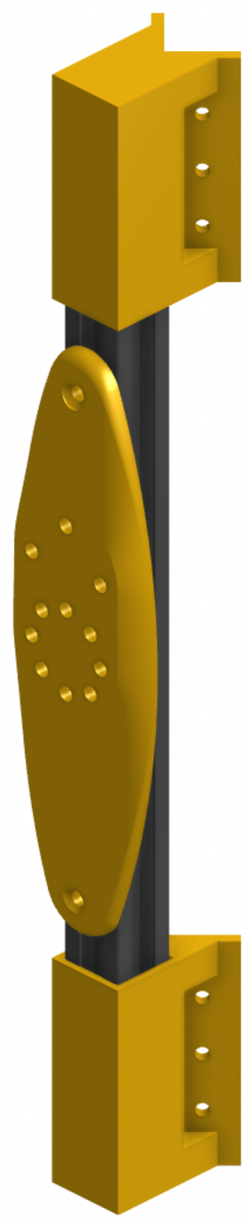
Lights:

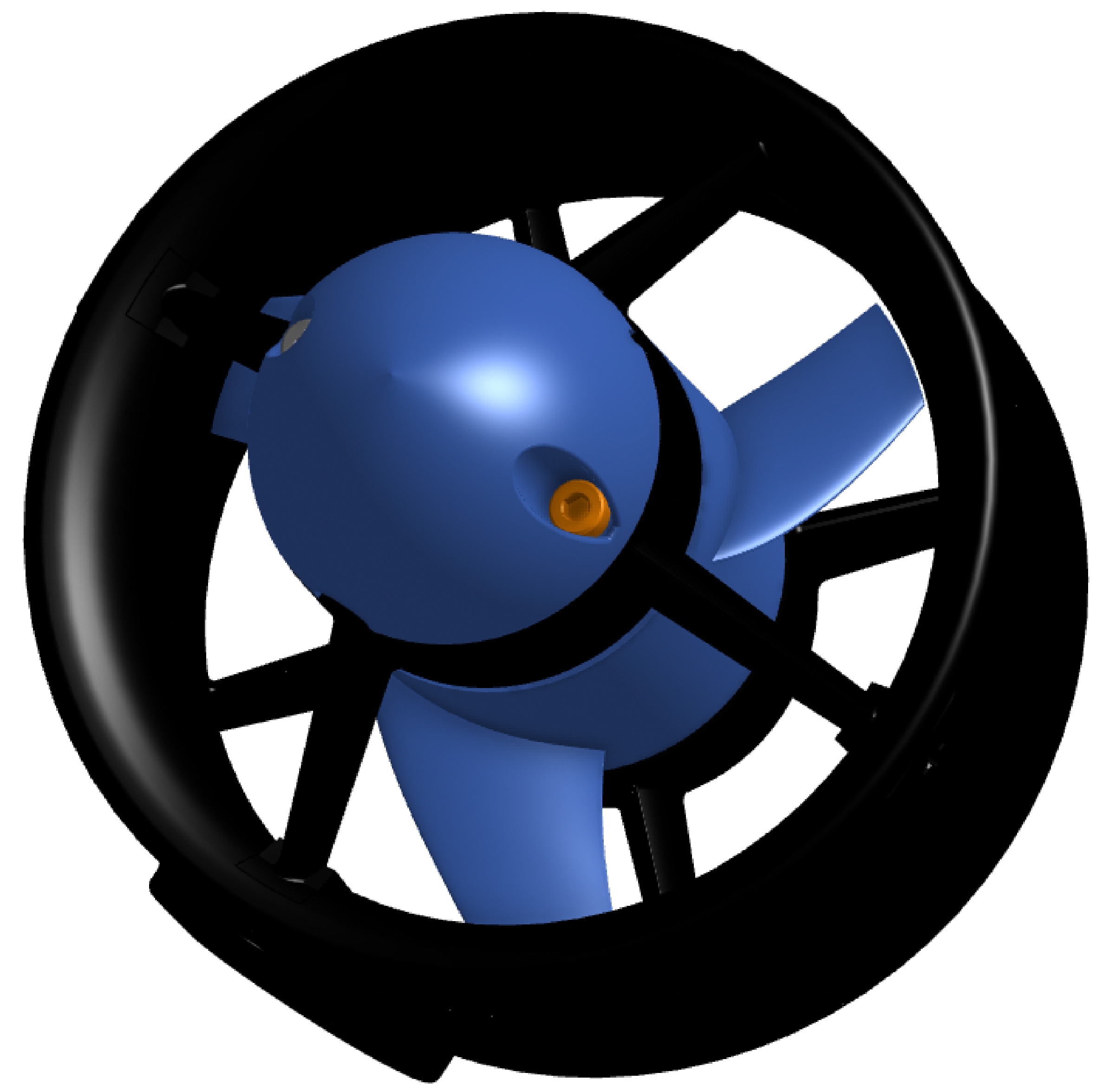
Kraken is equipped with two 1500 Lumen Subsea Lights purchased from BlueRobotics. For a total of $115.00 per unit, these LED lights have a 135-degree beam angle and omit 1500 lumens at 15W, making *Kraken* capable of exploring great depths amidst low visibility. The product comes waterproofed, which makes it easier to use. Each light is mounted horizontally on the sides of the ROV directed forward. Equipping the ROV with two lights minimizes the shadow effects caused by water, augmenting visibility.

