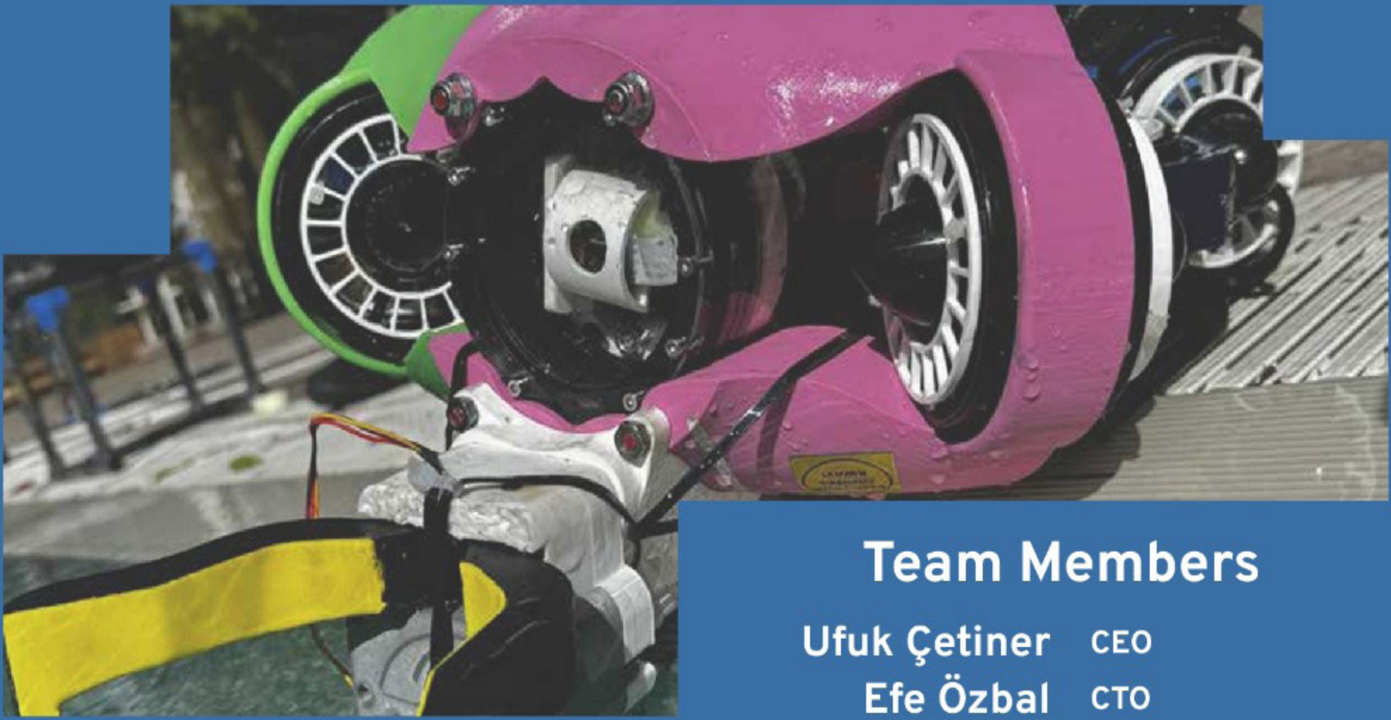
Marine Advanced Technology Education

ROV Technical Documentation

Robert College Makers

American Robert College of Istanbul
Istanbul, Turkey
11,040 km [6,860 miles] to the Championship

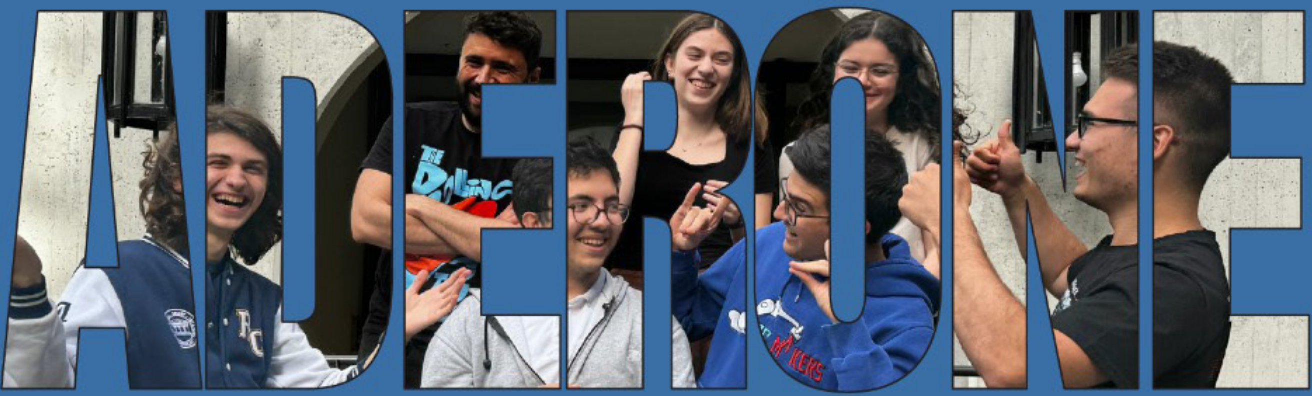


Team Members

Ufuk Çetiner	CEO
Efe Özbal	CTO
Emre Sarıkaya	CPO
Ece Yaşyerli	Head of Design
Önder Karataş	Head of Programing
Ada Coşkun	Head of Mechanic

Mentors

Can Yılmaz
Berkman Gülenç



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Abstract

The Robert College Makers (RCM) is a first-year underwater robotics company that consists of six highly motivated members. Along with their competence in engineering and programming, the team members' actions toward the Sustainable Development Goals are a factor that stands out. Located in Istanbul, Türkiye, the company has been working toward producing an ROV that can create an impact on the environment.

Aderone was produced by RCM and is its most recent product. Aderone is an underwater robot that is capable of tasks such as autonomous driving, photogrammetry, and collecting samples below water. Aiming to create impact, Aderone is ready to perform tasks in real-world conditions.

The RCM has benefited from research, prototyping, and testing techniques to get the desired results on its Aderone. Aderone has a durable, compact, and modular design, which was designed and produced solely by the RCM team with its innovative approach. These properties of Aderone further support it in the tasks it was designed to perform. The RCM team has worked on producing Aderone from the start of the year with determination.

This document aims to detail the technical properties of the ROV that showcase its ability to perform tasks. The RCM's planned process through the year and their preparation structure are detailed along with the budgeting and safety features of Aderone.

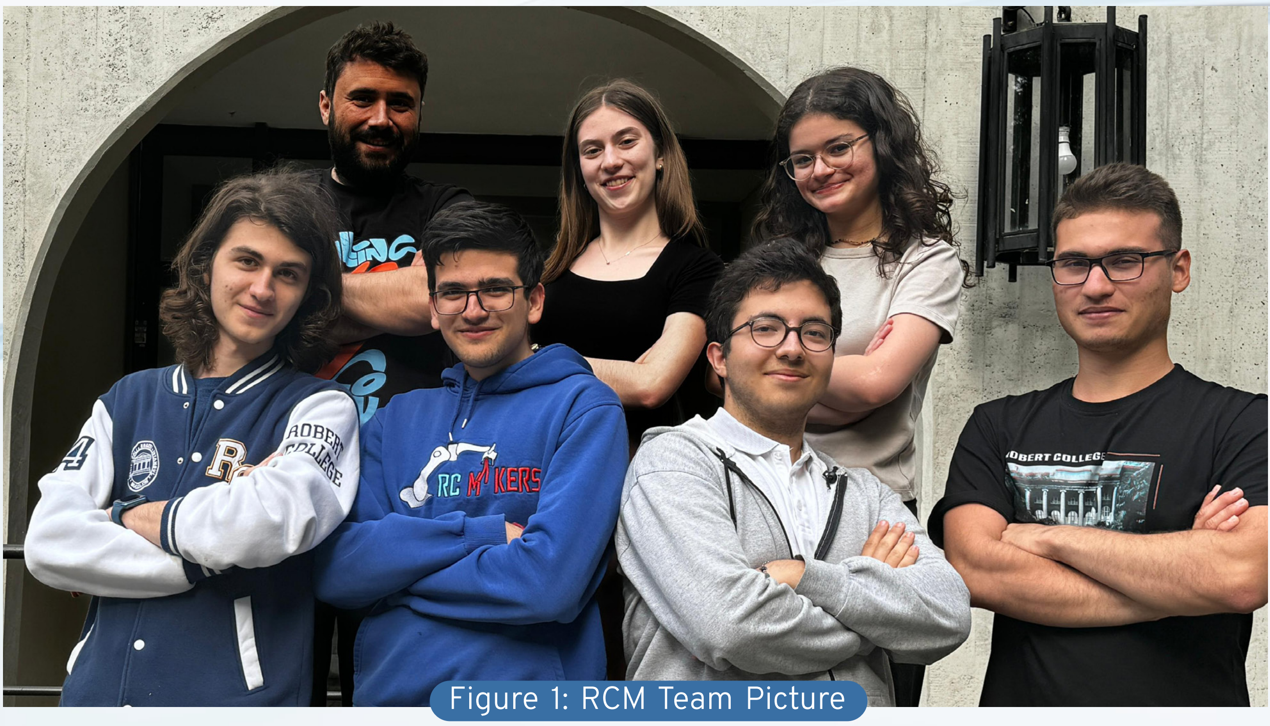


Figure 1: RCM Team Picture

Project Management

I. Company Overview

Robert College Makers (RCM) is a competitive company located in Istanbul, Turkey, that specializes in underwater robotics and solutions that targets climate change's and pollution's impact on marine life. Our goal is to design a ROV that is able to assist in problems concerning underwater life.

