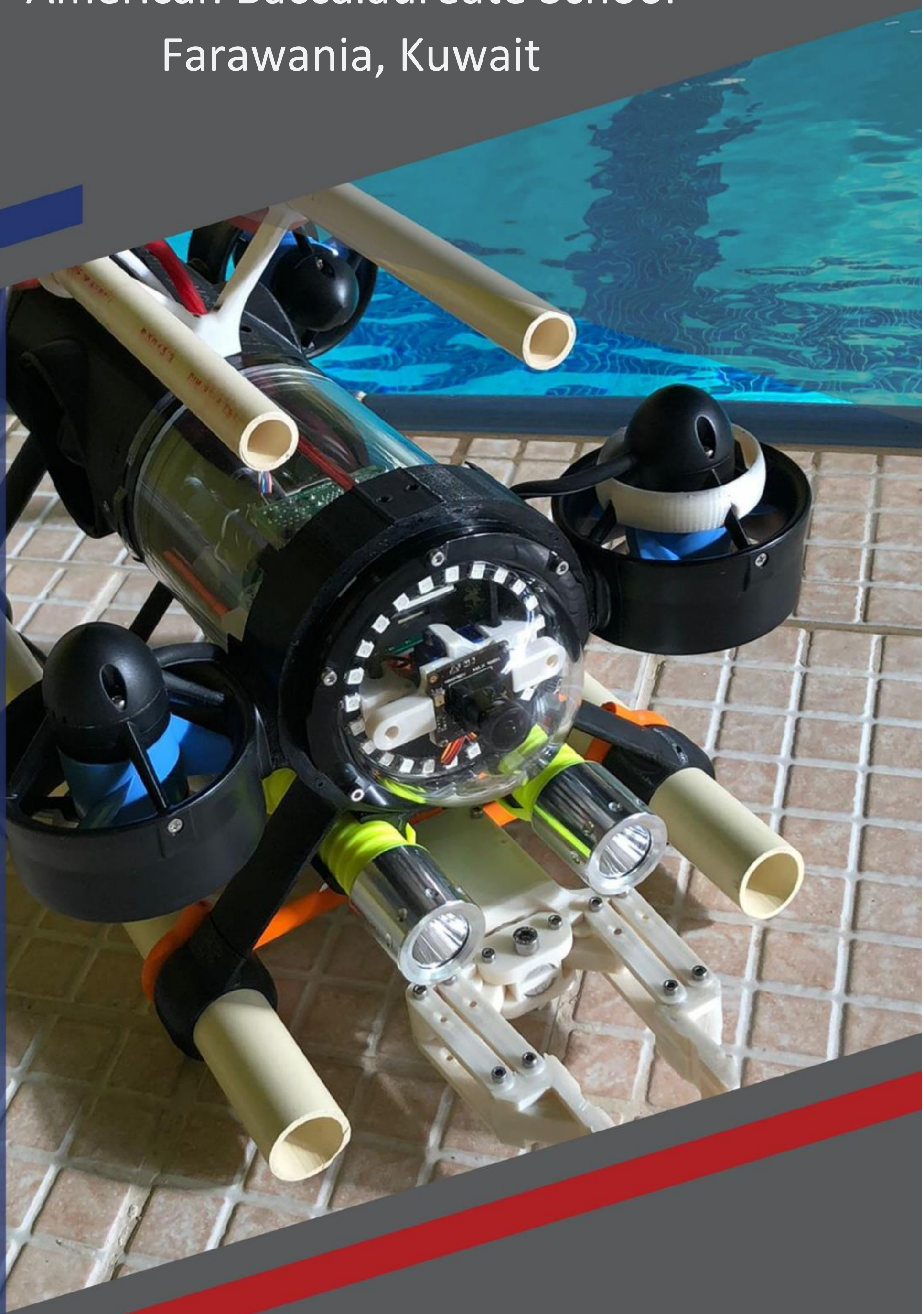
WILDCATS ENGINEERING

American Baccalaureate School
Farawania, Kuwait



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2022 MATE ROV COMPETITION
TECHNICAL DOCUMENTATION

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Abstract

The ABS Wildcats robotics team has worked tirelessly to produce what we have now considered being one of the most sophisticated ROV machines in the entire competition. Kuwait being a small coastal nation our understanding of the ocean is vast, and our sense of community is even vaster. Our team consists of the most talented workers our school has to offer each adding their own set of skills to this intricate machine. Consisting of a total of seven members our team is not as large as most, but our passion for machinery is just as fierce as the rest of the team. This being our first ever year entering the MATE ROV competition the pressure is on to ensure we bring the heat and bring the truth to all the promises we have made about our wondrous machine. We hope to exemplify all our arduous hours of work off in the competition. Using six rotors instead of the usual 8 our ROV can conserve as much energy as possible while also having full 6 degrees of motion sacrificing nothing for the conserved energy. That is just a taste of all the optimizations conducted throughout development. It is a true honor to be accepted into such a prestigious competition and we are excited to show the world what Kuwait is about!