Camera:

Kraken is equipped with one Blue Robotics Low-Light Analog Camera, which provides visuals for our pilot. Our camera is located on the front of our ROV and is waterproofed in a watertight housing with epoxy sealing the penetrators. The camera is mounted by using a hose clamp and is attached in an upright position due to how the inside mount is positioned.





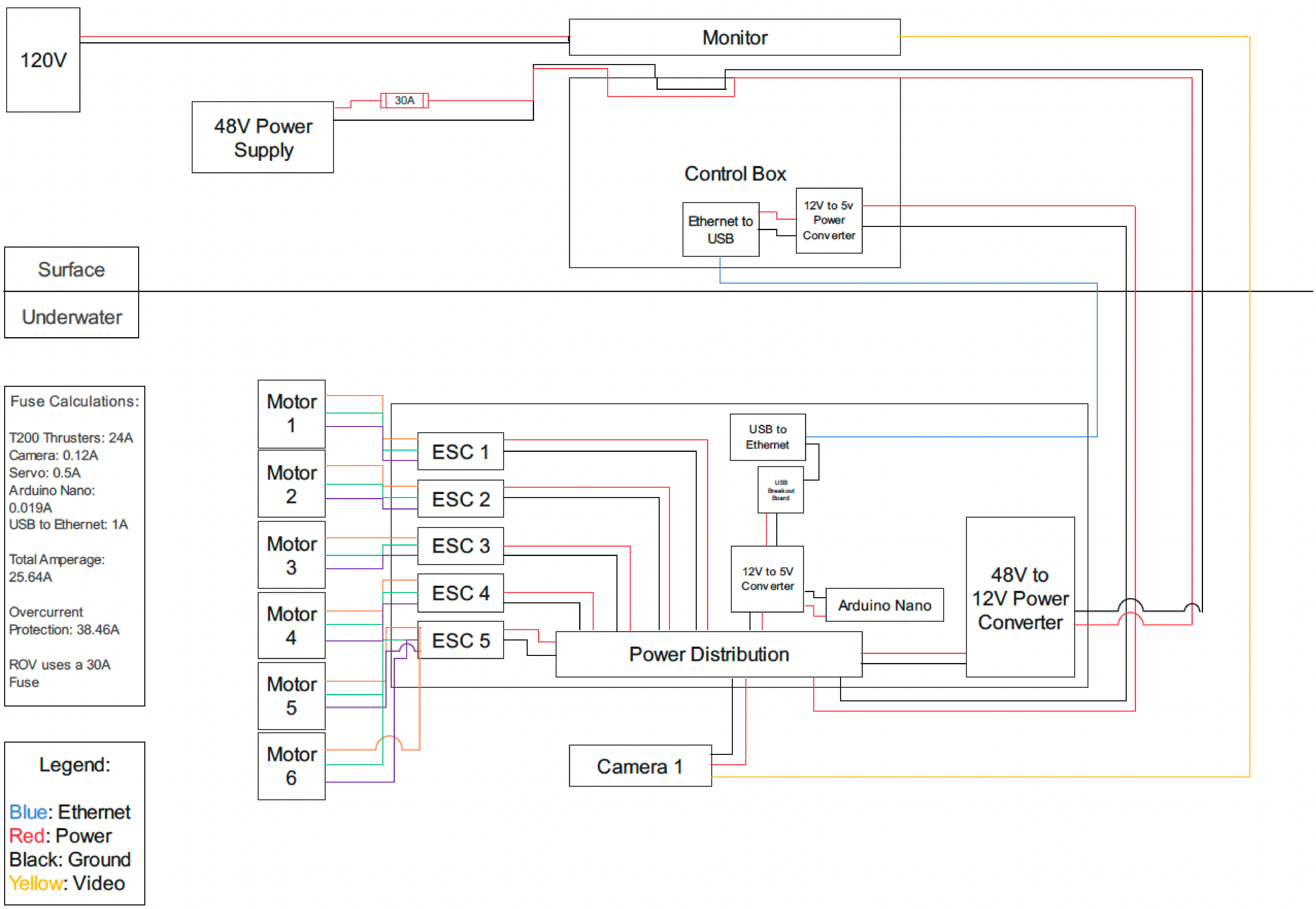


Thrusters:

When determining which thrusters to use, our team had a few criteria in mind. One; thrust capability, especially for *Kraken*'s vertical thrusters. Two; compatibility with our control system and preferably a thruster that had its own Electronic Speed Controllers (ESCs). Originally planned, the ESCs were to be used with a Raspberry Pi Model 3, but as our team found