RCM's members go through a rigorous selection process that requires knowledge in 3D design software and general principles of robotics. The 6 members of RCM specialize in a variety of areas while also having the experience and knowledge to contribute to the development of the designed robot as a whole. Robert College Makers has participated in local competitions before but is new in MATE ROV competition.

The process of feedback is of the utmost importance to RCM. Our process into designing the ROV included constant feedback from all the members of the team. The competitions we participated in before, such as the Turkish Technology Festival (Teknofest) held annually, provided valuable feedback for us as we worked on improving our vehicle and eventually adapted to complete the tasks of 2024 MATE ROV Championships and effectively contribute to the solution of problems concerning climate change's effect on underwater life.

II. Member Roles and Responsibilities

The team is advised by 2 experienced individuals, Berkman Gülenç and Can Yılmaz, who guide the team into producing the most effective results. The CEO, Ufuk Çetiner, is responsible for providing insight for all departments. He oversees the production of parts, management of electronics and programming.

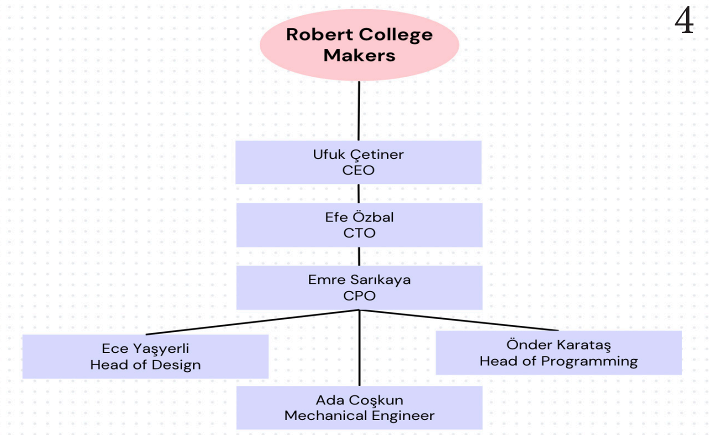


Figure 2: Team Tree Diagram

Efe Özbal carries the title of CTO, who leads and advises the usage of technology and determines the best approach to any problem the team might be facing. The CPO of the team, Ece Yaşyerli, manages expenses and is involved in the process of designing parts using 3D design softwares. Head of Design is Emre Sarıkaya, who reviews and advises designs before they are approved for manufacture. Önder Karataş is the team's Head of Programming and oversees all development regarding software. Ada Coşkun is involved in the design process of the ROV using 3D design softwares such as Fusion 360. RCM has participated in local competitions before but is new in MATE ROV competition.

III. Project Planning & Time Management

Since September of 2023, RCM has been meeting every Wednesday with available members doing additional work on other weekdays. We used a divide-and-conquer approach as every member took responsibility for different parts of the ROV and improved upon feedback from other members all while developing algorithms to successfully complete the tasks of the competition. As the design process finished in February, we began manufacturing and later brought the ROV together and started focusing on improving functionality. We conducted multiple tests and improved upon the results. Regular online meetings were conducted to determine deadlines and discuss future steps.

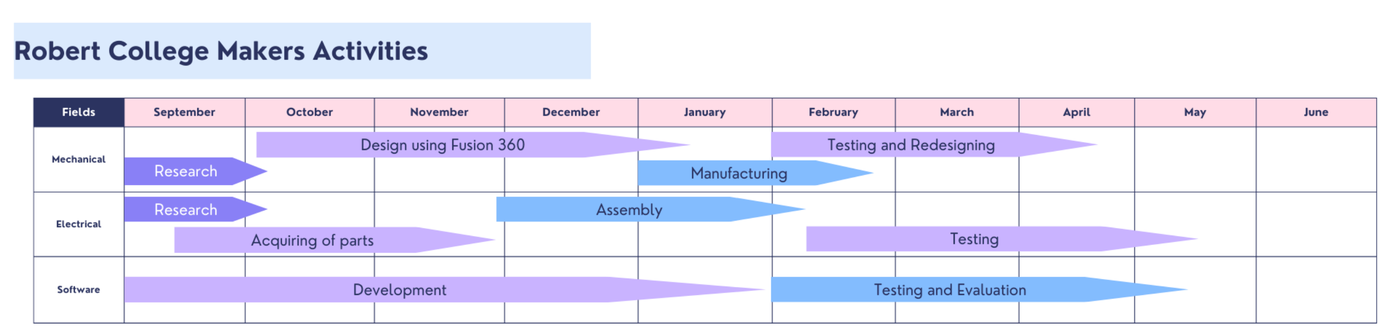


Figure 3: RCM Timeline

Project Management

RCM took upon many challenges in the process of building the ROV. This process involved revaluations of many designs and adjustments. Seeing the areas open for improvement was critical in our final design. The team works on a feedback system where every design and software is reviewed by other members and advisors. Problems that rose during testing were dealt with the efforts of the entirety of the team. Such cases of operational problems were discussed at length during meetings regularly held either online or in person. When the necessary improvements were determined, the tasks were distributed between members who would present their work later to retest. At the start of the year when a series of meetings were held to determine the course of action, it was to all the members' knowledge that a task such as this wouldn't be prone to error. Our resources were determined accordingly, leaving room for redesign and reevaluation of parts while keeping the budget in a reasonable amount. Our approach to problem solving allowed the team to reach their full potential and produce a final design that reflected the abilities of all the members of RCM.

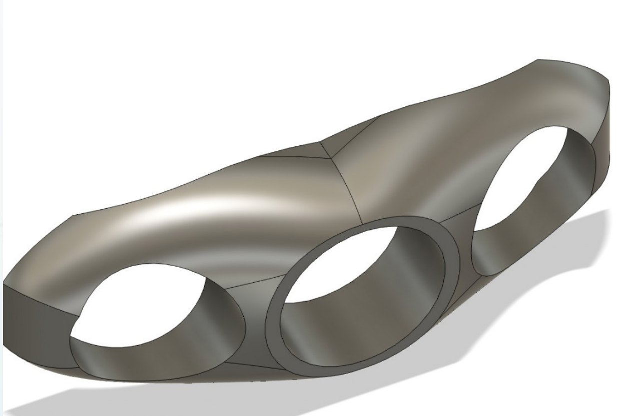


Figure 4: Initial Robot Desgin

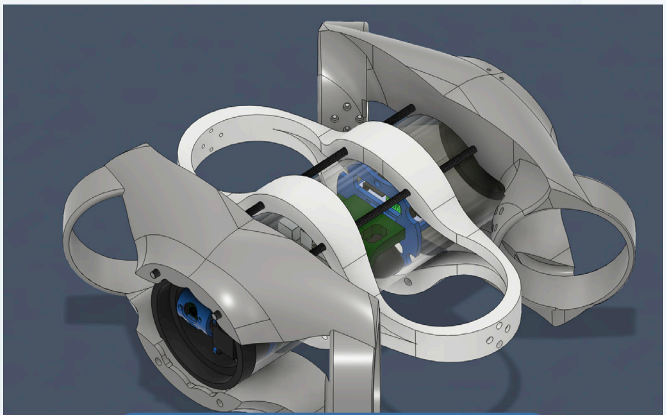


Figure 5: Initial Robot Desgin

Design Rationale

I. Design Overview

The key goals of the ROV design were creating a hydrodynamic and compact chassis, designing a modular and easy-to-access electronic tray, and designing a robot arm specific to the year's tasks. The first few weeks of the design process were spared specifically for the research and ideation process. During that time, the team had a chance to discuss possible designs, run tests on 3D-printed prototypes, and make final decisions regarding what to purchase in order to start the process of building the ROV. In the building process, it was determined that a 3D-printed chassis would benefit the ROV by being more hydrodynamic and compact, which were two of the aspects that shaped the design process of the team. 3D printing methodology provided the design team with more freedom and decreased the predicted cost of the ROV significantly. Thus, printing the chassis through 3D printers using tough PLA was the chosen way of producing the chassis of the ROV.

II. Chasis Design

The chassis consists of 3 separate main bodies, and four metal rods to maintain structural integrity. Furthermore, these metal rods are used as mounting points to attach necessary components such as the robot arm for the MATE ROV missions. The three-piece design of the chassis allowed the team to have a modular design onto which necessary components could be added.

Revolving around the electronic tube, the design of the chassis was made by ensuring the use of the smallest place possible, while bearing in mind the thrusters' need for open spaces to reduce induced drag forces. Initially, the design of the front and back parts of the chassis were as shown in figure 3. However, due to the parts of the chassis covering the side of the thrusters, the drag force would have decreased the mobility of the ROV by causing the team to not be able to benefit from the full capacity of the thrusters. Thus, the design was revised into the design on figure 4. This design covers the electronics tube from the front, whilst being in sync with the thruster alignment chosen for the team. A similar design for the back of the chassis design was made; however, due to the connector PCB, the same design could not be used for the back part of the chassis. The parts holding the front of the electronic tube from sliding were cut off and an additional component to be attached on the chassis after the electronic tube is inserted was designed, which can be seen in figure 5. The part that constitutes the middle of the chassis was designed specifically to ensure a broad perspective on the camera looking down at the ROV. Thus, the parts that grip the electronic tube were designed thinner compared to other parts, whilst not compromising the durability. The final design of the chassis, attached together with metal rods, can be found in figure 4.

