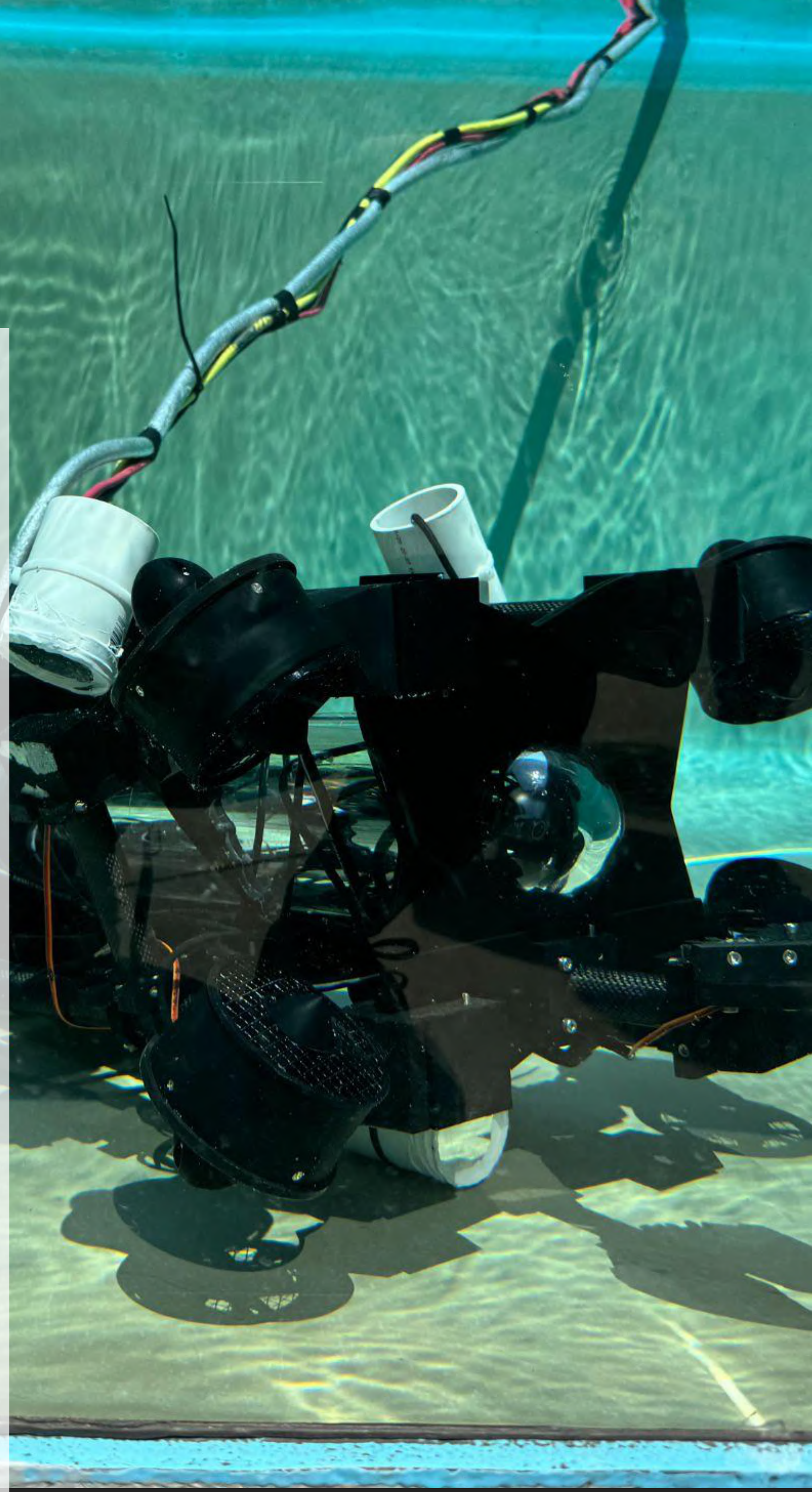


NIGHT OWLS

Patrick O'Leary	Chief Executive Officer	11th
Joshua Silversten	Chief Operating Officer	11th
Mark Zagha	Chief Financial Officer	11th
Eoghan McIvor	Chief Technology Officer	11th
Ava Palazzolo	Chief Marketing Officer	11th
Isabella Wong	Safety Manager	11th
Nidhi Begur	Tether Operator	10th
Ivan Koshkin	Electrical	11th
Charles Russo	Electrical	11th
Felipe Salvador	Mechanical	10th
Michael Frederick	Mechanical	11th
Maya Venkatesh	Marketing	11th

Allan Phipps	Mentor
James Nance	Mentor
Carol O'Leary	Mentor

MATE ROV COMPETITION 2023-2024

NIGHT OWLS

Florida Atlantic University High School

Boca Raton, Florida, USA

Table Of Contents

Abstract

The Night Owls are a 12-member MATE team from Florida Atlantic University High School in Boca Raton, Florida. The team strives to advance environmental sustainability in engineering, with an emphasis on underwater robotics. Their remotely operated vehicle (ROV), called “Dark Shark V2”, has been significantly enhanced from “Dark Shark V1” to fulfill the criteria set for this year’s MATE challenges. The robust frame is crafted from carbon fiber, laser-cut acrylic, and 3D printed polylactic acid (PLA). Carbon fiber provides for a lightweight design and improved integrity. The design also increased in size to accommodate for the larger tube, which makes it easier to work on the electronics inside. The team optimized the craft to be lightweight, sturdy, and equipped with onboard electronics to lighten the tether and allow for faster communication times between Raspberry Pi and accessories. The ROV features an 8-motor configuration, enabling remarkable accuracy in its movement. The agility of the vehicle allows the operator to swiftly accomplish assignments such as activating the irrigation system (Task 3.1). Likewise, equipping the ROV with a temperature sensor helps obtain data from the SMART cable (Task 2.1). Incorporating five cameras and one stereo camera provides peripheral vision, which proves useful in the MATE tasks, especially when modeling the coral restoration area (Task 3.3). The MATE product demonstration is designed to simulate real-world scenarios, portraying the challenges that are commonly faced in marine ecosystems. The ROV is designed to address such challenges with precision, creating a more sustainable future for the planet.

Figure 1: Team photo, photo by Carol O’Leary.

Teamwork & Project Management

Company Profile

The Night Owls is an underwater robotics company (also referred to as a team) composed of 12 high schoolers, with the mission of preserving marine ecosystems across the globe. Established in the fall of 2021 under the name “Sea Owls”, the team competed in the International MATE Competition at Long Beach California in the summer of 2022. The following year, the company rebranded itself to the “Night Owls” and placed 4th in the world at the 2023 International Competition in Longmont, Colorado. The goal for the upcoming MATE competition is to push the boundaries for what is possible in underwater robotics and find solutions that set up a safe, healthy, and flourishing ocean for future generations to enjoy.

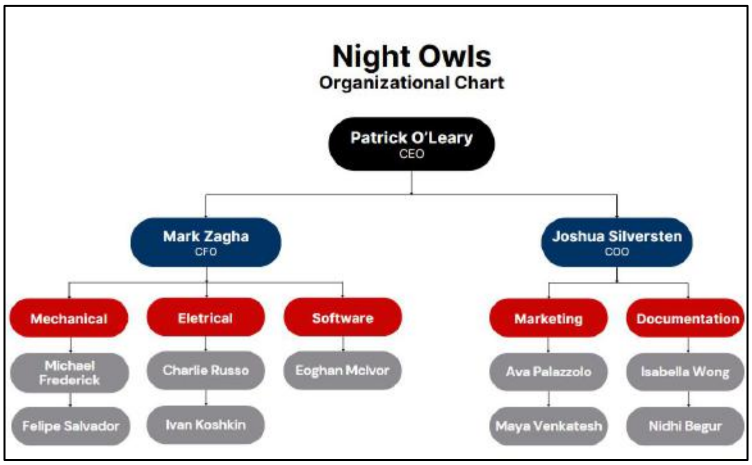


Figure 2: Night Owls team organization, created by Michael Frederick.

Overview of Company Personnel

The Night Owls, composed of 12 students, is organized into subdivisions that each work on their respective tasks. The five subdivisions of the company are as follows: mechanical, electrical, software, documentation, and marketing. Although members of each division focus on their given responsibilities, there is still plenty of crossover between all personnel on the team. Figure 2 shows a list of subdivisions and the members in those divisions.

Scheduling

The Night Owls began with weekly meetings, taking place on Monday to discuss the upcoming MATE competition. Once the materials for the ROV were secured and the craft was ready to begin construction, longer work days began, taking place during the week. Workdays generally lasted from 8 AM to 5 PM and members were expected to show up consistently, in order to ensure the completion of the craft. As the regional competition approached, practice sessions were hosted to get familiar with navigating the ROV through the MATE obstacles, as well as practicing the engineering presentation. Workdays and practice sessions were scheduled in advance; this played an important part in guaranteeing that members were able to show up to workdays and practice sessions.

All scheduling and communication for the Night Owls took place on Discord. This app allowed for easy communication with each other and the ability to discuss team goals, even when the company did not meet in person. At the start of the year, the Night Owls developed a timeline for the construction of the ROV and the goals for the craft. Developing a schedule ahead of time allowed the Night Owls to make sure that the ROV would be done well in advance, giving the company optimal time to practice before the regional competition.

An archived schedule is provided in Appendix D.