out, there was not much compatibility directly between the two without another CPU. The team learned that the Blue Robotics ESCs work better with an Arduino Nano running C++ rather than a Raspberry Pi with a servo bonnet running Python3.

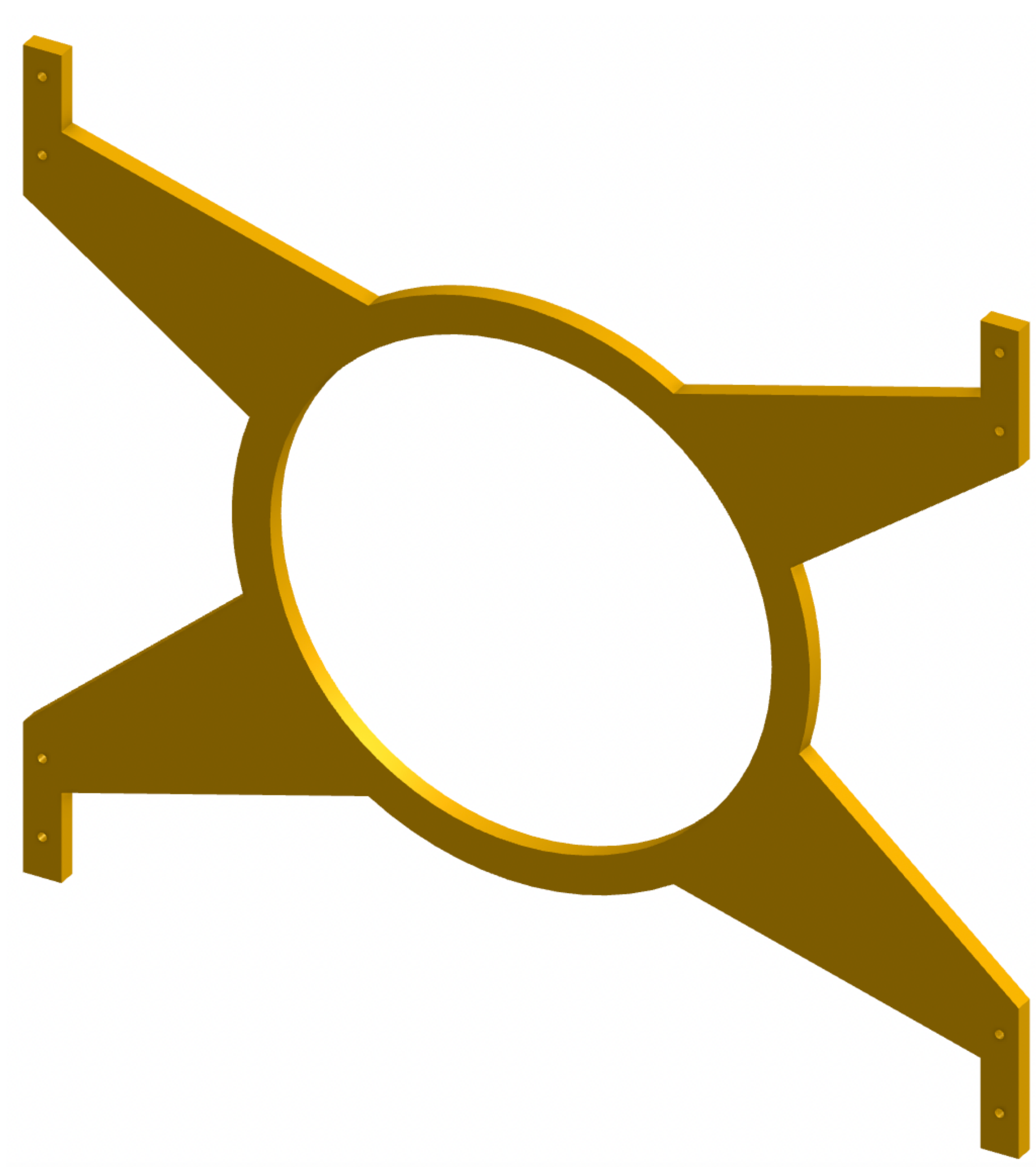
Four of the thrusters are placed at a 45-degree angle on each of the corners. These are in a vectored orientation so that whenever the joystick is calling on an axis, the motors are turned on in a specific pattern to give us maximum thrust from all four thrusters. The other two motors are placed on the sides near the center of gravity to propel the vehicle either upwards or downwards. The team decided to use two thrusters to acquire more vertical thrust when picking up objects from the bottom of the pool.