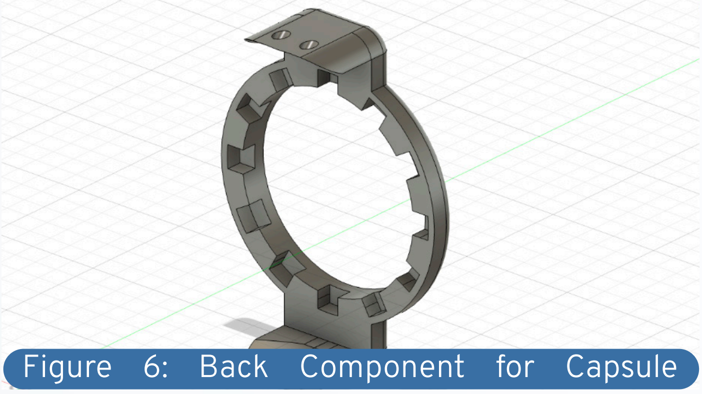


Figure 6: Back Component for Capsule

III. Chasis Simulation and Analysis

The team conducted a thorough analysis of the hydrodynamic forces acting on the ROV using SolidWorks Flow Simulation with the flow trajectory method. By simulating a water velocity of 0.8 m/s, they were able to detect design flaws and make necessary adjustments to minimize drag. This simulation provided valuable insights into how the chassis would react to moving fluid, identifying potential turbulent points and non-optimal sections that hindered smooth fluid flow.

With the insights gained from the simulation, the design team refined the shape of the chassis to streamline it further, reduced sharp edges, and modified surfaces to promote laminar flow. These changes aimed to minimize resistance and enhance the ROV's maneuverability and speed. The iterative design process ensured that the ROV would perform efficiently in real-world conditions, balancing structural integrity with hydrodynamic efficiency.

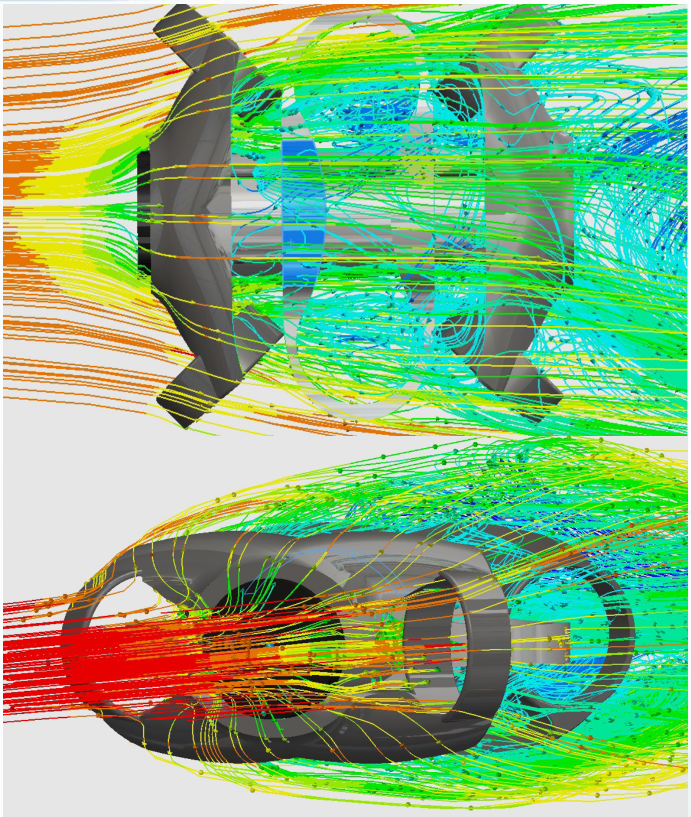


Figure 7 (a-b): SolidWorks Flow Simulation Results

IV. Innovation

The design process of the robot arm started after the missions were released. As seen in Figure 6, the initial robot arm comprised two claws (green), a universal joint (red), a watertight servo motor (black), and a stabilizing component (brown). The system uses a servo and mechanical joints to operate. The claws have a 4mm aluminum core and are curved enough to fit a 1-inch PVC pipe in the middle. Plus, the straight part of the claws is designed to grab anything other than 1-inch PVC pipes. It also has a hook at the end. The universal joint, on the other hand, is to gain vertical space. However, due to the low availability of universal joints for servo motors and the size of our design, this component will be omitted in the next iterations.

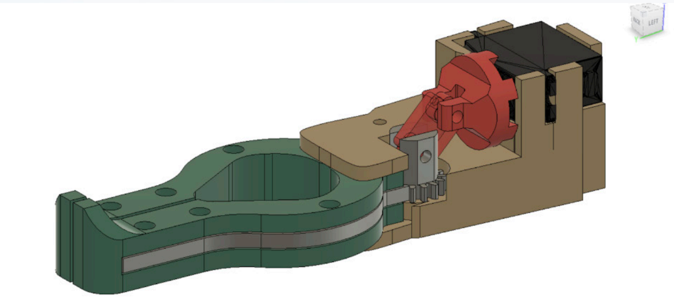


Figure 8: Initial Design of the Robot Arm

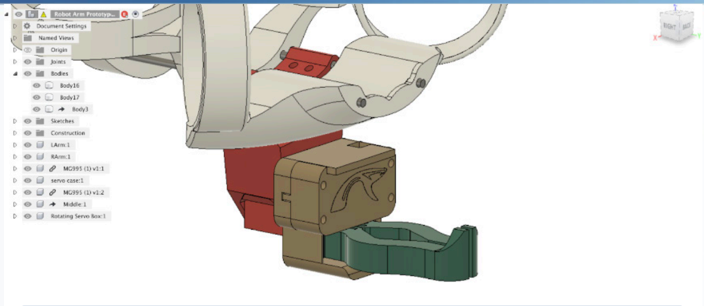


Figure 9: Second Iteration of the Robot Arm

As seen in Figure 7, the second iteration robot arm uses a similar claw, yet the aluminum core has been removed because of monetary and time constraints. Plus, 3D-printed PLA is simulated and tested to demonstrate a comparable performance in the tasks. The hook of the claws is also optimized for the tasks given. However, after testing the design underwater, the team concluded that such a design was inefficient as the gripping abilities were significantly reduced. With the universal joint removed, a servo (inside the brown box) is directly attached to one of the claws as seen in Figure 8E. Another addition to the design is the ability to rotate. To achieve this, a second watertight servo motor is placed in the red component similar to Figure 8D, and its head is connected to the brown part as seen in Figure 8F. Despite the added degree of motion, this design's greatest issue is that it is outside of the camera's vision. Thus, it is impossible to operate reliably.

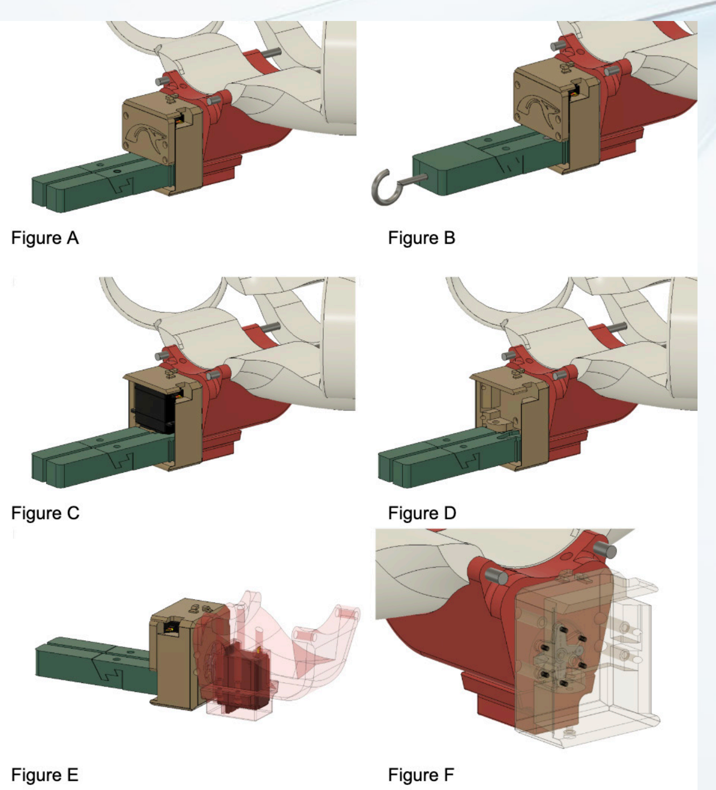


Figure A

Figure B

Figure C

Figure D

Figure E

Figure F

Figure 10: Final Iterations of the Robot Arm

The final iteration of the robot arm is seen in Figure 8A. Though the working principle remains the same, the team changed the claws into a straight shape to ease the gripping motion. Through testing, this new design proved to be better at gripping. In addition, EVA paper was used to increase the friction between the claw's and the target object's surfaces. The gripper is capable of opening up to 90°. This new claw design is also modular and customizable, allowing it to be switched to another tip within 30 seconds. Currently, there are two tips: "gripper tip" (Figure 8A) and "hook tip" (Figure 8B). Tips can be improved and diversified in the future. The other changes are the use of a smaller servo box (brown component) to increase the camera's field of vision and the updated chassis connection piece (red component) to bring the claws within the camera's field of vision. The robot arm and previous prototypes are manufactured via 3D printing PLA because they are non-toxic, durable, and cheap.

V. Electronics Tube & Tray

The electronics tube chosen for the ROV was chosen according to the initial goals the design team set for the ROV design, specifically compactness. Thus, the electronic tube from Degz, model H100, was chosen. A smaller electronic tube required the team to design an organized electronic tray. Easy access to the electronic components was prioritized for its design. After the prototyping process, the team concluded that a design that separates the electronic components with circular plates was the most appropriate design to ensure the compactness and orderliness of the electronics. In order to maintain the structural integrity of the electronic tray, a metal rod was used. A completed image of the electronic tray can be found in Figure 9.