Design Rationale

Resources and Protocol

The Night Owls had access to an abundance of resources provided by The Cane Institute for Advanced Technologies that allowed the team to successfully build a functioning and competitive ROV. Tools such as soldering stations, 3D printers, and a laser cutter all contributed to the speedy assembly of the craft. Procedures and protocols were highly important while working, ensuring that construction of the craft was done correctly and as safely as possible. Team members went through training on all equipment in order to certify their safe use of the technology. If the company faced any issues during construction of the craft, procedures were implemented in order to get back on schedule. For example, after realizing that the team needed more screws to finish the frame construction, the screws were ordered immediately. Until the required screws came, the team pivoted to another aspect of the craft that could be worked on. When screws for the frame were delivered later in the week, the new goal was to make progress on the camera system for the week instead of the frame. Having this essential protocol kept the team on schedule and allowed the Night Owls to build their ROV in a timely manner.

Safety Procedures are provided in Appendix B.

ROV Assembly

Figure 3: Front of ROV, rendered by Mark Zagha.

Figure 4: Back of ROV, rendered by Mark Zagha.

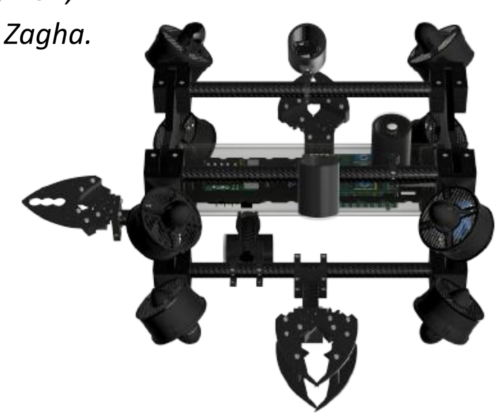


Figure 5: Side of ROV, rendered by Mark Zagha.

Design Rationale

Engineering Design Rationale

In order to successfully design and construct a working ROV, it is imperative to plan out the design and all aspects of the craft ahead of time. Having to improvise late into the construction phase of the craft can lead to unforeseen complications and lead to assembly delays. The Night Owls made sure to plan the configuration of the ROV, including cameras, manipulators, and other features before starting any assembly. For example, the ROV needs to have a temperature sensor to get a reading from the SMART cable (Task 2.1). The company planned for this, guaranteeing that temperature sensors were implemented into the craft before assembly of the ROV. By planning ahead, the company did not have to retrofit any components late in construction, saving time by avoiding the need to open up the electronics tube again. When the company had to deviate from the design plan, the company used an evaluation matrix to reevaluate progress and determine the best course of action going forward based on necessary design and mission criteria.

Figure 6: Night Owls ROV from 2023, photo by Ava Palazzolo.

Figure 7: Night Owls ROV for 2024, photo by Ava Palazzolo.

The Night Owls' latest ROV iterates on the most successful aspects of the team's previous craft. As in the previous year, the updated design incorporates eight Blue Robotics T200 thrusters, a transparent electronics enclosure, integrated cameras, manipulators, and a comparably structured frame. However, nearly every component of the new ROV has undergone redesign and enhancement. The electronics enclosure has been extended from 11.8 inches to 15.6 inches to enhance airflow and thermal management, while also providing space for additional electronic components. The incorporation of three additional cameras improves visibility, and the addition of more manipulators increases operational efficiency. The improved frame design features thruster mounts built according to results of the new numerical optimization algorithm. The frame is also larger in size to accommodate the new tube and improve the rotational movement. Constructed out of carbon fiber, laser-cut acrylic, and 3D printed PLA, the frame is both sturdy and serviceable, allowing for easy access to work on the electronics tube. The detachable tether improves the convenience of maintaining and transporting the ROV.

One of the biggest design decisions that the Night Owls faced when designing the ROV was if the electronics should be held onboard the craft or on the surface. Taking inspiration from past success, the team decided to go with the former. The electronics are housed in a clear tube with an internal diameter of four inches and a length of 15.6 inches. This approach increased costs compared to an equivalent design that only houses electronics on the surface. However, when evaluating this decision, it was determined that the benefits of faster communication, reduced signal attenuation and power losses, and a simpler tether outweighed the increased cost associated with onboard electronics. Additionally, the lighter tether this design enables results in enhanced maneuverability. This year, the team also decided to invest in optimizing the craft's thruster placement. Although this was a time consuming endeavor, the new thruster angles facilitate dramatically improved rotation, particularly along the pitch axis, and a more useful distribution of thrust along the translational axis. Pitch, which lacked on previous crafts, is extremely useful to the company especially for retrieving objects off the pool floor, such as the recovery of a sediment sample (Task 3.4). The optimized thruster configuration enables movement in all 6 degree of freedom. This investment into research and development has significantly improved the performance of the craft in the water.

Design Rationale

Innovation

The team took into consideration what material was best suited for the craft so that it would be lightweight but also durable. The team considered using 8020 extruded aluminum again, but researched into other materials before making this decision. After looking at the strengths to weight ratios of different materials, the team decided that carbon fiber was the best choice. As seen from Figure 8, both the tensile strength and specific tensile strength of carbon fiber proved to by way higher than the aluminum and titanium. Tensile strength is the maximum stress that a material can withstand before the material has a failure in tension. The tensile strength of an object is useful in determining the strength of a material. The tensile strength of carbon fiber is significantly greater than both the aluminum and titanium tested. Specific tensile strength is the strength to weight ratio: how strong a material is for its weight. In Figure 8, it is clear that the carbon fiber not only excels in tensile strength but also specific tensile strength meaning it is not just very strong but also very light. In Figure 9, the specific gravity of different materials were tested. Specific gravity can be defined as the weight of a material when compared to water: if an object has low specific gravity than it is very light in water. As shown in Figure 9, carbon fiber has the lightest specific gravity when compared to the other materials, showing why it is the ideal material for the ROV. The carbon fiber rods used were donated to the team by The Cane Institute.

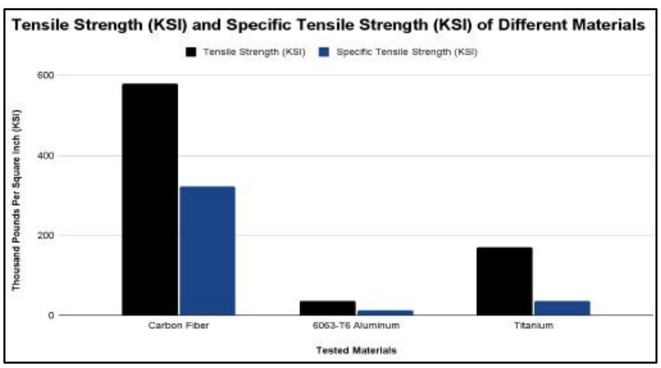


Figure 8: The durability and strength of carbon fiber proved to be significantly better than aluminum and titanium making it an ideal material to build the ROV out of.
Graph generated by Patrick O'Leary.
Data from Reference 8.

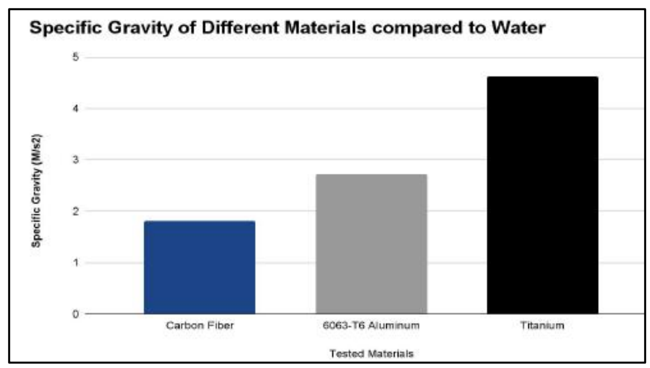


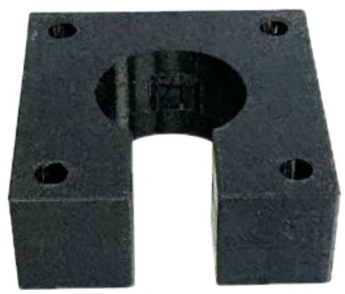
Figure 9: The specific gravity of carbon fiber is less than both aluminum and titanium making it a good choice for material because it is so lightweight.
Graph generated by Patrick O'Leary.
Data from Reference 8.

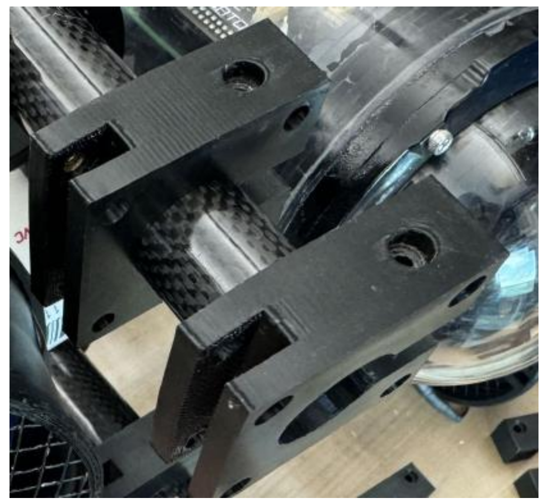
The ROV's custom software stack includes many innovative features ranging from software buoyancy to the ability to control multiple robots simultaneously. One of the most unique features of the code is its ability to control arbitrary thruster configurations. The software only needs to know where each thruster is placed and how strong it is in order to pilot the ROV. While this strength information is optional, it ensures that the internal "movement space" remains consistent with observed thrust, which is important for some advanced features, such as automatically computing where and how much buoyancy needs to be added to the ROV. All control algorithms and human input are implemented in a thruster configuration agnostic way. Additionally, nearly any of the code's configuration, including its "thruster model" is loaded from a configuration file and can be edited in real time through the intuitive user interface, facilitating future designs with dynamic, non-fixed thruster placement and the ability to adapt to the failure of multiple thrusters. This flexible motor math algorithm in combination with the configuration system makes the control software truly ROV agnostic. Additionally, this real time reconfiguration support makes debugging and fine tuning the ROV dramatically easier than many competing control software solutions.