(Word Counts: 226)

Figure 1- Wildcats Engineering Company Staff with Alboom ROV

Company Organization and Workflow

Project Management

Once Wildcats Engineering Co. decided to accept the challenge of participating in the new 2022 season for the first time, all employees have been given a training period conducted by the mentors to learn most of the required Engineering skills.

As a result of the onboarding process, significant developments were observed in the three sub-departments: mechanical, electrical, and software. To make use of project management and agile mythology, these departments planned, evaluated, and assessed an organized schedule based on the project management and agile theories.

Several selection phases were conducted by HR for each team member to measure their creativity, enthusiasm, team spirit, diligence, and academic credentials. Our company's organizational chart below provides a detailed view of how distinct parts of the company are managed.

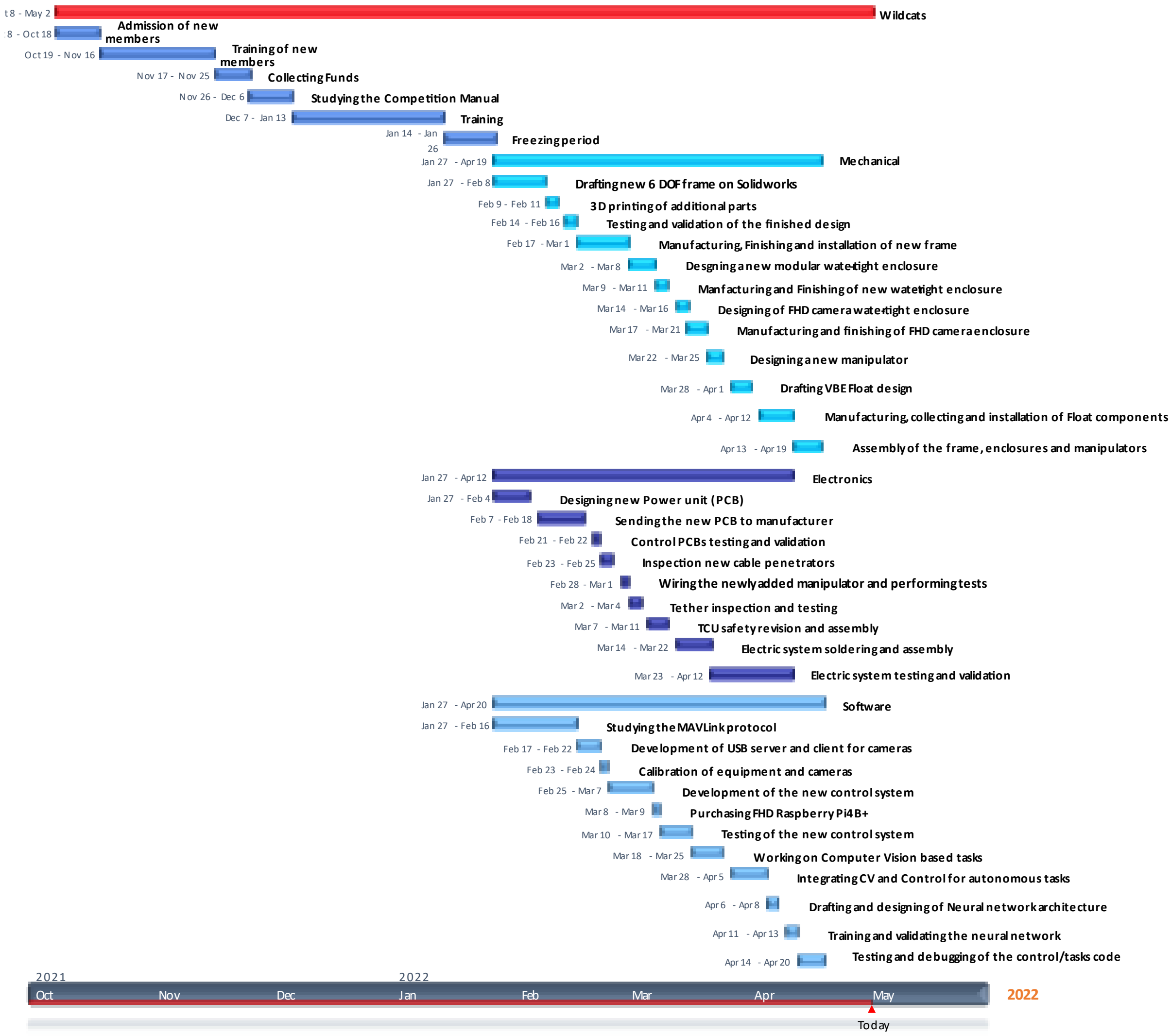

Figure 2 - Gant chart and workflow

Company Organization

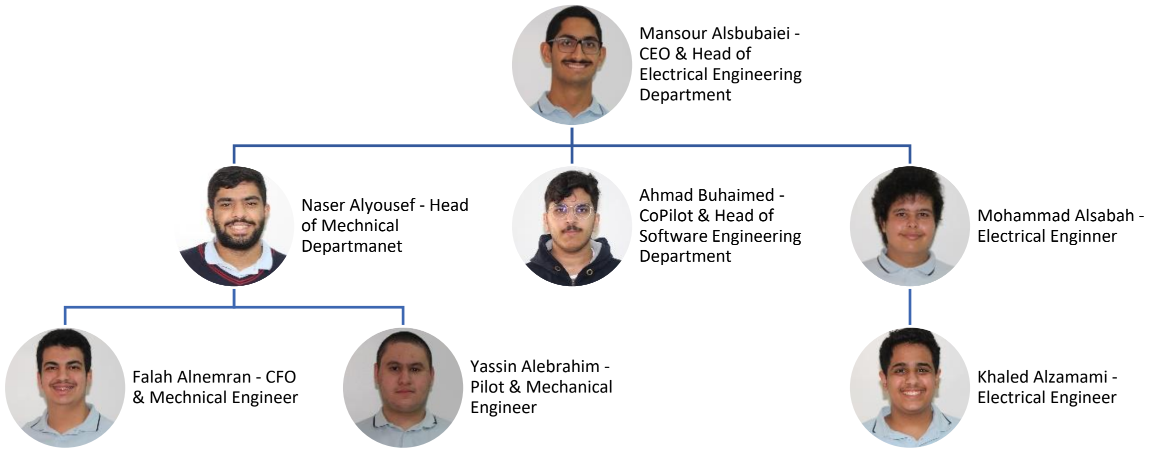

Figure 3 - Wildcats Engineering Hierarchy

Design Rationale

Design Evolution

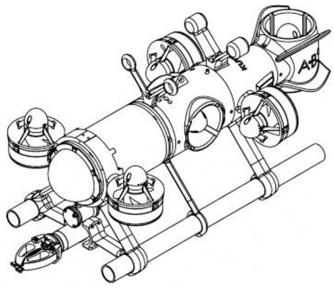