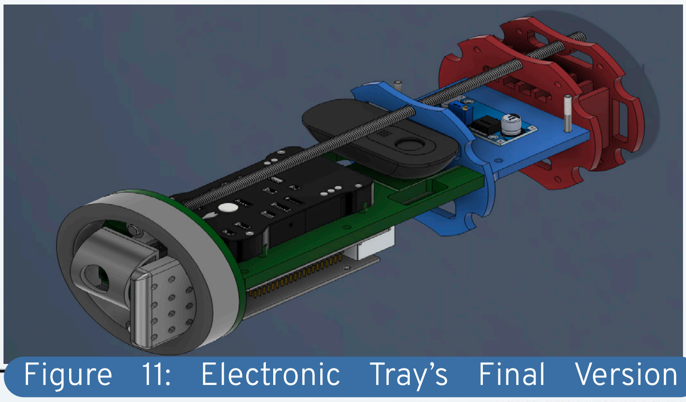


Figure 11: Electronic Tray's Final Version

VI. Problem Solving

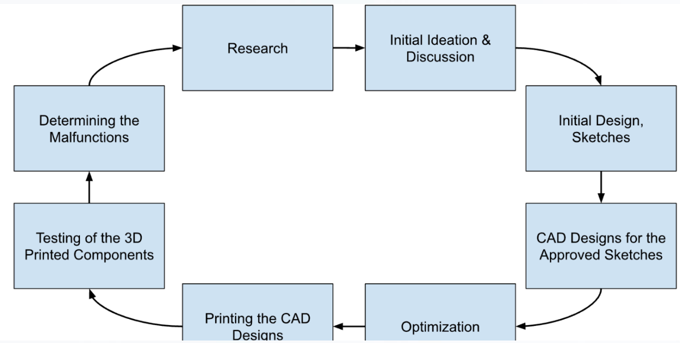


Figure 12: Brainstorming and Ideation Process

The RCM team used the process illustrated in Figure 10. For each of the components, the process was iterated until the desired outcome was achieved. RCM started off the design and brainstorming process by researching the technical requirements, how to make the ROV more hydrodynamic, and the necessary electronic components. The team gathered every week for ideation and discussion processes. It was a critical aspect of the design process for the team as this step determined the initial sketches. After it was determined that the idea behind the sketches would work, their CAD designs were made. In the weekly meetings, the optimization of the design was made after presenting the design to team members and taking their opinions on the design. Then the designed parts were printed with 3D printers, and they were tested accordingly in the aspects of durability, functionality, and efficiency. After determining the parts failed to meet the desired outcomes of the RCM, the same process was re-started with those parts until they yielded the desired outcomes.

VII. Systems Approach

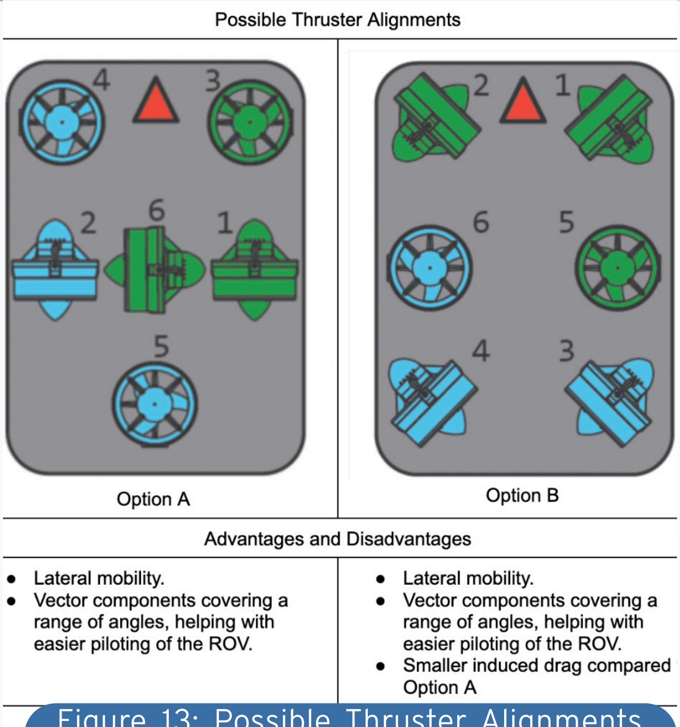
One of the RCM's goals from the beginning was to create a modular design so that the team could inspect and re-design the malfunctioning parts of the ROV. Thus, the chassis, along with the electronic tray were constructed accordingly. For the electronics part a modular and compact electronic tray allowed the team to use a compact electronics tube as well, which resulted in the overall design of the ROV to be more compact. Achieving a compact design without compromising the necessary components required thorough planning with a holistic view of the different systems that interact with each other. Thus, previous planning and systems maps were critical aspects of the design process.

The modular structure of the overall design of the chassis allowed the chassis to be more flexible and to be able to be altered according to the task specifications. When designing modular structures, whilst considering the individual functionality of the designed components, our team also had to consider its integration to the overall structure and make sure the parts work together without any malfunctions.

VIII. Propulsion

It was determined that the design would use 6 thrusters to ensure the mobility of the ROV. Although an eight-thruster design would cover a wider range of angles, thus improving the ROV's mobility, such a design would have major economic setbacks. A six thruster design, on the other hand, would still cover a wide range of angles and provide good mobility. A four-thruster design was not considered as it would fail to provide the lateral movement of the ROV, which is a key aspect of the missions in the MATE ROV competition. Their alignment was determined by research to provide the greatest mobility for the ROV. The image labeled as Option B shows the thruster alignment of our ROV which was determined to be used after evaluating different models of possible thruster alignments. The list the team prepared of their advantages can be found in Figure 11. As can be seen, Option B would provide the team with an ROV that is less affected by the induced drag. Thus, option B was determined to be used.

RCM improved the ROV's movement by finding the optimal thruster which will be enhancing lateral and rotational capabilities for more precise and faster mission task completion. After analyzing the impact on design, power, and maneuverability, RCM evaluated thruster options, testing and comparing different models of thruster as well as building our own thrusters. The ROV's thrusters were strategically mounted to maximize movement and avoid interference with other sections of the ROV.



Possible Thruster Alignments	
Option A	Option B
Advantages and Disadvantages	
• Lateral mobility. • Vector components covering a range of angles, helping with easier piloting of the ROV.	• Lateral mobility. • Vector components covering a range of angles, helping with easier piloting of the ROV. • Smaller induced drag compared Option A

Figure 13: Possible Thruster Alignments Photos by Bryan Johnson

The reasons for using T100 motors, which are reliable for underwater robotics due to their sturdy material and strong thrust, include:

- These motors are specifically designed for direct use in the open ocean or underwater environments.
- They provide up to 5 pounds of thrust, offering
- 2.4 kilograms-force in forward thrust mode and - 1.9 kilograms-force in reverse thrust mode.
- They are very easy to mount and use.
- They have a much better performance-to-price ratio compared to other motors on the market.

Thrusters are calibrated using QGroundControl by calculating the maximum power it takes and

IX. Buoyancy and Ballast

RCM aimed for a neutral buoyancy for the ROV to have maximum maneuverability and highest efficiency from the thrusters. In order to ensure neutral buoyancy, RCM has done density calculations and used an infill value from the 3D printers accordingly. At first, the chassis was printed with 20% infill, which resulted in the ROV floating. Thus, after some calculations, RCM realized that using 100% infill at the front and back components of the chassis would be the most beneficial way of yielding a neutral buoyancy. The chassis was printed, and the additional weight of the electronics were added, yet the ROV was still positively buoyant. Ballast was added to the front of the ROV, and the vehicle became negatively buoyant. Thus, pool noodles were used for neutral buoyancy. The ROV was tested with each additional piece of pool noodles, and the team finally achieved neutral buoyancy.

Tether is negatively buoyant, so the weight of the tether was also an effecting factor in the maneuverability of the ROV. For the tether, the team aimed for a positive buoyancy to reduce any risks of the ROV getting tangled in the tether. Thus, the same pool noodles tied to the chassis of the ROV were also tied to the tether.

X. Payload and Tools

Temperature Probe

The temperature probe is designed with the aim of simplicity and efficiency. RCM members drilled a hole in a prop construction's leftover pipe. This way, the leftovers were repurposed and a simple solution for the mission was accomplished. The temperature probe has a built-in battery and LCD, which team members soldered the originally 1-meter cable to be as long as 10 meters.

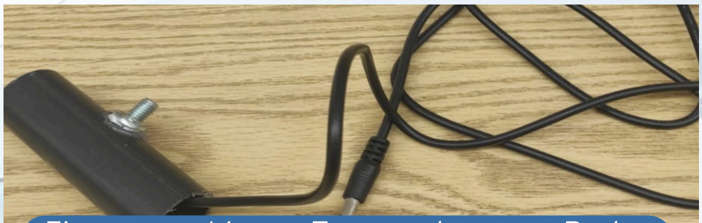


Figure 14: Temperature Probe

Camera Tilt System

After a review of the tasks set by the MATE ROV Competition, our team deemed it necessary to design a camera tilt system that will provide a wide viewing angle. The design of the system was made by the members of RCM, 3D printed using tough PLA filament and connected to the modular electronic tray. It allows rotation up to 90 degrees and is easy to access inside the watertight tube. An image of the camera tilt system can be seen in Figure 14.

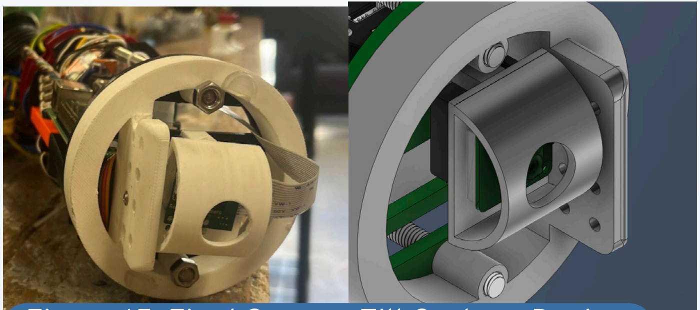


Figure 15: Final Camera Tilt System Design

Photogrammetry

For the photogrammetry task, we'll use RealityCapture 1.4 for the autonomous 3D model creation. RealityCapture was chosen for its cost, ability to operate without an internet connection and speed, completing this task faster than the other softwares tested. We will record the video of the ROV's camera while the pilot rotates around the coral restoration area. Later, with the help of a python script, we will capture necessary frames. After we upload these frames to RealityCapture 1.4, the software will autonomously create the 3D model of the coral restoration area by piecing the frames together.