Design Rationale

Innovation

The 3D printed pieces that the thrusters mount to are separate from the corner pieces that hold together the acrylic and carbon fiber tubes. This means that the thruster mount pieces can easily be switched out for new pieces with a different motor angle without having to rebuild the frame. This allows the craft to be easily modified to any eight thruster configuration. Using the novel optimization algorithm, the motor angles can be calculated to give the ROV any amount of power in the direction of the designer's choice. For example, the company is able to create thruster angles that increase the ROV's performance along the vertical axis. For the thruster configuration, forward is maximized, then upward and pitch. The algorithm allows for the creation of thruster configurations that maximize the strength of the most critical axis while still retaining a useful amount of strength along the axes which are used less frequently. Carefully choosing this compromise of strength along each direction allows the craft to be highly efficient at completing the MATE tasks.



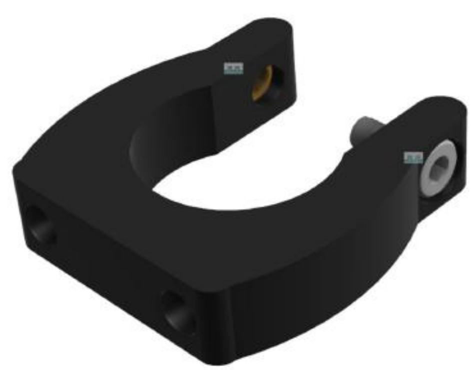


Figures 10, 11, 12 (From left to right): 3D printed motor attachments, photo by Joshua Silversten.

Another feature that aids towards the overall function of the ROV are the modular 3D printed clips. Cameras and manipulators are placed on these rotatable clips that attach to the carbon fiber components of the ROV. This allows the cameras and claws to be positioned at any angle on the roll axis, giving the pilot full usage of the craft's attachments. These clips are printed separately from the camera mounts and are attached using screws. This allows them to be 3D printed in bulk and easily replaced in the event that one breaks. Using 3D prints for frame attachments is a cost effective way at adding motors, cameras, and manipulators to arbitrary points on the craft, while still preserving durability, serviceability, and efficiency.

Figure 13: 3D printed clip on ROV, photo by Joshua Silversten.

Figure 14: 3D render of clip, rendered by Mark Zagha.



Design Rationale

Problem Solving

Ideas for this year’s ROV were conceptualized as a team. During the design phase of the craft, various members gave thought on how mechanical, electrical, and software systems should be constructed. The ROV’s frame was modeled in Fusion 360 by the mechanical team. A lot of the inspiration for this year’s craft came from the previous year’s build. Both builds hold electronics on board in a clear tube and each craft contains eight motors. The team did not only take inspiration from the successful elements of last year’s craft, but took a look at last year’s flaws and improved on those. Having only two cameras on the craft last year limited the visibility for the pilot, making it difficult to maneuver the craft through obstacles. This year, 3 additional cameras were added around the craft and a stereo camera system, improving visibility for the ROV pilot. Leveraging effective communication, analysis of past competitions, and insights from previous designs, the company is able to generate innovative ideas for the MATE ROV. These efforts aim to optimize the ROV's operational efficiency in aquatic environments, aligning with the long-term objective of enhancing marine ecosystems.

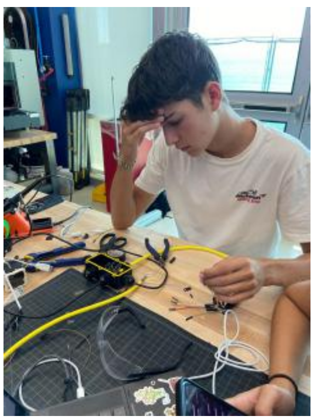


Figure 15: Company CEO encountering an issue with the camera box, photo by Ava Palazzolo.

Figure 16: Company CTO & CFO brainstorming alternative solutions to the buoyancy engine, photo by Ava Palazzolo.

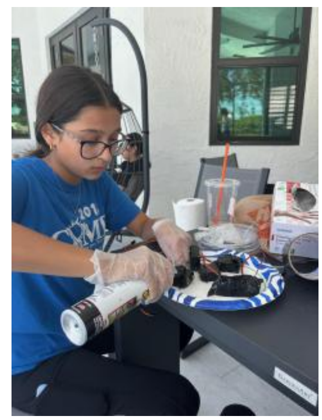


Figure 17: Company CMO waterproofing servos in-house, photo by Maya Venkatesh.

When issues arose in the ROV, the company implemented a thorough process to identify the root cause of the problem. The company followed the “engineering design process” throughout many phases of building the ROV: ask, research, imagine, plan, create, test, and improve. One example of a mechanical malfunction occurred in the case of testing the ROV’s claw for releasing the multi-function node (Task 1.1). First, the team thought about what they will need to complete Task 1.1 (ask). Once a claw-like manipulator was decided on, the team researched different ways to power the claw (research). One idea was to make a claw out of laser cut pieces, powered by a SeaPerch motor (imagine). A computer aided design (CAD) of the manipulator was created (plan). Once all materials were ready, the SeaPerch motor was waterproofed and acrylic was cut to make the actual claw (create). During testing, it was found that the SeaPerch motor did not produce enough torque to open and close the claw (test). The team went back to the drawing board to design a new manipulator to complete Task 1.1. The company researched the costs and effectiveness of motors taking into account their waterproofing and strength. Ultimately the team decided to use servo motors and waterproof them in-house [Figure 17] (improve). This solution proved the company's process to be quick and effective. Overall, the company's rational process is much more valuable for the team rather than guessing and checking all issues of the ROV.

Design Rationale

Systems Approach

The Night Owls' craft includes mechanical, electrical, and software systems; all of which work together to allow proper function in the water. The mechanics of the craft include all actuators, as well as the structure of the craft. Everything from the frame to the manipulators fall under this category. The different electronics on the ROV power the craft, letting the mechanics run efficiently. The cameras, servos, pressure sensor, temperature sensors, navigator, electronic speed controllers (ESCs) and motors are all unique electrical systems that comprise a moving craft. The software functions as the "brain" of the whole operation, telling different electrical systems how to act. The custom code programmed into Raspberry Pi controls all electrical systems on the craft.

Vehicle Structure

The Dark Shark V2 cost $5628.23. One major tradeoff regarding this cost was choosing how to structure the cameras. The team could rather pot the cameras themselves or use sealed camera tubes. While it is cheaper to pot them in-house, a sealed tube would come waterproofed meaning no time would be spent waterproofing cameras. However, the company still opted for potting the cameras because of the lower cost. By potting in-house, the team was able to save money and still produce working waterproof cameras. Regarding the size of the vehicle, the ROV increased from the year prior to a length of 63.5 cm, a width of 48 cm, and a height of 28 cm. The bigger tube was necessary in order to fit more electronics like the USB hub to power the cameras. A larger tube also has more air and surface area which improve heat dissipation, making sure the electronics do not get overheated and malfunction. The Dark Shark V2 is 11.6 kg on land and 1.65 kg in the water. The weight was heavily considered and the company decided to make the frame out of hollow carbon fiber rods. The 244 cm of carbon fiber on the craft weighs .3 kg. Using extruded aluminum tubes would have resulted in a weight of one kg for the frame; by using carbon fiber, the team saved .7 kg of weight on the craft. The tradeoff for this decision is that while carbon fiber is strong and durable, it is also quite expensive. Luckily, the company was able to offset this cost by having the carbon fiber rods donated by The Cane Institute. Carbon fiber rods were ideal for the company due to their strength and shape. The strength adds durability to the ROV, while the cylindrical shape allows one to clip on attachments without taking apart the entire frame [Figures 18 & 19].

Figure 18: Company CEO putting attachment on carbon fiber rod frame, photo by Ava Palazzolo.

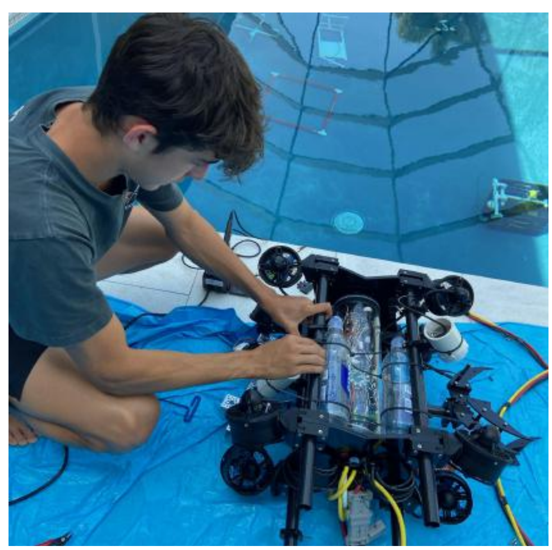


Figure 19: Company CEO placing camera holder attachment on carbon fiber rod frame, photo by Ava Palazzolo.