Kraken's Electrical Systems Integrated Diagram (SID):



Build vs. Buy:

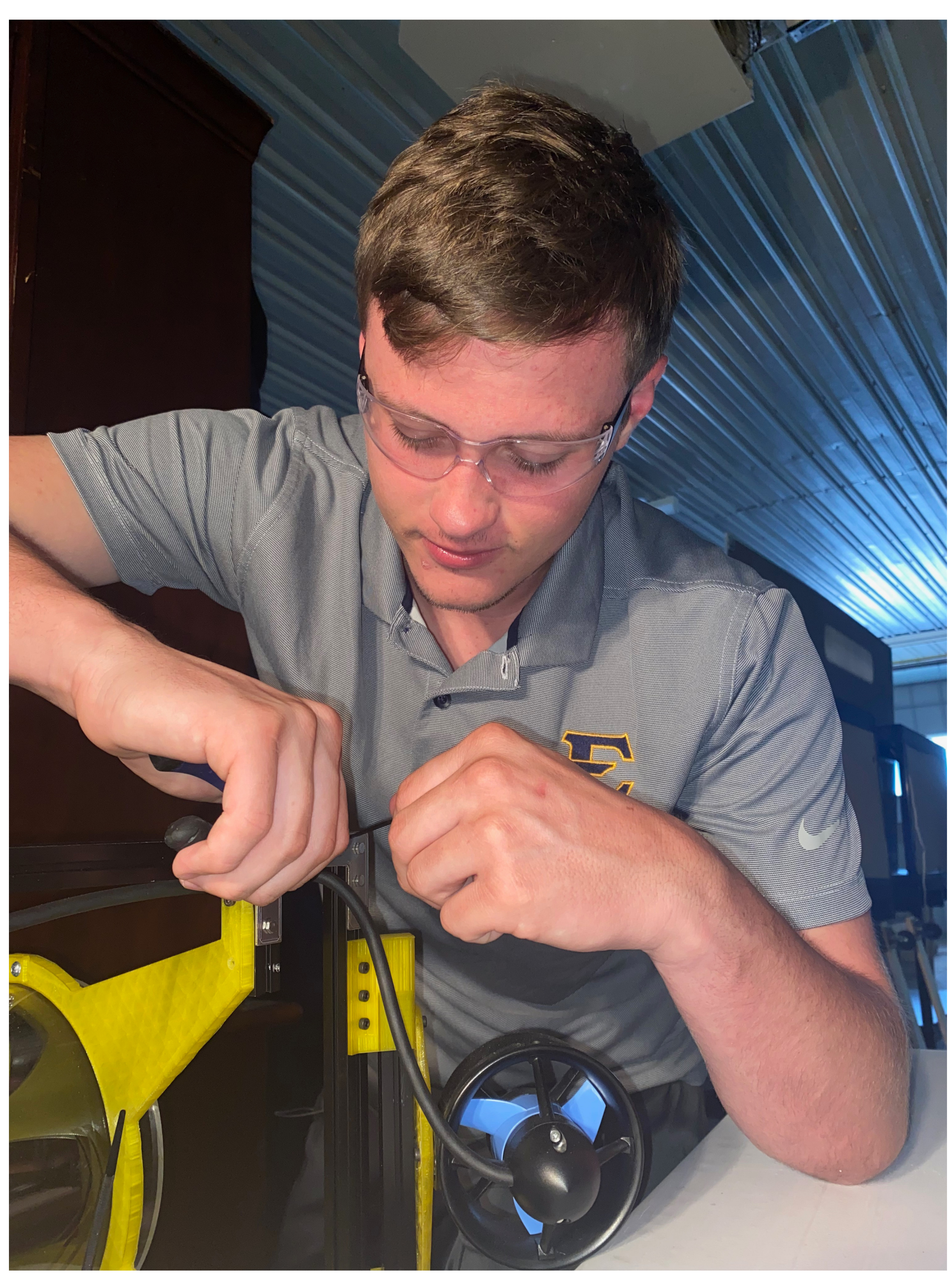
This year, our ROV is equipped with many 3D printed parts. Instead of buying pieces to put on our ROV, one of our team members designed them in CAD. Using the CAD software Onshape, they were able to design 45-degree mounts for our vectored motor scheme. Along with those mounts, they designed and printed mounts to vertically mount the T200 Thrusters, a mount to hold the watertight housing in the center of the ROV, and an electronics housing plate to go inside out watertight housing to hold all of our electronics. With help from STREAMWORKS and their Ultimaker S5 3D printers, we were able to 3D print our custom-designed mounts out of a cost-effective PLA material. We 3D printed them in gold to keep our school's color scheme.