The pilot will bring a test probe that has a known length and will place it next to the coral restoration area. Then, the ROV will scan the area from a distance where all the coral restoration area is visible with the test probe in place. The test probe and its relation to the envrionment will allow us to determine the scale.

Strain Relief

In order to securely attach the tether to the ROV, RCM members developed a modular strain relief mechanism. The body of the mechanism is attached to the metal rod and is supported with carabiners. In order to distribute the pressure on the tether, team members cut off and bent an aluminum pipe and attached it using a cable tie. Lastly, the tether is safely connected again with a carabiner. The ROV can be easily lifted using the strain relief system.

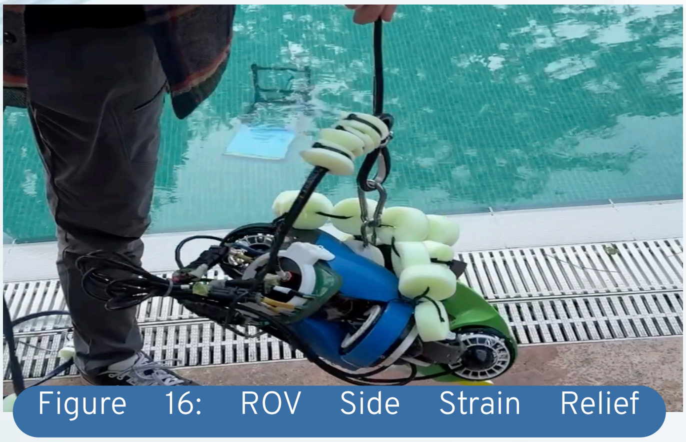


Figure 16: ROV Side Strain Relief

Robot Arm

Aderone has one robot arm capable of rotating 360°. Each claw of the robot arm can easily be customized thanks to the modular tip design. Currently, the company has two separate tip designs: gripper and hook. With the gripper tip, the robot arm can open up to 90°, allowing it to grip wide objects. Also, the inner surface of this tip is covered with EVA paper to increase the friction between the gripper and the target object. This tip can perform tasks like releasing the multi-function node's recovery float, carrying the failed recovery float to the surface, connecting a recovery line to the node, deploying the probiotic sprinkler on the coral head, transplanting branching and brain corals, recovering the acoustic receiver and a sediment sample, place ADCP in the designated area and connecting the AUV docking station to the SMART cable repeater. Moreover, the irrigation system can be activated by using the rotation ability of the robot arm.

On the other hand, the hook tip prevents the robot arm from opening. Due to this feature, the pilot is limited to rotating the robot arm for hooking and unhooking, which has proven to be sufficient. The primary goal of this tip is to carry objects from the surface like the SMART repeater and the probiotic irrigation system. Also, the hook tip is designed to hold the temperature probe for measuring temperature, allowing for the verification of SMART cable readings. Meanwhile, the Aderone's cameras provide a wide field of view and maneuverability for the pilot.

XI. Control Electrical Systems

The electronic design process of the ROV is as follows:

1)The company members identify the components that could be used in the vehicle's electronic systems.

2)The components are sourced from manufacturers.

3)Each component is tested individually. If a component does not perform adequately, the process is repeated from step 1 for that component.

4)The components are subjected to different scenarios, and their efficiencies in these scenarios are noted.
5)Based on the data from the previous step, the components to be included in the final design of the ROV are selected, and the electronic schematic is drawn.

Throughout the electronic design process, the members spent the most time on step four. For example, initially the team thought to use two Fathom-X boards to send power and data on the same cable to reduce the amount of cable going in and out of the ROV. However, testing showed this method was unreliable since the kickback current would interfere with Fathom-X's communication effectively creating a jammer when the motors stopped.

The system consists of parts that are underwater, on the surface and within the waterproofed enclosure. Their locations, functions, and selection reasons are detailed below, along with the electronic design schematic (see appendix).

Raspberry Pi 4 Model B:

The high processing speed of the Raspberry Pi 4B made it ideal for control and data collection tasks in the underwater ROV. Additionally, its small size allows it to fit easily into the waterproof enclosure. During operation, the Raspberry Pi serves as the main control board of the ROV. Its primary functions are to communicate with the surface computer, collect camera footage, and receive and transmit data from the Pixhawk.

Pixhawk:

The Pixhawk is a flight control board widely used in unmanned aerial vehicles and underwater vehicles. Its precise gyroscope and accelerometer make it ideal for the ROV as it ensures smooth operation. The Pixhawk's duties include controlling underwater movements, determining direction, adjusting speed, and managing depth.

Tether

The tether features one CAT6 Ethernet cable and 14 AWG power cables. The length of the tether is 22.5 meters. Our team concluded that a 22.5 meter, 14 AWG power cable is the best option that maximizes the gain in mobility while keeping the negatives of using long cables at a minimum. Our team chose colorful insulator tapes to increase visibility in the water. Also to achieve neutral buoyancy through the wire, we added foam rubbers throughout the wire.

Blue Robotics Electronic Speed Controller (ESC):

Used for motor control in underwater ROVs, the ESC is designed to electronically control the speed of a motor.

5V Voltage Regulator:

Since the motors operate at 12V, the power cable to the ROV carries 12V. However, more sensitive electronic components like the Raspberry Pi, Pixhawk, and servos operate at a lower voltage, necessitating a voltage drop. Therefore, a 5V voltage regulator is used.

Servo:

Three servos are used in the ROV, one of which is inside the watertight capsule and is responsible for tilting the camera. The other two servos are waterproof and is used outside on the ROV to control the gripper.

Cameras

To capture footage during operation, a Raspberry Pi Camera Module 2 and a USB camera are used. The Raspi Camera is mounted facing the front and the USB camera is mounted facing down at the pool surface. The USB camera is used when the robot is tilted forward and on autonomous tasks.

Connector Board and Watertight Connectors:

The connector board is used to transfer electrical signals from inside the watertight capsule to the outside much like a penetrator. It is sandwiched between the two aliminum pieces that are the ends of the watertight tube. Watertight connectors are soldered directly onto this PCB. Later on epoxy is poured on top of the PCB to eliminate any exposed wiring. Watertight connectors ensures easier connections with the thrusters and make the overall design more modular.

Figure 17: Watertight Connectors

Ground Station

The ground control station consists of a computer, joystick, an extra monitor, and strain relief. The design of the control station involved repurposing an old toolbox for a new purpose that both acts as a carrier for the ROV and the components needed. Company members cut a 16 mm plywood in the dimensions of the box and 3D printed the arrangements for the components that also act as a holder beneath the box.

Figure 18: Ground Station

XII. Build vs Buy, New vs Used

As the RC Makers team, it was important for us to recycle or reuse the components we needed as much as possible. Before purchasing the necessary components, a thorough search was made around the school's workspace to find necessary components, and a list of possible materials that could be used was made. Any reusable or recyclable materials were spared aside. We tried to purchase as little as possible to further support the sustainability of our ROV, however, as a new team, we didn't have any components we could reuse, so we had to purchase most of the necessary components. A list of the purchased components, along with which were re-used or recycled can be found on the budgeting sheet (see appendix).

XIII. Vertical Profiling Float

The floater design includes a stepper motor at the top of the floater. The stepper motor lets the syringe be either pulled up or down with the connected lead screw. When the syringe is pushed upwards, the water inside the syringe is pushed out of the floater, resulting in a positive buoyancy, and the floater floats. When the syringe is pulled downwards, the floater becomes negatively buoyant as it fills with water, and sinks. For the transmitter to stay at the top along with the stepper motor, a weight is inserted into the grey place in the figure.

The buoyancy engine is powered by a 9V alkaline battery. An Arduino Nano is used to control the stepper motor with a driver as well as to circulate the required data to the HC-12 transmitter. The software installed on the Nano consists of two sections. The first part controls the depth of the floater, while the second part modulates and transmits the required data. The Stepper motor is driven by A4988 driver. DS3231 RTC module integrates the Nano with adequate data. After the data is transmitted to the onboard Nano, with the given modulated data the Nano demodulates and creates the intended graph.

Figure 19: Floater Design

Testing and Trouble-Shooting

RC Makers prioritizes innovation and quality. The compact and modular chassis of the ROV is mainly 3D printed with tough PLA. After all of the prints, company members meticulously post-processed the product by removing the supports, sanding any dents, and using heat treatments. When the chassis was ready to test, company members assembled all the components such as the robot arm, tray table, and strain relief. Later in the testing process, all wirings of electronics were checked with a multimeter to ensure that there weren't any shortages. Then, the camera feed was checked and all the motors were powered up one by one to monitor any flaws. After safety protocols were met, the ROV was tested with the props and troubleshooting was done for the necessary flaws on mechanical, electronical, and software components.

Simulation

RCM Simulatus is an underwater robot which exists in a simulated universe, providing a working and training space for future pilots. RCM Simulatus, coded by Önder Karataş, is the first and currently the only example of its kind at the high school level. Developed using Unity, it works based on the rules of underwater physics and the real structure of the RCM Salutis. The simulation itself has an environment that consists of underwater drag. With realistic thruster configurations, the pilot can observe the effects of mission props including pitch and yaw fluctuations on the ROV. Other than the pilots getting initial training without entering the pool or even before the ROV is finished, RCM company has the chance to try out its artificial intelligence algorithms for the tasks that require autonomous appliances such as the photogrammetry task and creating a 3D model of a coral restoration area. With its unique approach, RCM achieved a multitasking simulation environment which saves time and increases the efficiency of the pilot and the algorithms.