Design Rationale

Vehicle Systems

The Night Owls' ROV was designed with the intention of being lightweight, structurally sound, maneuverable, cost effective, and environmentally sustainable. Each component that makes up the frame of the ROV was carefully selected to ensure optimal performance and stability. The carbon fiber rods were chosen for their durable, lightweight manner, offering a great way to support the entire craft. The acrylic plates, which hold the electronics tube on both ends, were chosen due to the material's strong composure and the ability to shape it as necessary using the team's laser cutter. Due to the unique shape needed, 3D prints were used to attach the motors to the frame [Figure 20]. The prints designed by the Night Owls allowed for the motors to be angled in the orientation of the company's choosing, maximizing maneuverability. All three materials that were used to construct the frame are parts that were donated to the team by The Cane Institute. The eight T200 motors on the craft were used due to their power and reliability. Having a powerful, maneuverable craft is essential when completing tasks like placing the probiotic irrigation system in its designated location (Task 3.1). The ROV's power lets the pilot move around the irrigation system with ease; the craft's mobility assures the irrigation system is placed in the correct position without any trouble.

Figure 20: Company members screwing motors into 3D printed joints, photo by Ava Palazzolo.

$$\mathbf{A}\vec{x} = \vec{b} \qquad (1)$$

In this equation, $\vec{x}$ $(N \times 1)$ represents the force applied by each thruster, $\vec{b}$ (6×1) represents the ROV's movement, and $\mathbf{A}$ $(6 \times N)$ represents the ROV's thruster configuration. For the rest of this section, it will be assumed $N = 8$ as the thruster configuration proposed in this project uses eight thrusters, but these same concepts apply to all thruster configurations.

The matrixes and vectors are filled out as seen in Equation 2.

$$\begin{bmatrix} F_{x1} & F_{x2} & F_{x3} & F_{x4} & F_{x5} & F_{x6} & F_{x7} & F_{x8} \\ F_{y1} & F_{y2} & F_{y3} & F_{y4} & F_{y5} & F_{y6} & F_{y7} & F_{y8} \\ F_{z1} & F_{z2} & F_{z3} & F_{z4} & F_{z5} & F_{z6} & F_{z7} & F_{z8} \\ \tau_{x1} & \tau_{x2} & \tau_{x3} & \tau_{x4} & \tau_{x5} & \tau_{x6} & \tau_{x7} & \tau_{x8} \\ \tau_{y1} & \tau_{y2} & \tau_{y3} & \tau_{y4} & \tau_{y5} & \tau_{y6} & \tau_{y7} & \tau_{y8} \\ \tau_{z1} & \tau_{z2} & \tau_{z3} & \tau_{z4} & \tau_{z5} & \tau_{z6} & \tau_{z7} & \tau_{z8} \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \\ F_7 \\ F_8 \end{bmatrix} = \begin{bmatrix} F_x \\ F_y \\ F_z \\ \tau_x \\ \tau_y \\ \tau_z \end{bmatrix} \qquad (2)$$

In the equation above, the matrix has a value for each force and torque component of every thruster along each axis. The 8×1 force vector represents the force each thruster should produce, and the 6×1 movement vector represents the net force and torque imparted on the ROV along each axis.

The previous equations convert thruster forces into ROV movement, however the goal is exactly the opposite: converting desired ROV movement into thruster forces. To do this, we need to take the inverse of $\mathbf{A}$; however, this is not possible as the matrix is non-square. This can be resolved by taking the Moore–Penrose inverse instead, denoted $\mathbf{A}^+$. This is a type of pseudoinverse which can be used to compute a least squares (best fit) solution to a system of equations. Using this pseudoinverse, we can rewrite Equation 1 as follows:

$$\mathbf{A}^+\vec{b} = \vec{x} \qquad (3)$$

This allows for the computation of the required thruster forces necessary to create the desired net force and torque on the ROV. The expanded version can be seen in Equation 4.

$$\mathbf{A}^+ \begin{bmatrix} F_x \\ F_y \\ F_z \\ \tau_x \\ \tau_y \\ \tau_z \end{bmatrix} = \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \\ F_7 \\ F_8 \end{bmatrix} \qquad (4)$$

Figure 21: Four mathematical equations used in the generalized model of ROV movement, math by Eoghan McIvor.

While designing the ROV, it was imperative that the craft would be able to complete the missions. Cameras were added to ensure that the drivers would have full sight of the environment around them and know where the obstacles are located in the water. The manipulators of the craft allow for completion of tasks where objects must be picked up and moved, such as deploying the SMART cable through the three waypoints (Task 2.1). The pressure sensor that has a built in temperature sensor was put into the craft, not only to measure the depth of the ROV, but to check the temperature of the SMART repeater (Task 2.1). On top of the built-in temperature sensor, the team bought a Blue Robotics temperature sensor to have two outputs of data when measuring the temperature of the SMART repeater, ensuring accuracy of the reading. The angles that the motors were mounted onto the craft were designed in such a way to maximize the turning compatibles of the ROV [Figure 21]. The advanced maneuverability of the craft allows the driver to finish tasks like activating the irrigation system quickly (Task 3.1). Designing a craft that could complete the MATE tasks efficiently was very important to the Night Owls. The team's determination is reflected in the high quality ROV provided.

Design Rationale

Control/Electrical System

Electronic Design & Cabling

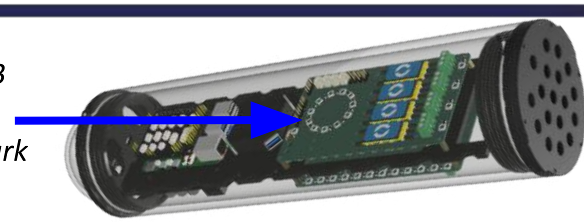


Figure 22: PCB Rendering, rendered by Mark Zagha.

The main components of the ROV are housed inside the tube. These components include the Raspberry Pi, ESC's, temperature sensor, depth sensor, and Navigator Pi Hat. The ESC's are placed on a custom printed circuit board (PCB) designed to organize them neatly within the tube and prevent overheating by incorporating an aluminum heat sink [Figure 22]. A custom PCB was developed to maintain a clean and organized setup while improving airflow. Additionally, securely soldering the ESC's to the PCB eliminates exposed wires and the risk of a short circuit. Both the power and ethernet cables can be detached from the craft with waterproof connectors, simplifying maintenance and mobility when not in use.

Gauge	Resistance over 60 feet	Voltage Drop	Voltage at ROV
6	0.0237Ω	1.19V	12.81V
8	0.0376Ω	1.88V	12.12V
10	0.0598Ω	2.99V	11.01V
12	0.0950Ω	4.75V	9.25V
14	0.1510Ω	7.55V	6.45V

Figure 23: Voltage drop across 60 foot wire for a 14V power supply. Ohm's law was used where V = IR and R = ρL/A. Cross sectional area of the gauges were taken from source 1. Resistance of copper was used for p and all other variables were taken from robot outputs. Math by Patrick O'Leary

Communication streamlined to involve interaction only with the Raspberry Pi through a 60ft Ethernet wire, allows control of all components. Calculating the required gauge for the power wire using Ohm's law [Figure 23] reveals the need for an 8-gauge wire. These are all the required wires for controlling the ROV, resulting in a light and small tether. With so few wires, the tether can be made detachable and easily coiled on a small spool for deployment.

The ESC's allow each motor to drive with a single signal wire from the Raspberry Pi. Along with this, the Raspberry Pi has a Navigator Pi Hat. This Pi Hat has a built-in gyroscope and accelerometer, and also allows the Raspberry Pi to get data from the external depth and pressure sensor. Additionally, there is a powered USB hub for cameras and an external 5v step-down for the servos. These tools allow the components to be separately powered with their own fuse, which means that if a system has a short, it will not affect the entire ROV but instead just blow the fuse the component is attached to. Since each component is linked to a fuse, it's very unlikely that the main fuse on land would blow because there are so many precautions set in place inside the tube already.

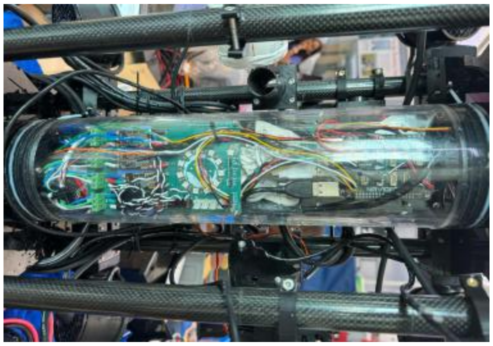


Figure 24: PCB, photo by Nidhi Begur.

The ROV incorporates five cameras, one stereo camera, and three servos. Of the five cameras, four are external and one is internal at the front of the tube. The internal camera is mounted on a servo for tilting, providing a broader view of the pool. Of the external cameras, three are dedicated to observing the claws, while one looks upward to monitor the hole in the ice during resurfacing. The stereo camera points forwards at the top of the craft to get a clear view of what is front of it. This is so it can complete tasks like mapping out the coral restoration area (Task 3.3). Due to the high camera and servo count, power is supplied externally through the ROV's power distribution module within the tube, as the Raspberry Pi unable to provide sufficient amperage to power these components directly. Additionally, all cameras include H.264 compression, relieving the Raspberry Pi any video compression workload and enabling the team to stream all video feeds simultaneously at 1080p with 30fps.