SAFETY

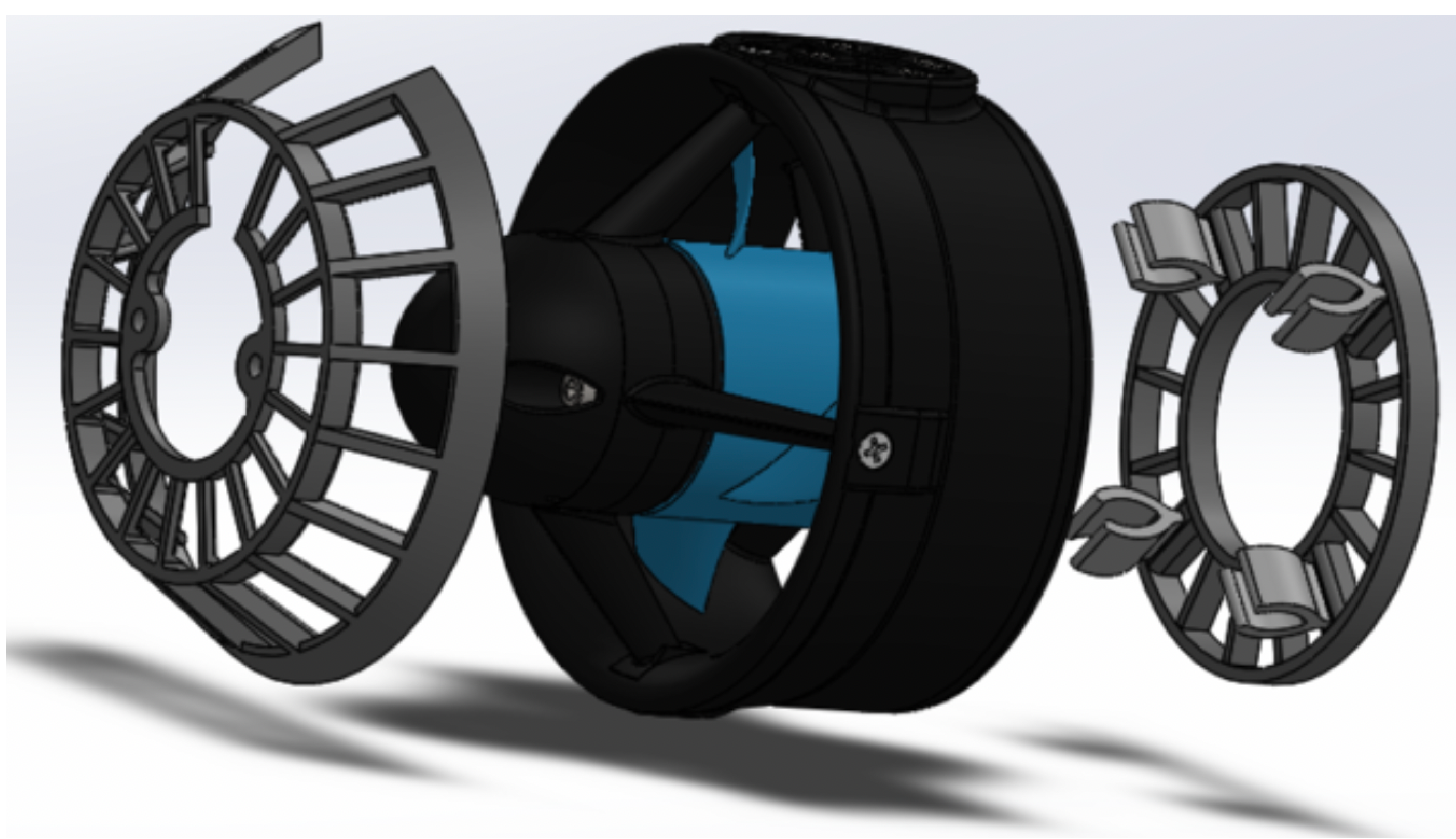
Company Safety Measures:
Whenever in operation of *Kraken*, the team had a series of protocols that were executed to ensure safe procedure of the vehicle. For example, whenever *Kraken* was to be deployed, the team used a 'Preflight Checklist.' The checklist included a fuse check, motor test, enclosure test, a tether check, a visuals check, and basic ROV operation safety protocol.