Safety

I. Safety Rationale

Personnel safety is the top priority of Robert College Makers (RCM). We believe that any risk threatening the health of any living being can and must be avoided. Extending upon the MATE safety instructions, we have formed and followed strict safety protocols to ensure an environment in which the members can work without safety hazards. To establish the most appropriate safety protocols, precautions, and features for our workshop and ROV design, we collaborated closely with our advisors - who have extensive experience and knowledge regarding workshop safety. Each year, the protocols are brought up to date. Each new member goes through training regarding the safe use of devices and the necessary precautions to be taken before any manufacturing and testing. A senior member supervises their activity until they are deemed capable of managing materials and machines safely and independently. All members must prioritize safety by following protocol and reminding others of safety to uphold the highest standards in the workshop and poolside.

II. Safety Protocols, Precautions, and Features

Every member of RCM must wear the necessary safety equipment before engaging in any activity regarding the ROV. This includes safety glasses, gloves, closed-toe shoes, and other safety measures required to operate any device. Furthermore, Advisors and senior members of the team supervise safety protocols to ensure no accidents occur. Members must work with their hair tied, wear appropriate clothing, and have enough knowledge of the tools they handle. The devices in the workshop are checked regularly for any signs of malfunction.

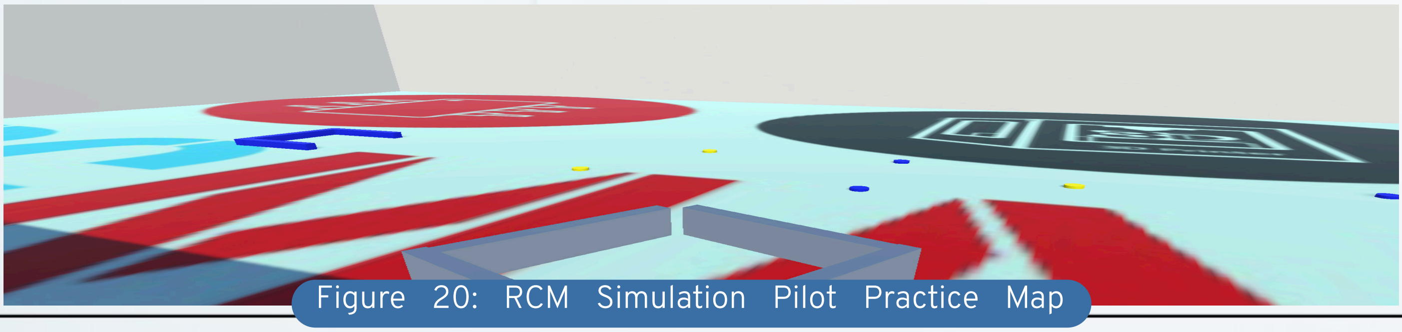


Figure 20: RCM Simulation Pilot Practice Map

Safety

During assembly, numerous safety measures were placed to minimize safety hazards during operation and testing. The cables were properly wrapped and labeled. 25A in-line fuse was also used to prevent overdrawing current and strain reliefs were placed on both the ROV and control station.

Every component was checked for signs of rust or weak points and changed to a stainless-steel counterpart. All the sharp edges are either eliminated from pre-production or sanded off. The electronics are placed in a watertight acrylic enclosure with double o-ring seals. The voltage was checked in each test. On top of the IP-20 thruster guards, warning labels were placed around the ROV informing of any necessary precautions.

When the ROV is operated, certain safety protocols are placed by RCM to ensure a safe process. It is determined that the team's priority after entering the pool area is that a dry and higher-than-ground level is established for the vehicle and power tools to be placed without risk of contact with water. All team members must wear the necessary safety equipment in the designated operations area regardless of an active test to prevent all kinds of accidents. The vacuum tube is checked to make sure it is sealed and electronic parts are at no risk of water contact.

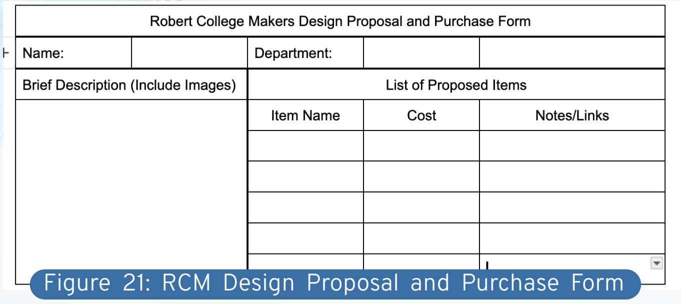
During operation, the team members communicate closely by announcing significant steps such as contact with water or the start of thrusters and always act according to the safety checklist (see appendix). This enables a smoother process with no errors due to miscommunication. Before being placed in the water, the function of the ROV's critical components is checked, and the vehicle is inspected for all visible damage. Upon contact with water, team members stand by for any signs of leaks or other malfunctions. If damage is detected, the ROV is quickly taken out and attended to. Members, no matter the size of the problem, never act out of panic. It is crucial that the determined safety procedures are followed entirely and with composure. Several drills were conducted during the manufacturing process to ensure that everyone is prepared for any case that might occur during testing or competition. Safety is a matter taken very seriously within RCM. All precautions regarding safety were placed and practiced before any operations were carried out.

Accounting

I. Budgetting

The team's income is based on funding from American Robert College of Istanbul. The workshop found inside the high school provides the team with a vast array of tools and resources like 3D printers, dremels, power drills. This allowed the team to operate with a relatively small budget.

Makers keep a rigorous inventory of all the tools, resources, and equipment found in the workshop. After reviewing the task requirements of MATE 2024 and the workshop inventory, team members submit design proposals and purchase requests. The CEO and mentors review the proposals and either approve or deny the request.



Robert College Makers Design Proposal and Purchase Form

Name:		Department:		
Brief Description (Include Images)		List of Proposed Items		
		Item Name	Cost	Notes/Links

Figure 21: RCM Design Proposal and Purchase Form

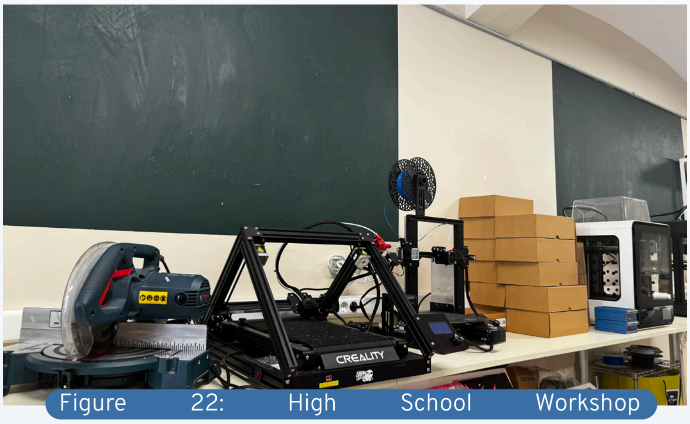


Figure 22: High School Workshop

Accounting

After reviewing the proposal forms, the CEO creates the budgetting sheet (see appendix) which determines the how this years income will be used.

II. Cost Accounting

After the money is budgetted the team orders parts, tools that are needed. Orders are written down in a sheet (see appendix) to accurately reflect the team's running balance which ensures the project is not going over budget. It also enables the team members to track their orders, as the sheet also has a status column.

Conclusion

Acknowledgments

We would like to extend our heartfelt gratitude to our school for providing us with the resources and support necessary for this project. We thank our friends who helped us throughout our journey. We are also deeply thankful to the Schmidth Foundation for their generous funding, which helped with the travel costs. DEGZ company for their discounts on underwater solutions products. Lastly, we express our sincere appreciation to our mentors for their helpful guidance and encouragement throughout this journey. Their dedication were instrumental in the successful completion of our project.

References

Blue Robotics. "Frame Configuration Advantages / Disadvantages." Blue Robotics Community Forums, 13 Aug. 2020, discuss.bluerobotics.com/t/frame-configuration-advantages-disadvantages/7968. Accessed 22 May 2024.

Safety Checklist

Before Powering:

☐ The deck area is neat and under control

☐ All team members are wearing glasses and the pit manager wears cut-resistant gloves.

☐ Inspect the tether and verify that it is freely able to move and is not damaged

☐ Tether is connected to the strain relief and secured to the ROV

☐ Cat6 output of the tether is connected and secured to the pilot's computer

☐ Verify the vacuum tube is sealed

☐ Visual inspection to check for damaged or loose connections

Powering Up:

☐ Ensure that the pilot's computer is on and running

☐ Co-pilot calls out, "Power On"

☐ Anderson output of tether is connected to the power supply and secured

☐ Vacuum check of the ROV(see Vacuum Control below)

☐ Co-pilot calls out, "Thruster Test"

☐ Pilot test thrusters and check that they are working properly

☐ Verify the video stream from the ROV's cameras

☐ Ensure the camera's angle is right

☐ The robot arm's rotation is set to 0 angles and close.

Vacuum Control:

☐ Verify the electronics tube is properly sealed by utilizing a vacuum pump

☐ Check the pressure after vacuuming the tube and see if it rises. If the pressure rises refer to leak detection.

ROV Launch:

☐ The pit manager calls out, "Hands On"

☐ Carefully place the ROV in the water

☐ Check for the bubbles

☐ Visually inspect to check if there is a water leak in the tube

☐ If there are large bubbles on the surface, recover the ROV immediately and proceed with Leak Detection

☐ If there are no issues detected, call out "Launching!"