Design Rationale

Control System Design

The ROV control system is written entirely in the Rust programming language using the Bevy game engine and is divided into six components for organization. The “robot” component, “motor_code” component, “surface” component, “common” component, “networking” component, and the “runner-rpi” component. First, the “robot” component is the binary running on the underwater Raspberry Pi. It implements the depth hold and orientation control algorithms and utilizes “motor_code” component to compute the correct speeds for each motor. The “motor_code” component implements the math that drives the 3D Thrust Vectoring system. This code calculates the force and torque outputs of each motor and uses that information to find the optimal speed each thruster requires. The control algorithm is able to drive any thruster configuration provided that the position and angle of every thruster is known. This is an advantage over most existing control systems, which do not allow or require heavy modification to support motor configurations outside the original developer’s intentions. Additionally, the control system is able to gracefully handle the failure of up to two thrusters. Next, the “surface” component contains the code that runs on the drive station laptop. It is responsible for reading inputs from the pilot and displaying camera feeds and telemetry. The “common” component handles the tether connection between the ROV and the drive station as well as other shared functionality, such as error handling. The “networking” component is used by the “common” component for the low level communication between the ROV and the drive station. The “runner-rpi” component is used to compile and deploy the component “robot” to the Raspberry Pi underwater.

Tether Design

The tether consists of an eight gauge power wire, and an ethernet cable, and a backer rod for buoyancy all connected at intervals by electrical tape and covered with a snakeskin sheath [Figure 25]. The power wire starts from the power supply and passes through an on-land box containing a Watt Meter, which monitors the power supply voltage, and current draw of the craft during operation. On the box is a 3D printer attachment that acts as a strain relief to tug on the box rather than the wires. It then extends down the tether and connects to the craft via a waterproof connector. From there, it traverses the tube, connecting to the power distribution module. The ethernet cable starts plugged into a laptop on the surface, then travels down into the tube to interface with the Raspberry Pi. This cable facilitates the transfer of code and control inputs from the computer to the Raspberry Pi.

Figure 25: Coiled tether detached from ROV, photo by Isabella Wong

Tether Management

Due to the ROV's onboard electronics, the tether only consists of power wires and an ethernet cable. With only three wires in the tether, it is very easy to manage. In addition, the tether can be easily taken off the craft by unplugging it from the waterproof connectors, meaning that when wanting to work or move the ROV from place to place, the tether does not have to be attached. The ability to detach the tether allows for easier operation when moving and working on the craft. The tether is also kept on a spool so it does not tangle or get knotted up when carrying it around or using it during a run. Having the tether on a spool allows for pushing out and retracting as much tether as needed during a run without it getting tangled or messy.

Design Rationale

Propulsion

From previous years the company has learned that DC brushed motors do not have as much thrust output as 3 phase brushless motors. While a clear downside is that phase 3 brushless motors are more expensive and require an electronic speed controller (ESC), thrusters are an essential part of an ROV. With this information the company made an unanimous decision to spend the extra grant money on 3 phase brushless motors. With plenty of team research the company concluded that Blue Robotics T200 thrusters would be the best fit for the Dark Shark V2 since they are the most reliable brushless thrusters in the industry. Thruster placement in the Dark Shark V2 was influenced by the company's ROV from the year prior. The company narrowed down the ideal thruster configurations for the ROV down to either an optimized 3D Thrust Vectoring configuration [Figure 26], and the BlueROV2 Heavy configuration [Figure 27]. These configurations were considered because they both facilitate movement along all 6 axis. The company chose the current Dark Shark V2 configuration because together with the novel thruster optimization software and the modular thruster mounts it can be easily fine tuned to create any thrust performance profile. Additionally, the distance between the thrusters spreads out the thruster wake and increase the ROV's torque output. On the other hand, the BlueROV2 Heavy configuration can not be optimized in this way and has thruster placement that limits pitch performance and obstructs other thrusters.

Figure 26: Dark Shark V2 thruster configuration, rendered by Mark Zagha.

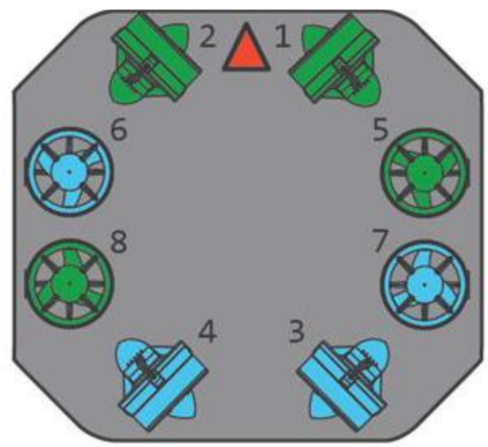


Figure 27 : BlueROV2 Heavy frame configuration, photo credits to https://www.ardusub.com/quick-start/vehicle-frame.html .

Buoyancy & Ballast

The buoyancy system of the Dark Shark V2 includes both software and physical buoyancy. Without any buoyancy, the craft weighs about 2 kg in water and is therefore quite negatively buoyant. Dark shark's custom control software contains a software buoyancy algorithm that stabilizes the ROV and is capable to adjusting to real time changes in the ROV's mass, such as when picking up an object. To determine where physical buoyancy was necessary, the ROV was deployed in a swimming pool with the software buoyancy feature enabled. Once the control system stabilized, the company was able to use the internal state of the software buoyancy algorithm to determine how much buoyancy was necessary and where it should be placed. Before the addition of physical buoyancy, the software buoyancy algorithm needed to expend half of the ROVs entire power budget on just staying afloat. Although it is possible to pilot the ROV in this state, its performance was substantially handicapped. Physical buoyancy was added in the form of airtight PVC tubes, placed in the areas determined by the software buoyancy algorithm. The installation of physical buoyancy enables the control system to expend nearly all of its energy in following pilot movement, resulting in higher speeds and increased agility.

Design Rationale

Payload & Tools

The Night Owls' ROV is equipped with five Arducam cameras and a stereo camera system, all strategically positioned throughout the craft. Arducams were chosen for their affordability and seamless compatibility with a Raspberry Pi, while the stereo camera system facilitates precise measurement of the coral restoration area (Task 3.3). Positioned within the front dome, one camera is connected to a servo mechanism, enabling the craft operator to adjust the vertical viewing angle without repositioning the entire craft. Five additional cameras are mounted externally on the frame, encased in PVC pipe and sealed with marine-grade epoxy for waterproofing. Among these, three cameras are strategically placed near each manipulator, providing optimal visibility for object manipulation tasks. This setup ensures smooth completion of tasks like deploying the probiotic sprinkler on coral heads (Task 3.1), aided by clear views of the manipulators. The final camera, part of the stereo camera system, faces forward, offering a direct perspective crucial for accurate measurements during coral restoration assessments.

The craft consists of three manipulators, each powered by its own servo. The servos used were waterproofed by the team in-house, filling the servos with grease to stop water from getting inside the electronics and sealing off the outside with a 3D printed case, dipped into epoxy resin. All three claws are placed in various places on the ROV to minimize the time it takes to complete the obstacles. There is one claw placed at the front of the craft and the two other manipulators are each placed on one of the sides. Laser cut acrylic was used to make the manipulators to ensure durable claws that could withstand the marine environment. Each manipulator has a slightly different design, as each claw is tasked with picking up different items [Figure 28]. *All images below rendered by Mark Zagha.*

Left Claw

Front Claw

Right Claw

Uses of Left Claw	**Uses of Front Claw**	**Uses of Right Claw**
- Retrieve sediment sample (Task 3.4) - Return failed recovery float (Task 1.1)	- Transplant branching coral (Task 3.2) - Connect a recovery line (Task 1.1) - Deploy SMART cable through waypoints (Task 2.1)	- Placing probiotic irrigation system (Task 3.1) - Placing an ADCP (Task 3.4) - Recover an acoustic receiver (Task 3.4)

Figure 28: All manipulators on ROV and table of uses of each claw.

Sensors

The ROV consists of four types of sensors: temperature, depth, inertial, and vision. The depth sensor is utilized in the programming to maintain a set depth while driving, ensuring unintentional vertical shifts. Additionally, a depth sensor is attached to the buoyancy engine to report depth back to the surface for the float task (Task 4.1). The temperature sensors are employed to fulfill the mission task of measuring temperature to verify the SMART cable sensor readings (Task 2.1). The ROV's cameras display the surroundings to the pilot, and a stereo camera is also integrated into the ROV to measure object lengths, and aiding in mapping out 3D objects such as the coral restoration area (Task 3.3).

Design Rationale

Build vs. Buy

The Night Owls' ROV was mostly constructed in-house with the exception of the eight T200 motors on the craft. The eight T200 motors pair well with the ROV, providing the craft with enough thrust to move efficiently through the water while completing the MATE mission requirements. In order to have a unique, well constructed design, it was important to the company to construct almost all parts in the team's lab, guaranteeing the best quality product. Each aspect of the craft's frame was designed and assembled by the company. The lightweight carbon fiber tubes that provide structural support to the craft were measured and cut to length. The acrylic pieces on each end of the craft that hold the tube in place were designed by company members and laser cut in the lab. In order to attach the motors to the frame, 3D prints were made. The Night Owls developed two custom PCB one to organize the electronics inside the tube, and the other to control the buoyancy engine. Having an organized electronics tube allowed the team to optimize wiring for convenient electronic additions to the craft, such as adding a new manipulator. By designing and fabricating their own ROV, the Night Owls are able to execute the MATE tasks to the best of their ability. Designing a craft with multiple manipulators allowed the ROV to complete different MATE obstacles at the same time. Tasks such as returning the failed recovery float (Task 1.1) and recovering an acoustic receiver (Task 3.4) could both be executed without having to return to the surface in between, increasing efficiency in the water.