During the construction of the ROV, it was mandatory that all members wore safety glasses. Along with proper Personal Protective Equipment (PPE), it was required that team members wore closed-toed shoes and removed jewelry, especially when using power tools. Members with long hair were required to pull it back so it would not get caught in the tools.



ROV Safety Measures:

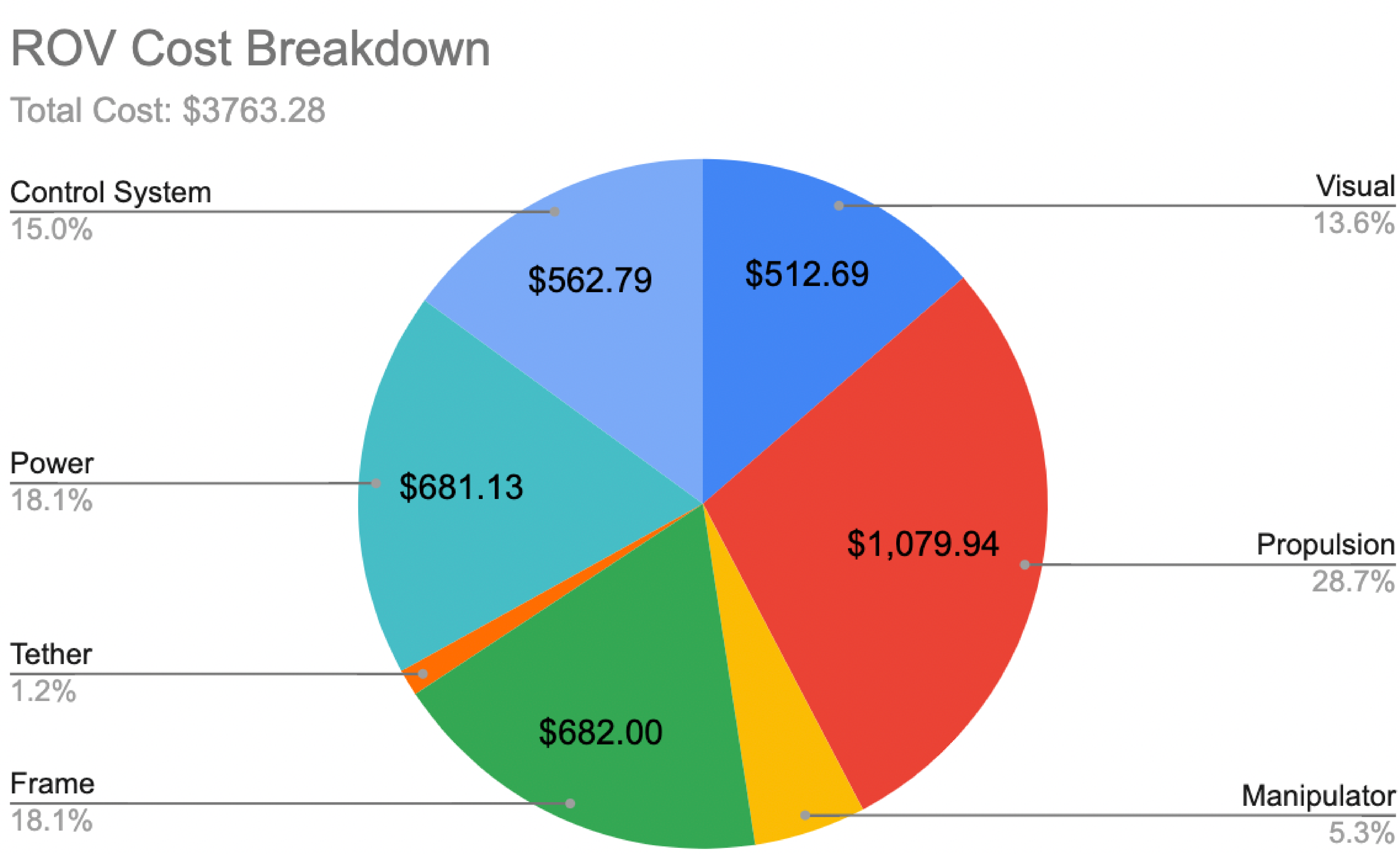
Kraken was designed to be effective at completing its desired tasks, all while maintaining a safe operation. One way the team ensures the operation is safe is by following a preflight checklist. Another way is to make the ROV itself safe through its design. All of *Kraken*'s thrusters are properly shrouded to fit within the MECH-006 requirement. The mesh is smaller than 12.5mm to fit the requirement listed as "this IP code equates to a mesh size >12.5 mm" on the 55th page of the 2021 Explorer Class Competition Manual. *Kraken* was also designed without sharp edges to also fit the MECH-006 requirements to pass safety.