Figure 4 - Alboom's Contour Render

The mechanical design team had obligation to produce a high-end design that lives up to our company's expectations. First, the team had to study the past years' documentation of MATE World Championship qualified teams. Then, a technical learning/training phase ensued to focus on revising the physics and theories related to our product. After that, we followed a period of brainstorming and group discussions to reach the optimum design concept that solves last year's problems and achieves our goals with the available resources.

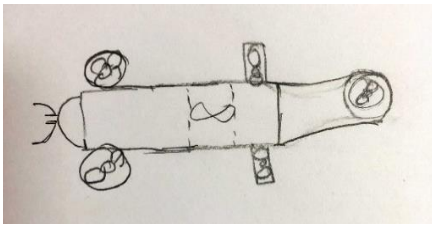

Figure 5 - One of Alboom's draft sketch during the brainstorming sections

Alboom is the result of the accumulated challenging work and dedication of our Research and Development (R&D) team. It is specifically designed to answer the need of MATE's proposal.

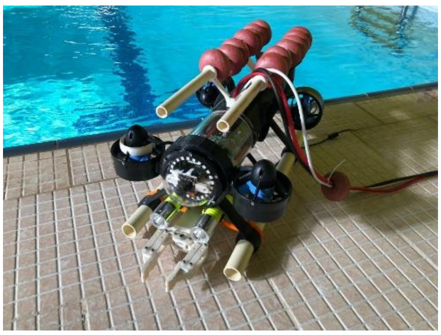

Figure 6 - Alboom Underwater Vehicle

Our goal is to design an ROV that could be perfect all-around and not just for the missions ahead with room for adding more payloads and features. Therefore, Alboom includes our company's original designs for some key components –such as attachment points and a frame which are to be broken down in the following sections in detail.