New vs. Used

The Night Owls prioritized keeping cost down when designing the ROV. Most of the craft is composed of parts and materials that were from past projects or excess materials that the team's lab had. The carbon fiber tubes on the craft were donated from The Cane Institute. Due to the high success of the T200 motors [Figure 30] on the 2023 competition ROV, the Night Owls decided to reuse these motors for this year, as well as their respective ESCs, continuing to have great motor output and to save money.

Through FAU's Office of Undergraduate Research and Inquiry (OURI), the Night Owls were able to receive two grants, each worth $1,200, to help purchase necessary materials for the ROV. Using this grant money, all purchases the team made were covered by the grants. This year, five cameras and a stereo camera system were bought for the craft. Although some money had to be invested into cameras, the different camera angles the pilot has while driving the craft makes the investment worthwhile. The pilot has a much easier time seeing the water, as well as the manipulators on the craft due to the high number of cameras on the ROV. This is helpful when picking props up in the water and completing tasks such as transplanting the branching coral (Task 3.2). Even though the team tried to reuse as many parts as possible on the craft, some of the design required new elements to be purchased. The craft featured a 15.6 inch tube to house the electronics. New electronic components such as the Raspberry Pi and pressure sensor were bought as well. These purchases were necessary in order to ensure the ROV had updated electronics that could allow optimal functionality in the water.

Figure 29: Temperature sensor added to craft to complete task specific to this years mission, photo by Patrick O'Leary.

Figure 30: T200 thruster used from last years craft due to their success from last year and to save costs, photo by Isabella Wong.

Critical Analysis

When an issue arises in the function of the ROV, the team employs an effective methodology to rectify the problem. The first step taken in this process is to identify the issue, which begins with brainstorming all potential causes. For instance, if the system is found not to hold pressure during testing, the team would begin by compiling a list of all possible areas where the system could be leaking. The next step is to isolate the components and test them individually. In the case of pressure loss, there would be no need to conduct individual testing on the electronics inside the tube, as a problem with the electronics would not cause this issue. Once all potential problem components are identified, certain components are removed from the equation. For example, if there are suspicions about the waterproofing of the cameras, the cameras are removed from the tube, the penetrator is filled with a blank one, and the waterproofing system is retested. This process is repeated until the issue is identified. Once the issue is identified, the faulty component is replaced, or a new solution is found for the problem. One issue discovered during prototyping was the powering of the cameras. Since the cameras are separately powered, they need to receive power from a power source. The original prototype involved running a power wire and a signal wire to a breakout box, where each camera would be powered separately. After prototyping and troubleshooting, it was realized that because the power wires and signal wires were in different bundles, the USB cameras were not functioning correctly. It was then understood that the power and signal wires needed to be run in the same sheath. This prototyping helped avoid the installation of a malfunctioning system on the craft and the need to troubleshoot a larger system.

Buoyancy Engine

The buoyancy engine [Figure 32] comprises six main components: the engine itself, a depth sensor, a Pi Pico, a custom PCB, a battery, and an infrared light-emitting diode (LED) array. The decision was made to use a larger buoyancy engine this year, compared to the previous year, as the previous one only displaced 50 ml. This small displacement meant that the old buoyancy engine weight had to be carefully fine tuned to the water chemistry, leading to inconsistent performance. This year's engine is designed to displace 500 ml of water, achieved using a 500 ml syringe powered by a 35 kg continuous servo. A pair of redundant limit switches in the syringe determines the required travel distance to displace the desired 500 ml of water, increasing reliability of the float. To measure pool depth, a Blue Robotics depth sensor is used, and the depth sensor data is transmitted to the surface using the infrared LED array where the depth over time data can be graphed. Additionally, an infrared receiver is employed to wirelessly turn the engine on and off, thereby conserving battery power when the engine is not in water. All components are controlled by a Pi Pico with a custom PCB for neatness. To accommodate the combined high amperage draw of these components, a custom 12V battery was created using eight C batteries in series. This setup also enables running the infrared LEDs at 12V while other components operate at 5V. The buoyancy engine requires a 5 amp fuse, placed after the battery and before any power splitting occurs.

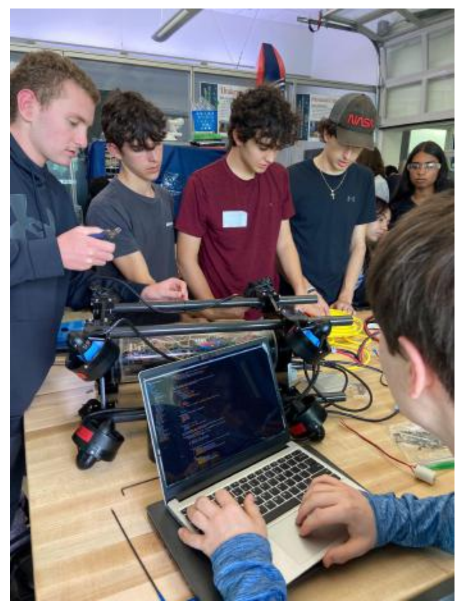


Figure 31: Team discussion for evaluating thruster layout, photo by Ava Palazzolo.

Figure 32: Night Owls' buoyancy engine, photo by Ava Palazzolo.

Safety

Safety Procedures

The safety of the Night Owls team is maintained through OSHA's "Hierarchy of Controls" [Reference 6] which includes PPE, administrative controls [Figure 33], engineering controls, substitution, and elimination. The safety protocols aim to prevent accidents and enable effective team communication, while emergency preparedness ensures swift responses. Personnel safety is ensured by using personal protective equipment (PPE), comprehensive training, and supervision. Administrative controls were ensured through a mandatory boating license course for every team member to educate on water safety. Engineering controls are ensured with warning signs, instructive labels, and lab assistants who supervise work with machinery. Substitution occurred when the company applied a less waterproof anderson connector to prevent wire shortage rather than a waterproof connector susceptible to shortage, possibly causing sparks. Elimination involves ceasing ROV electronics adjustments poolside and ensuring opened electronics are kept indoors away from water. These safety measures foster a secure a working environment, safeguard team members, protect spectators, and preserve the integrity of the equipment.

The ROV is also equipped with many safety features to ensure general safety. The custom-made prop guards were made in CAD to be 3D printed. The motors gaps are filled with recycled chicken wire from the company's previous MATE ROV. This year's design was inspired by both the 2022 and 2023 motor guard renditions, taking the best aspects of each and combining them to still fit IP-20 standards. Another feature is strain relief attached to both sides of the tether to ensure accidental tug on the tether does not unplug the ROV or cause the control electronics to be damaged.

Safety Procedures for ROV Operation: **(BOLD = double check)**
1. Conduct a thorough risk assessment of the ROV and its operating environment to identify potential hazards and develop appropriate safety measures. 2. Ensure that operators and personnel involved in ROV preparation receive comprehensive training on safe operating procedures, emergency protocols, and equipment handling. Only trained individuals are authorized to operate the ROV. 3. Implemented suitable safeguards and protective measures to prevent accidents and injuries. This **includes an emergency stop button** to always have full control of the ROV. 4. Provide and enforce the use of appropriate PPE, such as safety glasses and gloves when necessary, to protect operators and personnel from potential hazards associated with the ROV's operation. **5. Established clear emergency procedures and communication protocols in the event of an incident.** 6. **Conduct routine maintenance and inspections of the ROV** to identify and address any mechanical or electrical issues that could compromise safety. 7. Always maintain a clean and organized work area, free from unnecessary obstructions or potential trip hazards. 8. Have qualified supervisors present during ROV operation to provide guidance, monitor safety compliance, and intervene if unsafe practices are observed.

Figure 33: The risks associated with ROV operation can be minimized, ensuring a safe working environment for operators and greatly reducing the potential for accidents or injuries.

SID provided in Appendix A

Further Safety Procedures for machinery and tools provided in Appendix B

Accounting

Travel Budget

This year, the team knew they wanted to make significant changes to the Dark Shark, and this would require a larger budget. To make sure the team didn't spend carelessly, the budget was carefully planned and documented in Google Sheets. The estimated spending amount was around $17,000 dollars, which would include all components that went into building the ROV, the control system, and travel expenses.

Travel Logistics	Total Estimated Costs
Worlds Registration	$100.00
Hotel ($250/room/night x 4 rooms x 5 nights) students	$5,000.00
Hotel ($250/room/night x 2 rooms x 5 nights) chaperones	$2,500.00
Flight from Miami to Asheville - American Airlines ($404/person x 12 students)	$4,848.00
Flight from Miami to Asheville - American Airlines ($404/person x 2 chaperones)	$808.00
Car Rental (2 mini vans) $319.56	$639.12
Baggage (AA $200 for oversize fee, plus two bags $30)	$260.00
Gas $200/per car (airport is over 1 1/2 hours)	$400.00
Total Adult Meals (2 chaperones x $180)	$360.00
Airport Parking ($25/day x 2 vehicles x 6 days)	$300.00
Total Estimate:	**$15,215.12**
Total Estimated Per Student:	**$1,383.19**

Figure 34: Travel logistics and budget, photo by Carol O'Leary.