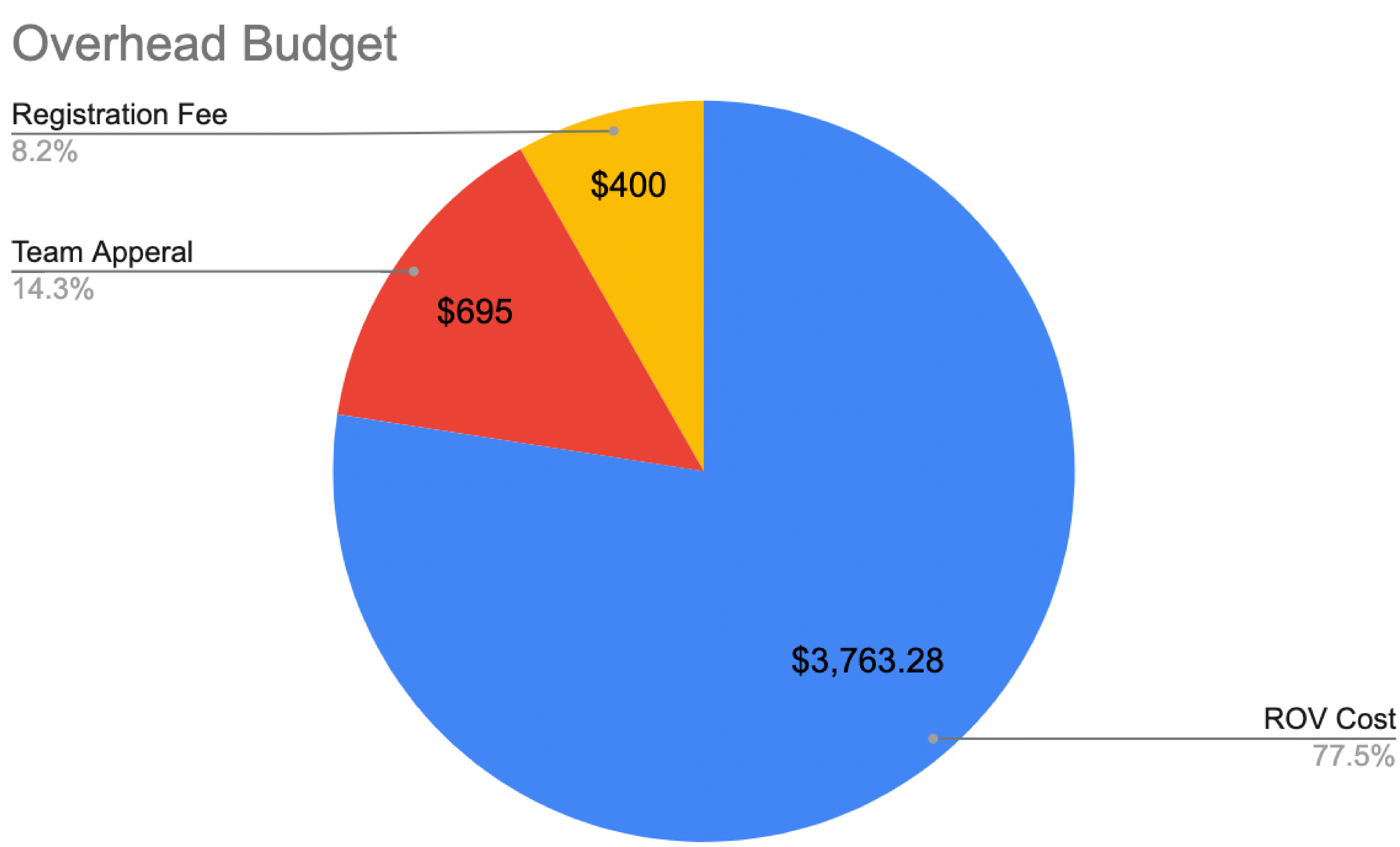
Along with mechanical safety measures, *Kraken* has some important electrical safety features that ensure safe operation. One of the most important devices the Buccaneers have incorporated into our ROV is a properly sized inline fuse to fulfill the ELEC-001E "properly sized Littelfuse" requirement. *Kraken*'s wires are properly waterproofed and heat shrinked to secure a good and safe connection. This also helped fulfill the ELEC-022E "workmanship" clean electrical design.