Mechanical Drafting Phase

Frame

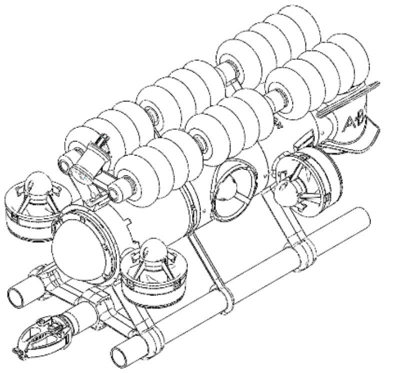

Figure 7 - Alboom Final Design

The frame was designed using SolidWorks®, a CAD program with a limitless toolkit that allowed us to build our ROV with complete freedom. We properly accounted for all the components required for the frame's construction and assembly using this software before purchasing materials that would otherwise go to waste. SolidWorks has proven to be a valuable resource in our efforts to create efficient and streamlined d designs for a variety of applications.

Figure 8 - Alboom Exploded View

Alboom's frame is made of five main 3D printed parts: Three cylindrical parts connected to the main electrical housing, and two parts for attaching the skeds and the payloads attachments points like a gripper, etc.

Propulsion

The team decided to utilize six thrusters for better control and stability. Moreover, it allows flawless maneuvering. Therefore, the T200 thruster was the optimal choice to fulfill the above characteristics. Alboom utilizes the Differential Thrust System arrangement, which comprises three vertical mounted thrusters. And three thrusters horizontal mounted with one of them perpendicular to the vehicle body. Giving Alboom the freedom of navigation in three dimensions (Lateral, Vertical, Horizontal, Roll, Pitch, Yaw).

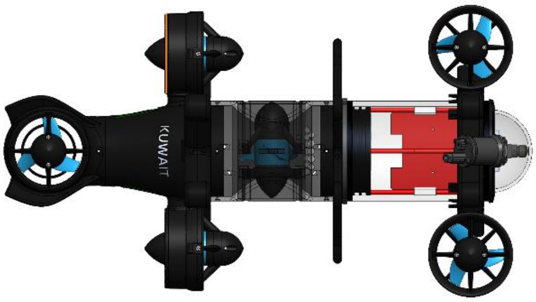

Figure 9 - Alboom Thrusters Layout

This range of motion was achieved by adjusting the speed of each motor until the net thrust generated by all six thrusters produces the desired motion. That is, maximum thrust on all motors will move the ROV in a cardinal direction; however, using a variety of motor speeds allow the user to operate the ROV in a variety of translational, rotational movements and velocities.

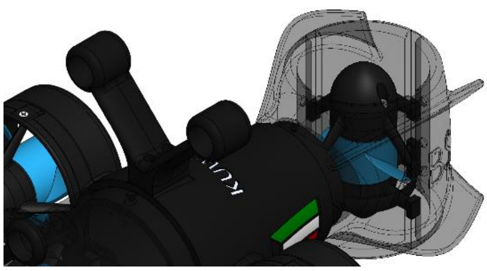

Figure 10 - Alboom's Tail Thruster Housing

Buoyancy

Alboom, along with its components and tether, has a maximum displacement of 1.5x10 cm3 it has two main buoyancy components: electronics housings and synthetic foam. At over 4.5x10cm3 the two electronics housings are Alboom's largest displacement component and serve as the main floatation devices. As it is seen in the spreadsheet Alboom is inherently negatively buoyant, meaning the ROV has a slight tendency to sink downwards at a very slow rate. A spreadsheet was made to record the displacements and densities of each part of the ROV. Following Archimedes' Principle, this data was used to calculate Alboom's weight in water.

Component	Quantity	Material	Mass (KG) in Air	Volume (Cubic Meter)	Density (KG/M^3)	Total Buoyant Force (N)	Mass of Displaced Fluid (KG)
Frame Assembly	6	PETG	8	0.0041	970	-40.21	4.1
Power Electronics Enclosure	1	Acrylic	1.2	0.00031	1720	10.1	0.31
Control Electronics Enclosure	1	Acrylic	0.8	0.0015	1720	14.7	1.5
Main Gripper	1	HDPE	1.3	0.0006	970	-5.8	0.6
T200-Thrusters	8	Mix	2.75	N/A	N/A	-8.1	N/A
Camera Housing	3	Acrylic	0.9	0.0005	970	2.4	0.2
Tether	1	Mix	3.6	0.00362	N/A	0.09	N/A
Buoyancy Foam	N/A	Polyurethane	N/A	0.04	50	35.1	N/A
Total	N/A	N/A	**19.25**	**0.01153**	N/A	**-0.54**	**7.61**

Table 1 - Buoyancy Sheet

Electrical System

Our mentors arranged a Zoom® meeting with the experienced MATE ROV team from Egypt **Abydos**. Their electrical team advised us to use PCB for power distribution, so we considered the idea and designed and built our PDB (Power Distribution Board) PCB using EasyEDA an online PCB designing tool that allows collaboration between the electrical team members over the cloud.