ROV Spending

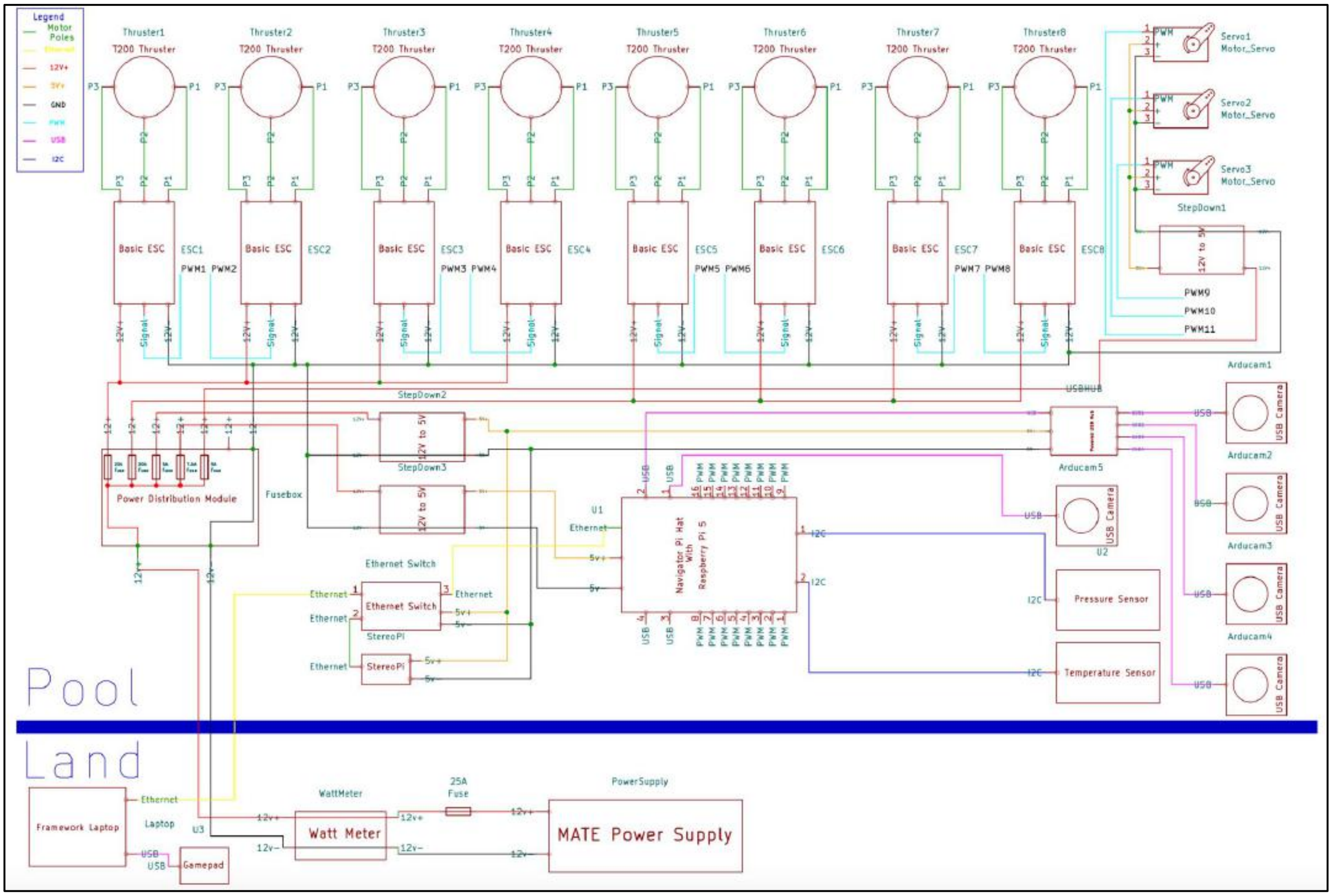
Upon completion of the ROV construction, a thorough assessment of the expenditure was conducted and totaled $5,628.23. Slightly less than half of this budget is consumed by the eight T200 motors and motor controllers. Having an eight-motor configuration would be pricey, so the team attempted to upcycle as many parts as possible. Most of the pieces that were not purchased came from old robots built for different competitions, such as T Slotted Bars from old RDL (Robot Drone League) robots and carbon fiber from Advanced Experimental Vehicles (AEV). Since all of the ROV expenses were covered by donation or grant money, the only expense the team is paying for is the trip to the international competition. The team fundraised for part of the trip and paid for the expenses not covered.

Spending amounts further detailed in Appendix C & D

Acknowledgments

The company would like to acknowledge all contributors that helped them make it to internationals this year. Firstly, the team would like to thank Mr. Nance, Mr. Phipps, and Mrs. O'Leary whose guidance and commitment helped shape the Night Owls team. Also, a huge thanks to the team's sponsors, Florida Power and Light, Broward Bolt, Advanced Circuits and the FAU Office of Undergraduate Research and Inquiry (OURI), whose donations have helped cover ROV expenses, allowing the team to be here. Furthermore, the company would like to extend immense gratitude to The Cane Institute for Advanced Technologies for graciously providing the company with access to their facilities. Last but certainly not least, the company would like to thank MATE for hosting these events and allowing the Night Owls to compete in this amazing competition. Their commitment to fostering collaboration, knowledge sharing, and excellence in the field of robotics has been a true inspiration.

Appendix A: SID



Fuse Calculations

Eight Motors = 18 amps with custom motor calculations

Three Servos, 1 amp each = 3 amps

Raspberry Pi = 1 amp

Stereo Camera = 1 amp

Five USB Cameras, 0.3 amps each = 1.5 amps

Depth Sensor = 0.00125 amps

Temperature Sensor = 0.0014 amps

Navigator Pi Hat = 0.2 amps

Total = 24.70265

24.70265 *1.5 = 37.053975

The ROV uses a 25 amp fuse.

Appendix B: Equipment Safety

Safety Tools	***Safety Procedure***
3D Printer	- *Ensure that the printer is in a well ventilated area and placed on a stable surface and away from flammable materials.* - *Regularly inspect printer for any signs of damage, and promptly address any issues.* - *Always monitor the printing process closely and avoid leaving the printer unattended for long periods.* - *Follow posted Standard Operating Procedures (SOPs) and ensure all Preventative Maintenance (PMs) are up to date.*
Epilog Laser Cutter	- *Inspect laser cutter for any signs of damage or malfunction before use and address any issues promptly.* - *Ensure proper ventilation in the workspace to help minimize the concentration of potentially harmful fumes.* - *Maintain a clean and clutter-free workspace, keeping flammable materials away from the laser cutter.* - *Leave lid closed during and 15 minutes after operation.* - *Follow posted SOPs and ensure all PMs are up to date.*
Power Tools	- *Members are familiar with specific instructions and guidelines provided by the manufacturer for each tool used.* - *Maintain a clean and organized workspace to prevent tripping or other accidents.* - *When using drills or other rotating power tools, ensure that the workpiece is securely clamped or held in place to prevent unexpected movements.* - *Never remove or tamper with any safety features or guards on the tools, as they are designed to protect us.* - *Follow posted SOPs and ensure all PMs are up to date.*
Soldering Iron	- *Always handle the soldering iron with caution, keeping it away from flammable materials and ensuring it is placed on a stable surface.* - *Inspect the soldering iron for any damage or loose connections and address any issues promptly.* - *Make sure the work area is well-ventilated to prevent the accumulation of fumes produced during the soldering process.* - *Never touch the hot tip of the soldering iron, and allow it to cool down completely before safely storing.* - *Always use lead free solder.* - *Follow posted SOPs and ensure all PMs are up to date.*

In case of emergency, fire extinguishers are always nearby, and all company members know how to operate them effectively. Machinery is never left unattended to reduce the risk of injury and accidents. Proper PPE is always equipped when operating, which includes using safety glasses, gloves, hearing protection, and safety vests.

Appendix C:Project Costing Sheet vs Budget

Projected Donated:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
Ethernet Ends	13.97	1	13.97
Custom PCB Board	120.00	1	120.00
Mechanical			
M4 Bolts	9.99	1	9.99
Carbon Fiber Tubes	177.20	1	177.20
Black Acrylic	20.79	4	83.16
		Total:	404.32

Projected Purchased with Grant Money:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
Temperature Sensor	70.00	1	70.00
Arducam	47.99	5	239.95
Power Wire	133.40	1	133.40
Power Sense Module	90.00	1	90.00
Raspberry Pi 5 Active Cooler	11.99	1	11.99
Raspberry Pi 5	97.29	1	97.29
Mechanical			
Watertight Acrylic Tube	300.00	1	300.00
Dome Endcap	40.00	1	40.00
18 Hole Endcap	55.00	1	55.00
M4 Threaded Inserts	9.99	1	9.99
Water Proofing			
O Ring Flange	45.00	2	90.00
		Total:	1137.62

Projected Reused:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
T200 Thruster	200.00	8	1600.00
Pressure Sensor	75.00	1	75.00
Thruster ESC	38.00	8	304.00
Navigator Flight Controller	320.00	1	320.00
Fathom ROV Tether by Meter	6.50	25	162.50
5v Pi Power Supply	9.99	1	9.99
Watt Meter	27.11	1	27.11
12 Gauge Wire	12.98	1	12.98
Anderson Connectors	14.70	1	14.70
Logitech Gamepad	17.33	1	17.33
Framework Laptop	849.00	1	849.00
Power Distribution Module	11.43	1	11.43
Mechanical			
M10 Enclosure Vent and Plug	10.00	1	10.00
Chicken Wire	24.99	1	24.99
Pelican Case	119.95	1	119.95
		Total:	3558.98

Proj. Donated	$404.32
Proj. Grant Money	$1,137.62
Proj. Reused	$3,558.98
PROJECTED TOTAL	**$5,100.92**