☐ Pit manager calls out, "Hands Off"

☐ Co-pilot calls out, "Ready to Fly" and the pilot begins the mission plan.

ROV Retrieval:

☐ The pilot calls out, "Pit Stop"

☐ Pit manager calls out, "On the Surface, Disable"

☐ Co-pilot calls out, "Thrusters Off"

☐ Pit manager calls out, "Hands On" and removes the ROV from the water

☐ After securing the ROV, the pit manager calls out, "ROV Secured"

☐ According to the mission plan, the pit manager modifies the ROV. (see below Pit Stop Modify)

☐ If missions are ended, the co-pilot calls out, "Power Off" and powers down the system

☐ Team begins demobilizing

Leak Detection:

☐ Immediately power down the ROV and remove the ROV from the water if a mission is occurring

☐ Visually inspect the ROV to check if there is any source of leak Do not disassemble the ROV until the source of the leak is detected

☐ Use soapy water to verify the source of the leak

☐ Create a plan and fix the leak

☐ Check all systems for any damage and replace damaged electronics

☐ Log the source and the cause of the leak. Detail the possible corrective design changes made and the actions taken

Communication Lost:

☐ Check if the cat6 cable and the Anderson connector are still connected.

☐ Unplug the cat6 and replug it to reboot communications.

☐ If communication is restored, confirm there are no leaks and continue the mission

☐ If all else fails, power down the ROV, and retrieve via tether.

☐ Check the fuse. If blown, check for leaks and verify the integrit of waterproofed elements.

☐ Begin troubleshooting procedures and isolate the issue Investigate whether the problem is related to hardware or software

☐ Log the problem and the cause of the loss. Detail the possible corrective changes made and the actions taken

Pit Stop Modify:

☐ Pit manager calls out, "Modifying" and either switches the gripper tip or gives/ retrieves parkour items for the next missio

☐ Verify all the changes are secured and done

☐ Pit manager calls out, "Changes Done" and proceeds with ROV Launch

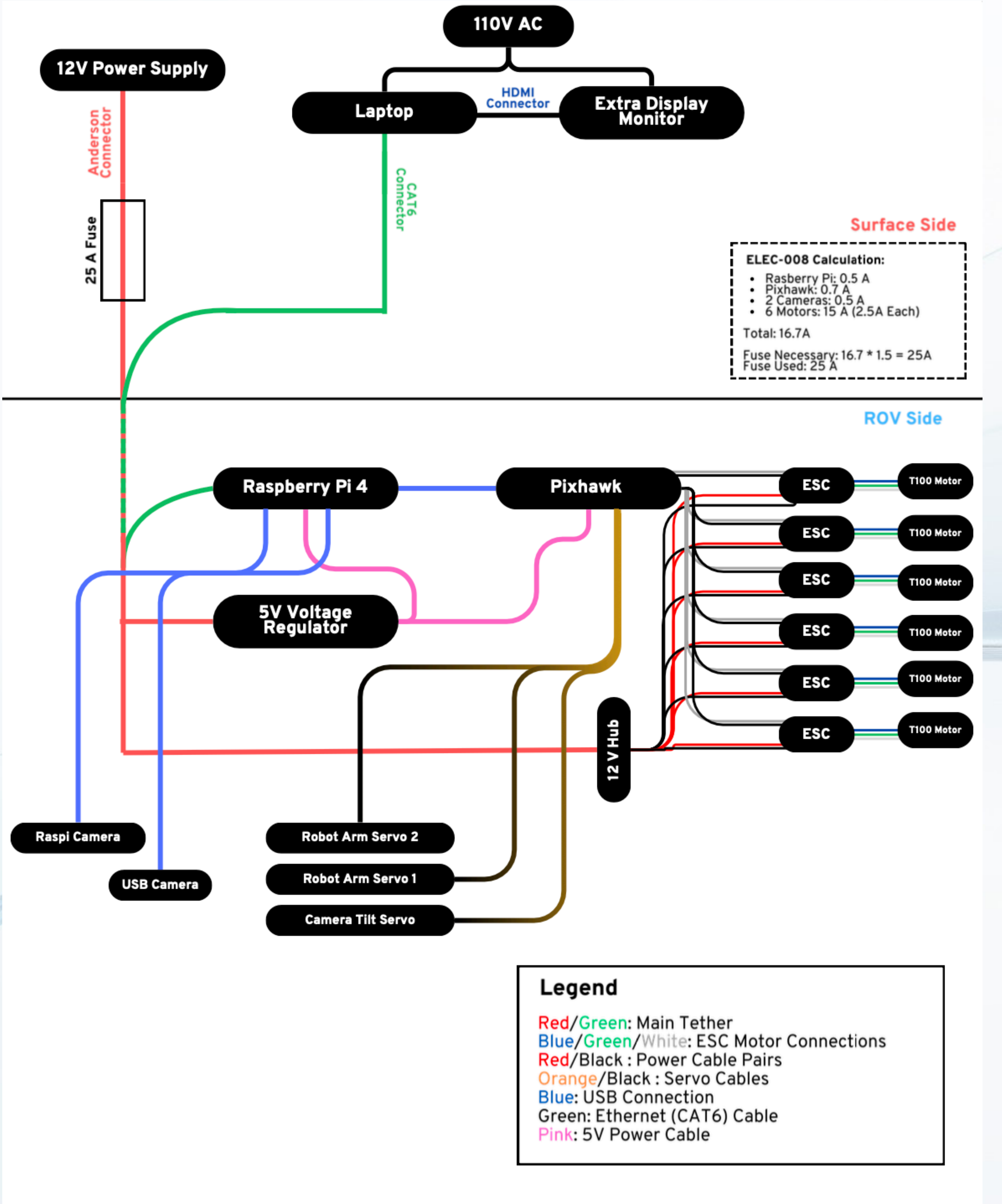
Pit Maintenance:

☐ Pit is neat and free of debris

☐ All equipments are safely stored in their designated space and there are no tripping hazards

☐ Check all electrical cords and correct any electrical hazards

ROV SID



ELEC-008 Calculation:

- Rasberry Pi: 0.5 A
- Pixhawk: 0.7 A
- 2 Cameras: 0.5 A
- 6 Motors: 15 A (2.5A Each)