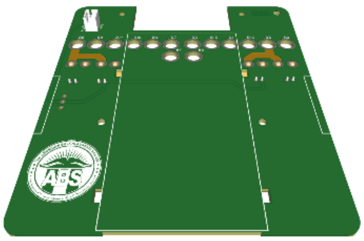

Figure 11 - Wildcats Engineering PDB PCB

The use of the PDB reduced the number of wires needed to power the different electrical components inside the electrical enclosure and let us avoid any kind of rats nest and facilitate the troubleshooting if any problem arise.

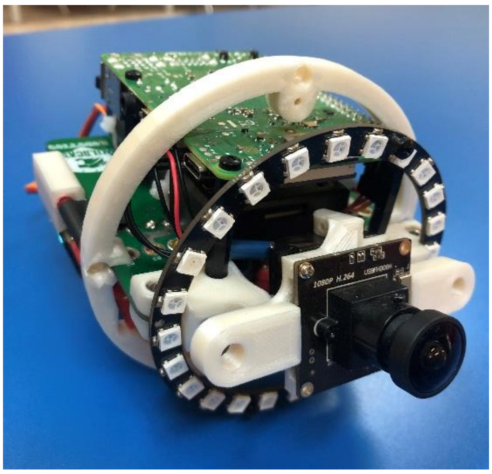

Figure 13 - Alboom Control Module

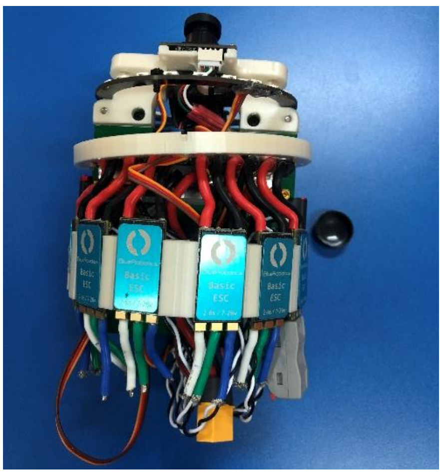

Figure 12 - Alboom Control Module Bottom View

Control Station

After reviewing other competitors from previous years' product demonstration and how much it takes them to set up their Control Station, Wildcats Engineering decided to take the fastest route which was to use an AIO laptop to be our main screen while running the ROV software. This approach lets our station crew deploy and clear the product demonstration area in under 2 minutes.

Control System

Our Control system uses Raspberry Pi4B+ which handles all the communication between the vehicle and the control station laptop. The choice of this SBC came after comparing different models and manufacturers and the final decision was taken based on the capability, size, and cost of the SBC.

The second main component in Alboom's control system is a Pixhawk flight controller that supports a wide array of sensors and actuators, it has a 64-bit ARM Cortex M4 core with FPU, which makes it ideal when it comes to real-time and delays intolerant operations. It also includes an MPU6000 as the primary accelerometer and gyroscope, ST Micro 16-bit gyroscope (a strap-down gyro), and MEAS internal barometer.

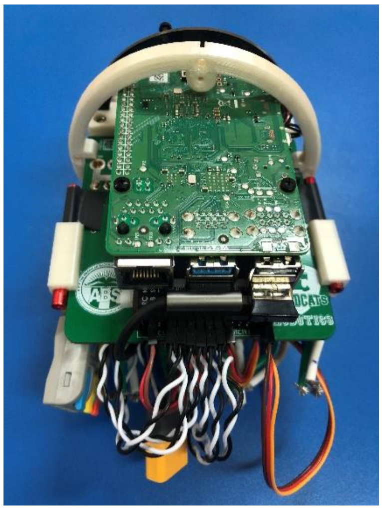

Figure 15 - Alboom Control System

Tether

Alboom tether construction philosophy was to build a tether with minimum resistance to the vehicle that can use the maximum amount of energy that can be delivered from MATE PSU within the requirement with minimum power losses along the tether, thus we settled on using 4 AWG made from OFC with a maximum number of strands to the tether can be flexible yet able to carry a huge amount of electrical current. Along the power cable, the tether also contains a CAT6E cable to carry the data stream from and to the vehicle.