Donated:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
Ethernet Ends	13.97	1	13.97
Custom PCB Board	120.00	1	120.00
USB Cables	14.99	1	14.99
Solder Shrink Connectors	13.59	1	13.59
USB Splitter	14.99	1	14.99
Mechanical			
M4 Bolts	9.99	1	9.99
Carbon Fiber Tubes	177.20	1	177.20
2 Inch PVC Pipe	9.99	1	9.99
Black Acrylic	20.79	4	83.16
Zip Ties	15.99	1	15.99
		Total:	473.87

Purchased with Grant Money:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
Temperature Sensor	70.00	1	70.00
5v Camera Power Supply	9.49	1	9.49
Arducam	47.99	5	239.95
Stereopi	64.99	1	64.99
Raspberry Pi Camera	9.98	2	19.96
Power Wire	133.40	1	133.40
Waterproof Servo	24.99	3	74.97
5v Servo Power Supply	11.99	1	11.99
Power Sense Module	90.00	1	90.00
Large Anderson Connector	12.99	1	12.99
Ethernet Switch	20.99	1	20.99
3 Conductor Wire	29.99	1	29.99
Raspberry Pi 5 Active Cooler	11.99	1	11.99
Raspberry Pi 5	97.29	1	97.29
Mechanical			
Watertight Acrylic Tube	300.00	1	300.00
Dome Endcap	40.00	1	40.00
18 Hole Endcap	55.00	1	55.00
Black PLA	17.99	2	35.98
M4 Threaded Insets	9.99	1	9.99
Table Top Epoxy Resin	99.99	1	99.99
M2.5 Standoff Kit	11.99	1	11.99
Black Spray Paint	10.87	1	10.87
Water Proofing			
O Ring Flange	45.00	2	90.00
Waterproof Anderson Connector	18.99	1	18.99
Silica Beads	12.99	1	12.99
9 Pin Waterproof Connector	14.60	1	14.60
		Total:	1588.40

Reused:			
Item	Unit Value ($)	Quantity	Total ($)
Electronics			
T200 Thruster	200.00	8	1600.00
Pressure Sensor	75.00	1	75.00
Thruster ESC	38.00	8	304.00
Navigator Flight Controller	320.00	1	320.00
Fathom ROV Tether by Meter	6.50	25	162.50
5v Pi Power Supply	9.99	1	9.99
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12 Gauge Wire	12.98	1	12.98
Anderson Connectors	14.70	1	14.70
Logitech Gamepad	17.33	1	17.33
Framework Laptop	849.00	1	849.00
Jumper Wires	6.98	1	6.98
Power Distribution Module	11.43	1	11.43
Mechanical			
M10 Enclosure Vent and Plug	10.00	1	10.00
Chicken Wire	24.99	1	24.99
Pelican Case	119.95	1	119.95
		Total:	3565.96

Donated	$473.87
Grant Money	1588.40
Resued	$3,565.96
TOTAL	**$5,628.23**

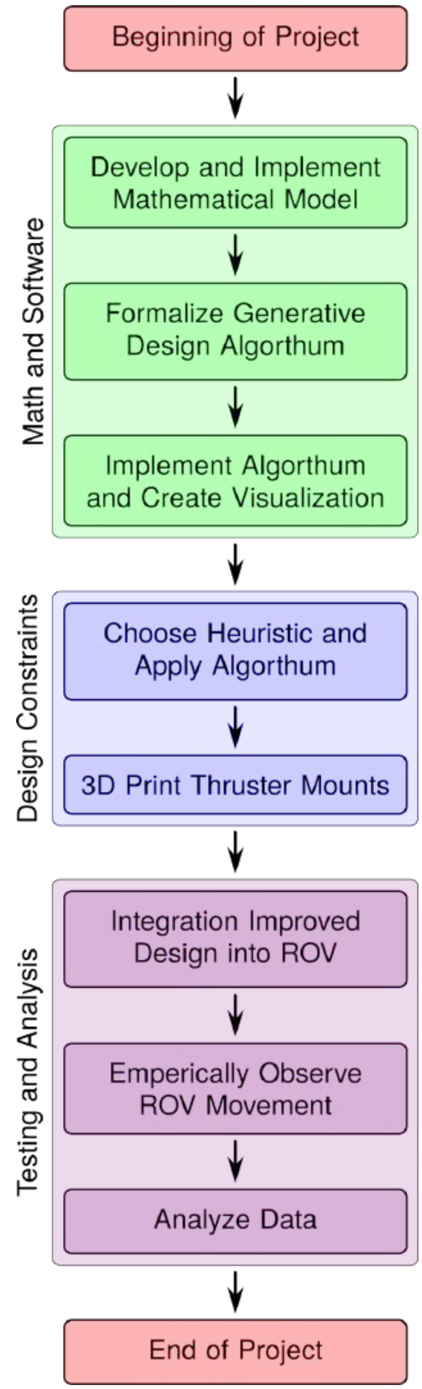
Appendix D: Schedule

Week	Time	Duration	Objective
August 28 – September 3	3 pm - 4 pm	1 hour	Meeting kickoff, give a presentation about MATE to new members
September 11 – October 15	3 pm- 4pm	5 hours	Work on OURI grants
October 16 – November 5	3 pm - 4 pm	3 hours	Plan for the budget
November 6 – December 3	3 pm - 4 pm	8 hours	CAD frame, code ROV, begin organizing electronics, and order custom PCBs
January 1 – March 4	3 pm - 5 pm	16 hours	Mount components to PCBs and assemble tube
March 4 - 10	8 am - 5 pm	9 hours	Boating license class, build props, build the frame of robot, and continue assembling the tube
March 11 – 17	8 am - 5 pm	Whenever available	Build props, build the physical frame of the robot, and continue assembling the electronics tube
March 18 – April 7	8 am - 5 pm	Whenever available	Make marketing poster, finish tube and frame
April 8 – 14	8 am - 5 pm	Whenever available	One week cushion to finish
April 15 – May 5	10 am - 6pm	24 hours	In pool practice for regionals
May 6 - 12	8 am - 5 pm	9 hours	Make merchandise for marketing display, practice

Appendix E: Thruster Optimization Project

This year, two members of the Night Owls conducted a research project titled "Optimizing Thruster Layout on an Underwater ROV." Many applications of ROVs differ in the maneuverability charastics they require, and this project investigated how the thruster configurations of underwater ROVs can be optimized to best suit the needs of specific applications. Many state of the art ROVs employ a one size fits all approach to thruster configurations, but in a world with rapid prototyping through 3D printing and generative design, this approach is far from optimal.

This research enhances ROV maneuverability by using gradient ascent optimization to iteratively improve thruster angles in ROVs using the 3D Thrust Vectoring (3TV) thruster layout. Additionally, cost-effective PCBs were developed to simplify onboard electronics and support the eight ESCs required to drive an ROV with this thruster configuration. We present novel ROV control software that enables efficient control of any thruster configuration as well as a custom ROV equipped with these innovations that displays enhanced maneuverability compared to previous designs, paving the way for future ROVs to better serve specific industrial needs. To fund this project, the Night Owls received a $1,200 grant from FAU's OURI, along with taking 4th place at the Florida State Science & Engineering Fair in the Intelligent Machines, Robotics & System Science category.



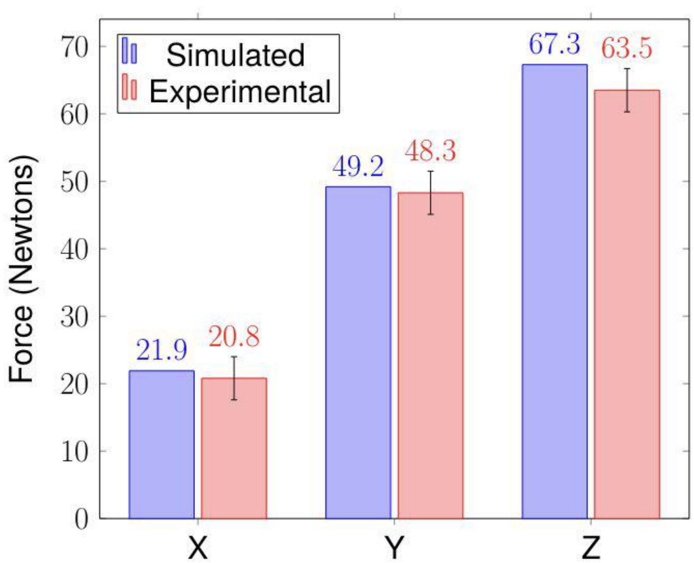


Fig. 7: Comparison of simulated and emperically observed force

X: 21.87 N, **Y**: 49.18 N, **Z**: 67.26 N,
Pitch: 10.37 Nm, **Roll**: 10.81 Nm, **Roll**: 4.53 Nm

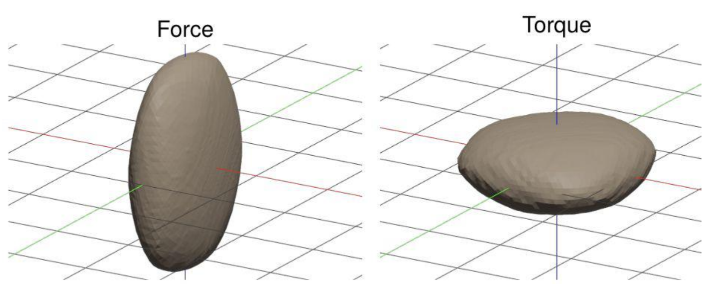


Fig. 6: Simulated force and torque plots for the ROV in **Figure 2**

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