FINANCES

The Buccaneers' budget this season was $6,500 - gifted by STREAMWORKS Education, a non-profit organization founded to start and facilitate robotics teams, and a generous anonymous donor. The team did not have to worry about purchasing many tools as STREAMWORKS allowed us to use the tools present at the ETSU Valleybrook campus where they are located. The team sat down and began budgeting how much we believed it would cost. It brought us to an estimate of $4,000 for the construction of the ROV. After we constructed the vehicle, the team sat down and listed out every part of our vehicle to determine its final cost. The graph below is the ROV Cost Breakdown which shows the cost of every subsystem of *Kraken*.



In addition to the cost of the ROV, the team had some other expenses we had to address. The team's registration fee to be able to participate in the international competition this August was $400. Along with the registration cost, our team also needed shirts to look professional come competition day. This apparel cost came out to be around $695 for team polos and blazers for the engineering presentation.



TEAM ANALYSIS

Challenges:

This is the first year that East Tennessee State University has had a MATE Team. Starting up a MATE team is hard, especially when you are starting fresh. This year we have had many challenges including: lack of team members, beginning late into the season, and ROV troubles. Because of the COVID-19 pandemic, and the university being completely virtual, it was hard trying to recruit team members into our program. Luckily, two of our team members participated in MATE in high school. We were finally able to recruit one additional person, which allowed us to meet the minimum requirement to be able to compete. Because of this setback, we got a late start into the season and began building in late April, which limited us to finishing in just under two months.

Troubleshooting:

We encountered a few issues with our ROV that set us back. Coding was the biggest setback for us. At first, we tried programming our ROV with a Raspberry Pi, but did not succeed. Because of the ESC's we were using, it was hard to communicate with the ESC's, T200 Thrusters, and the axis on the controller. This forced us to change our approach to how we control our ROV. After long discussions with some computer science experts and electrical engineers, we decided to go with the Arduino Nano. This was a whole new coding language for us since we only knew Python. Having to learn C++ took time and we were still having issues with our code. Eventually, we were able to iron out the issues and solve the problem.

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APPENDIX

Preflight Prep

Preflight Prep

1. Connect to power
2. Notify team members power has been connected
3. Flip on power
4. Pilot call out "Power on"
5. Team member place ROV in water
6. Team member calls out "hands-off"
7. Initiate Motor test
8. Pilot drive Forward
9. Pilot Turn Right
10. Pilot Turn Left
11. Pilot Lift Down
12. Pilot Lift Up
13. Pilot Drive Back
14. Pilot call out "Motor Test Complete"
15. Visual systems Check
16. CEO asks teammates if systems are ready to go
17. When all confirmed, CEO says "mission launch"