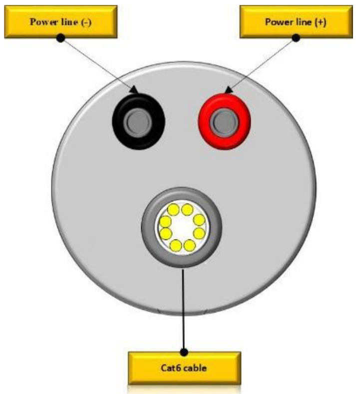

Figure 16 - Alboom Tether Construction

Sensor Fusion

IMU measures the change of kinematic energy of a moving body. The sensors are divided into two groups: gyro sensors and accelerometers. The gyro sensor gives the rotation rate of the body. The accelerometer provides information about the linear acceleration of the body. The first one is a classical gyroscope, which preserves the same (initial) position, remaining independent of body movement. The real orientation of the body is measured as a difference between gyroscopes axes' orientation and the present orientation of the body (its roll, pitch, and yaw). The second one, also called a strap-down gyro sensor, is fixed tightly on the body and provides a measurement of the rate of rotation of the body. After data acquisition, all these signals are time-stamped, fused, and processed to keep Alboom in a stabilized mode. Further tests proved that whatever power is acting on any side of Alboom it will keep its horizontal/vertical orientation. This greatly boosts Alboom's ability to maneuver, scan and map, and move with absolute precision.

Software

This year, we decided to improve the architecture of our control system that would make the most of the strengths available in the current technology to aid the pilot in performing missions efficiently. In addition, the control system is possible to quickly debug or add extensions to facilitate new requirements or ideas. Besides, Alboom's software categorizes into the bottom-side and top-side software. Firstly, the topside is concerned with all aspects of data science, machine learning, and the estimated width. The topside software runs on the pilot's laptop, is written in python, and uses PyQt5 for the GUI. Secondly, the bottom side is the main code to operate and runs on the Raspberry Pi4 housed on the control board.

Bottom-side

Bottom-side communication method works as follows: we utilize a serial connection between the Raspberry Pi4 and the Pixhawk, then we use USB virtualization over ethernet to interact with the Pixhawk as if it were linked to the topside via serial connection. As a result, we may control Alboom through serial connection using the Pymavlink protocol. Pymavlink is a Python version of the MAVlink protocol for use with Pixhawk sensors. Pixhawk has two gyro sensors, the first of which records the original position and the second of which measures the current location based on its roll, pitch, and yaw; we developed a stabilization mode for Alboom using the given data. Using accelerometer sensors and Pymavlink, we were capable of translating inputs from the joystick to modify Alboom's speed and using Pymavlink to convert signals given by the joystick into movement. Finally, we utilized General-Purpose.

Topside

The Top-side Control Unit (TCU) controls all ROV functions through a Graphical User Interface (GUI), which can display a live camera stream, connect to the PS4 controller, and communicate with the ROV. The GUI is highly customizable, with the ability to develop and run on all operating systems. The TCU consists of two software programs that use PyQt5. The first software runs on the pilot's laptop during navigation, and the second software process all the required tasks. PyBoom used YOLO (You Only Look Once) algorithm that detects and recognizes various objects in real-time. Its speed, high accuracy, and learning capabilities are what it takes to get the best results from any dataset. Inspired by the Google Net architecture, YOLO's architecture has 24 convolutional layers with two fully connected layers at the end, which means that prediction in the entire image is done in a single algorithm run. The CNN (Figure 18) is used to predict various class probabilities and bounding boxes simultaneously. This algorithm is used to detect various types of animals in forests. Wildlife rangers and journalists use this type of detection

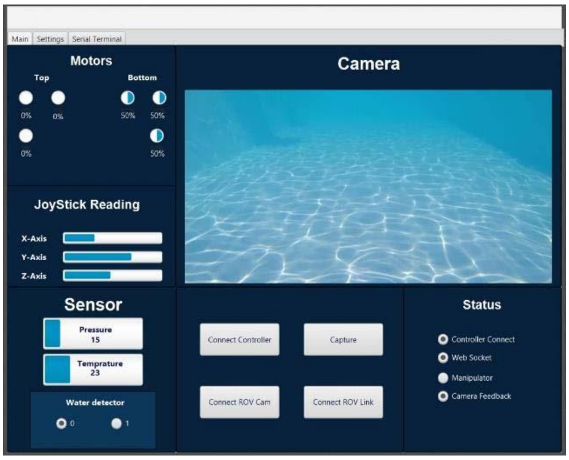

Figure 17 - PyBoom GUI

to identify animals in videos (both recorded and real-time) and images. Some of the animals that can be detected include giraffes, elephants, and fish. Furthermore, PyBoom used OpenCV (Open-Source Computer Vision Library), an open-source computer vision and machine learning software library. It is a process by which we can understand the images and videos, how they are stored, and how the computer can manipulate and retrieve data from them. Computer Vision is mainly used for Artificial Intelligence and object detection, as shown in the following tasks.