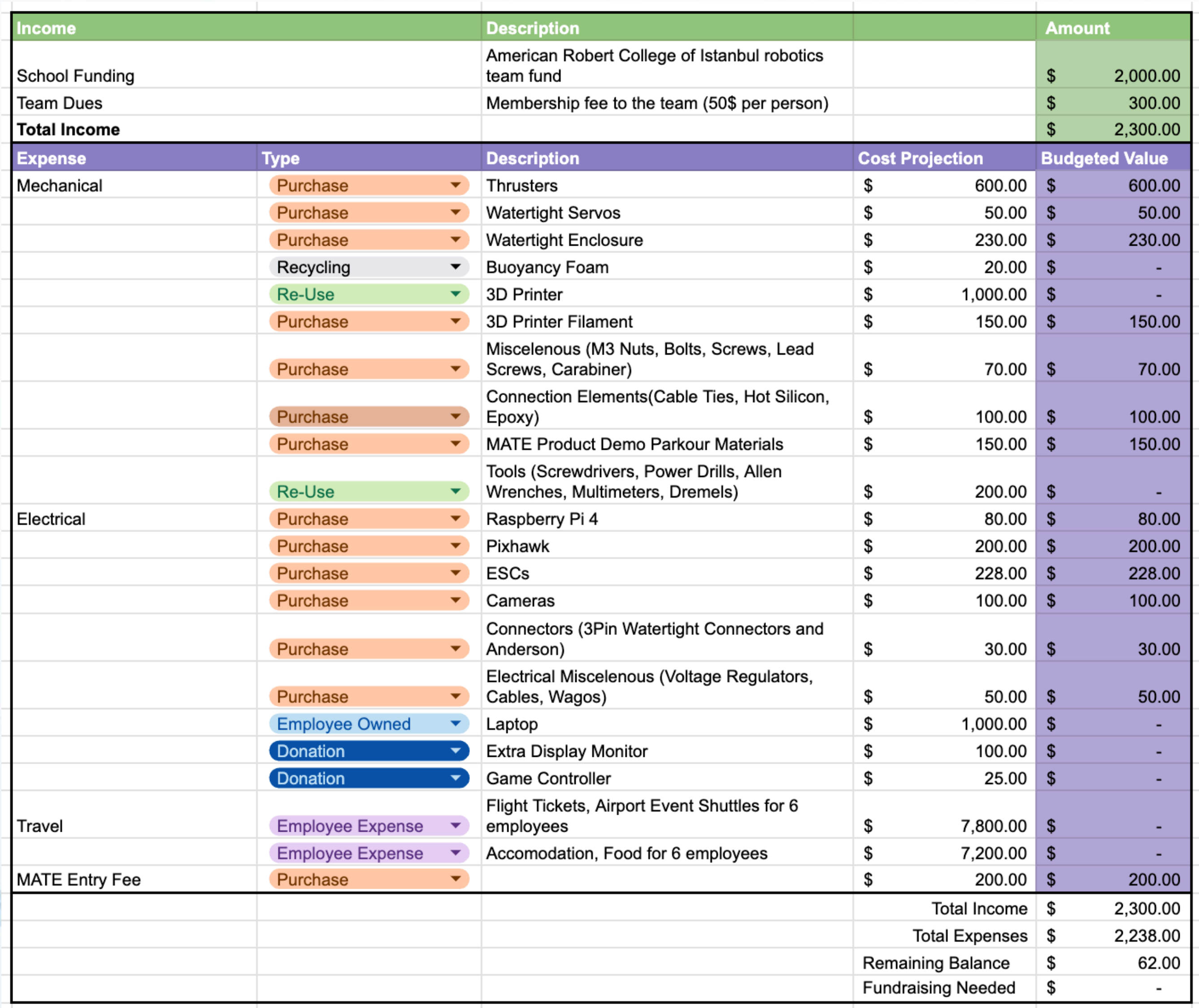
Total: 16.7A

Fuse Necessary: 16.7 * 1.5 = 25A
Fuse Used: 25 A

Legend

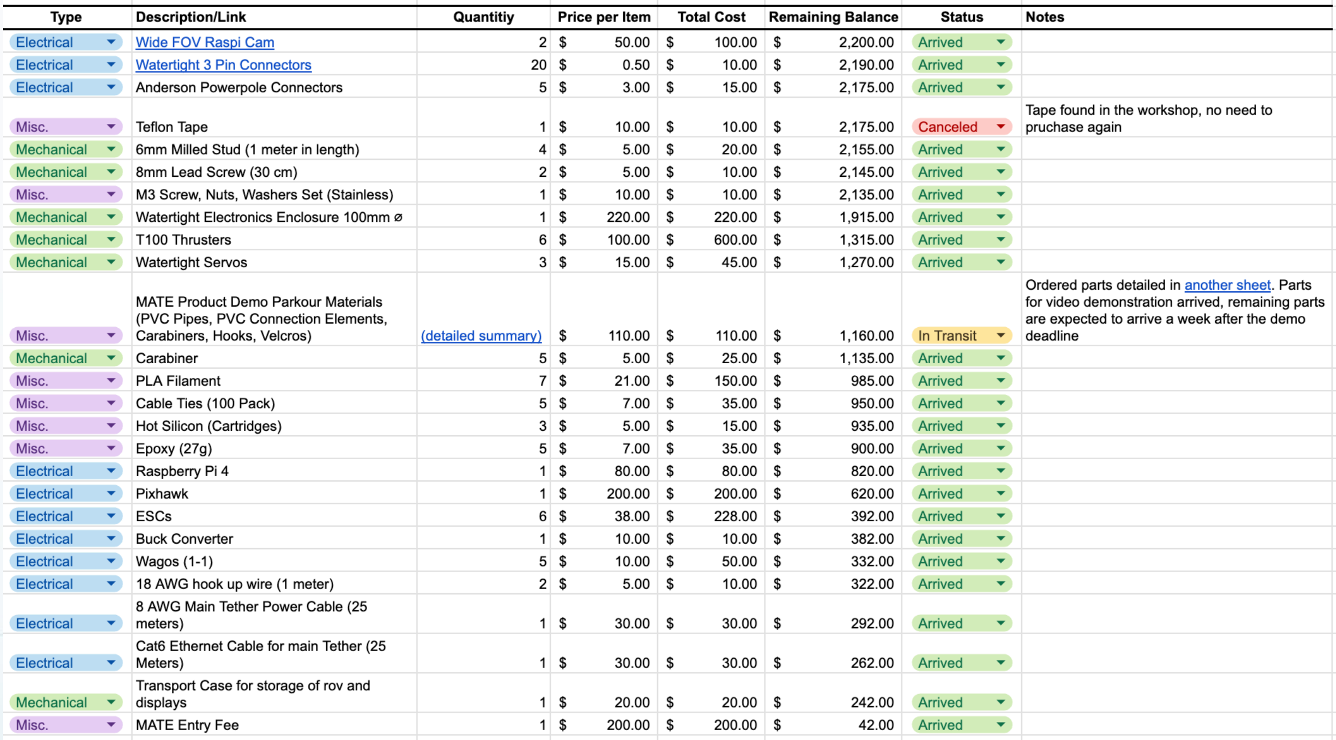
Red/Green: Main Tether
Blue/Green/White: ESC Motor Connections
Red/Black : Power Cable Pairs
Orange/Black : Servo Cables
Blue: USB Connection
Green: Ethernet (CAT6) Cable
Pink: 5V Power Cable

Budgetting Sheet



Income		Description		Amount
School Funding		American Robert College of Istanbul robotics team fund		$ 2,000.00
Team Dues		Membership fee to the team (50$ per person)		$ 300.00
Total Income				$ 2,300.00
Expense	**Type**	**Description**	**Cost Projection**	**Budgeted Value**
Mechanical	Purchase	Thrusters	$ 600.00	$ 600.00
	Purchase	Watertight Servos	$ 50.00	$ 50.00
	Purchase	Watertight Enclosure	$ 230.00	$ 230.00
	Recycling	Buoyancy Foam	$ 20.00	$ -
	Re-Use	3D Printer	$ 1,000.00	$ -
	Purchase	3D Printer Filament	$ 150.00	$ 150.00
	Purchase	Miscelenous (M3 Nuts, Bolts, Screws, Lead Screws, Carabiner)	$ 70.00	$ 70.00
	Purchase	Connection Elements(Cable Ties, Hot Silicon, Epoxy)	$ 100.00	$ 100.00
	Purchase	MATE Product Demo Parkour Materials	$ 150.00	$ 150.00
	Re-Use	Tools (Screwdrivers, Power Drills, Allen Wrenches, Multimeters, Dremels)	$ 200.00	$ -
Electrical	Purchase	Raspberry Pi 4	$ 80.00	$ 80.00
	Purchase	Pixhawk	$ 200.00	$ 200.00
	Purchase	ESCs	$ 228.00	$ 228.00
	Purchase	Cameras	$ 100.00	$ 100.00
	Purchase	Connectors (3Pin Watertight Connectors and Anderson)	$ 30.00	$ 30.00
	Purchase	Electrical Miscelenous (Voltage Regulators, Cables, Wagos)	$ 50.00	$ 50.00
	Employee Owned	Laptop	$ 1,000.00	$ -
	Donation	Extra Display Monitor	$ 100.00	$ -
	Donation	Game Controller	$ 25.00	$ -
Travel	Employee Expense	Flight Tickets, Airport Event Shuttles for 6 employees	$ 7,800.00	$ -
	Employee Expense	Accomodation, Food for 6 employees	$ 7,200.00	$ -
MATE Entry Fee	Purchase		$ 200.00	$ 200.00
			Total Income	$ 2,300.00
			Total Expenses	$ 2,238.00
			Remaining Balance	$ 62.00
			Fundraising Needed	$ -

Cost Accounting Sheet



Type	Description/Link	Quantitiy	Price per Item	Total Cost	Remaining Balance	Status	Notes
Electrical	Wide FOV Raspi Cam	2	$ 50.00	$ 100.00	$ 2,200.00	Arrived	
Electrical	Watertight 3 Pin Connectors	20	$ 0.50	$ 10.00	$ 2,190.00	Arrived	
Electrical	Anderson Powerpole Connectors	5	$ 3.00	$ 15.00	$ 2,175.00	Arrived	
Misc.	Teflon Tape	1	$ 10.00	$ 10.00	$ 2,175.00	Canceled	Tape found in the workshop, no need to pruchase again
Mechanical	6mm Milled Stud (1 meter in length)	4	$ 5.00	$ 20.00	$ 2,155.00	Arrived	
Mechanical	8mm Lead Screw (30 cm)	2	$ 5.00	$ 10.00	$ 2,145.00	Arrived	
Misc.	M3 Screw, Nuts, Washers Set (Stainless)	1	$ 10.00	$ 10.00	$ 2,135.00	Arrived	
Mechanical	Watertight Electronics Enclosure 100mm ⌀	1	$ 220.00	$ 220.00	$ 1,915.00	Arrived	
Mechanical	T100 Thrusters	6	$ 100.00	$ 600.00	$ 1,315.00	Arrived	
Mechanical	Watertight Servos	3	$ 15.00	$ 45.00	$ 1,270.00	Arrived	
Misc.	MATE Product Demo Parkour Materials (PVC Pipes, PVC Connection Elements, Carabiners, Hooks, Velcros)	(detailed summary)	$ 110.00	$ 110.00	$ 1,160.00	In Transit	Ordered parts detailed in another sheet. Parts for video demonstration arrived, remaining parts are expected to arrive a week after the demo deadline
Mechanical	Carabiner	5	$ 5.00	$ 25.00	$ 1,135.00	Arrived	
Misc.	PLA Filament	7	$ 21.00	$ 150.00	$ 985.00	Arrived	
Misc.	Cable Ties (100 Pack)	5	$ 7.00	$ 35.00	$ 950.00	Arrived	
Misc.	Hot Silicon (Cartridges)	3	$ 5.00	$ 15.00	$ 935.00	Arrived	
Misc.	Epoxy (27g)	5	$ 7.00	$ 35.00	$ 900.00	Arrived	
Electrical	Raspberry Pi 4	1	$ 80.00	$ 80.00	$ 820.00	Arrived	
Electrical	Pixhawk	1	$ 200.00	$ 200.00	$ 620.00	Arrived	
Electrical	ESCs	6	$ 38.00	$ 228.00	$ 392.00	Arrived	
Electrical	Buck Converter	1	$ 10.00	$ 10.00	$ 382.00	Arrived	
Electrical	Wagos (1-1)	5	$ 10.00	$ 50.00	$ 332.00	Arrived	
Electrical	18 AWG hook up wire (1 meter)	2	$ 5.00	$ 10.00	$ 322.00	Arrived	
Electrical	8 AWG Main Tether Power Cable (25 meters)	1	$ 30.00	$ 30.00	$ 292.00	Arrived	
Electrical	Cat6 Ethernet Cable for main Tether (25 Meters)	1	$ 30.00	$ 30.00	$ 262.00	Arrived	
Mechanical	Transport Case for storage of rov and displays	1	$ 20.00	$ 20.00	$ 242.00	Arrived	
Misc.	MATE Entry Fee	1	$ 200.00	$ 200.00	$ 42.00	Arrived	