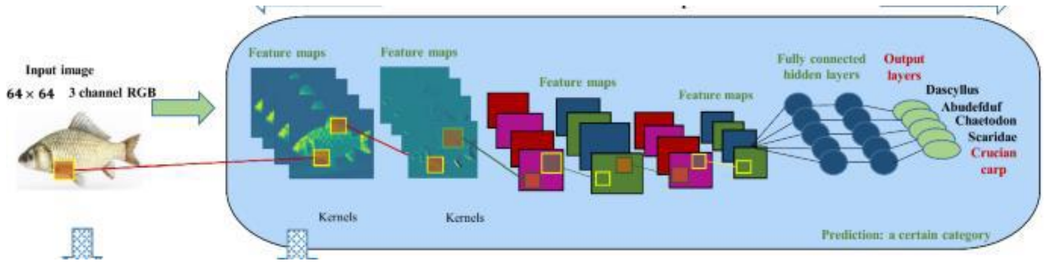

Figure 18 - CNN Architecture

Software Developed for Tasks

- *Using AI to Differentiate "Morts" from Live Fish*

Aquaculture contributes significantly to the world food supply. It will continue to do so, which is essential for "food security." inspecting offshore aquaculture cages and ensuring a healthy habitat for fish and the adjacent ocean community. We used YOLO (You Only Look Once) algorithm to remove fish mortalities, which detects and recognizes various objects in real-time. Its speed, high accuracy, and learning capabilities are what it takes to get the best results from any dataset. Yolov5 is considered the leader in real-time object detection because it is faster as it outputs 140 frames per second (FPS), speed inference, and better mAP.

Figure 19 - Morts fish using Yolo v5

First, we gathered our dataset from the videos uploaded by MATE and extracted about 9000 frames for the data preparation. However, after deletion for the frames that do not contain mort fishes, the output was about 3700 frames. Then, we annotated all the frames, scaled them, and split them into three sets: Training 70%, Validation 20%, and Testing 10%. In addition, preprocessing the dataset by applying image transformation decreases training time and increases performance.

Finally, training our dataset for recognizing and detecting mort fishes perfectly, and the training evaluation (Figure 19) to reflect the training outcome.

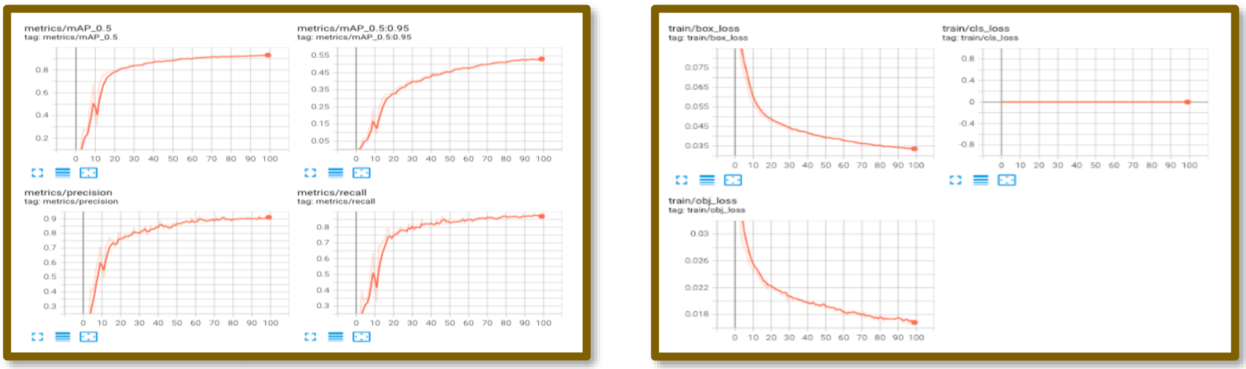

Figure 20 - Evaluation Matrices

- *Flying a transect line to identify the damaged area*

To autonomously fly the transect line, we start by detecting the red lines; the Zed camera is used to live stream the captured grid for perfect line following. Next, the captured images are masked in four specific Regions of Interest. The mask hides everything in the image except for the red lines. This happens after the acquired frames are enhanced using General Adversarial Network (GAN), specifically designed to enhance, correct, and sharpen underwater captured images. They were used because they proved their robustness under various lighting conditions. Finally, after the red lines are detected, we use Stereo Lab's Zed camera positional tracking feature to localize Alboom's position relative to the detected lines (Figure 21) for supreme navigation accuracy.

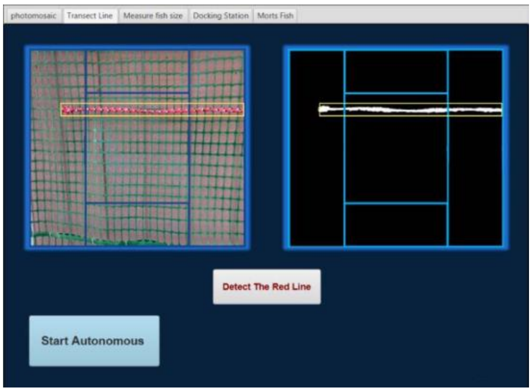

Figure 21 - Detecting transect line

- *Creating a Photomosaic of the Endurance Wreckage*

The main theme of making a photomosaic is based on taking eight photos of the seabed to compare the damaged wreckage every year. Our Alboom software system generates the photomosaic of the wreck using several libraries, starting with "PyAutoGUI", which is a Python automation library used to drag, scroll, click, move, etc., using the wxpython Mouse Event that tells the position associated with a mouse event it is used to take screenshots of every rectangle and transfer them to the processing computer. Finally, the role of the OpenCV library is to stitch all the images together autonomously using the GLOB library that returns all file paths that match a specific pattern used in stitching in photomosaic, draws contours to the brown wreck, and determines their positions to help in detecting the wreck position.

- *Piloting into Resident ROV Docking Station*

After finishing the tasks, Alboom is programmed to auto-pilot itself to a docking station. To navigate the station, Alboom utilizes the FHD camera to detect the PVC station and the Red Marker on the station’s frame. Then, focusing on Marker Pixel coordinates (X, Y, W, H), we transform these coordinates into real-world coordinates localizing Alboom’s position in perspective to the docking station. After Alboom localizes its position using the SLAM algorithm, the algorithm generates movement commands to be transferred to the Pixhawk to move Alboom to the docking area.

Payloads and Tools

Manipulator

Our Mechanical engineers thought that it would be extremely beneficial if we had a rotating gripper setup on Alboom due to this year's multiple picking and precise placement missions and tasks. Our new setup is comprised of a primary manipulator (Figure 22) is made of high-grade, lightweight 3D printed parts with an impressive jaw width opening of 8 centimeters, controlling of the jaws is a Linear Actuator to control the main gripper.

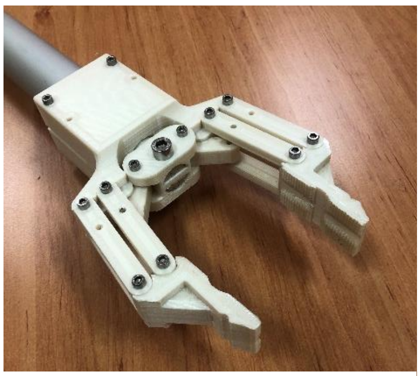
Figure 22 - Wildcats Gripper

Vertical Profiling Float

At Wildcats Engineering., we heard MATE's RFP for building a vertical profiling float capable of doing multiple profiles. Our approach differs from the traditional buoyancy engine that moves oil from a reservoir inside the float to an external bladder that displaces water, changing the total float's buoyancy. Instead, we use a dual DC Servo pump (Figure 23) system that is open and only utilizes water around the float, and in the following short paragraphs, we will dive deeper into how it works. We utilize two high-pressure DC diaphragm servo pumps to move water surrounding the float into an internal tank; the float's buoyancy is positive by default. After collecting a specific amount of water, the vertical float begins to sink slowly. To bring it back up, another pump pushes water from the internal reservoir to outside the float. Again, changing its buoyancy to return to its normal state of positively buoyant and slowly ascends from the depths. For batteries, we are using a standard array of Triple-A alkaline batteries neatly put in a special enclosure that is designed to open if the inside pressure increases dramatically and uses a pressure relief valve to relieve any built-up pressure inside the housing.

Figure 23 - Vertical Float

Testing and Troubleshooting

Software

During the construction and development of Alboom, Wildcats Engineering members started following two main processes: testing to find if there are any bugs or errors and debugging to correct the bugs found during testing. Every sub-team started following these steps differently. **To** avoid excessive time spent on debugging Alboom's software, it's better to follow well-organized and straightforward steps of testing as follows:

Checking correctness and tracing: Checking codes by examining them using the logical methods of correctness proofs. For example, by knowing the preconditions, invariants, and terminating conditions for the docking task's loop we were able to make some checks like checking whether the precondition and the loop entry code imply that the invariant is initially true or not and does the loop body preserve the invariant or not, this stage also often gets errors detected while tracing through the execution. Even if these checks do not find all errors, it helps gain a better understanding of the algorithms.

Peer reviews: After finishing the previous steps, it's very effective to have a peer examining the code for errors. The code writer should present the code with explanations of how it correctly implements the algorithms, and if the reviewer disagrees with part of the implementation, they must discuss it until both agree. The reviewer's role is only as an aid to detect errors and does not have the right to correct them.

Electronics

The mainboards have several diagnostic LEDs, each of which displays system status. The green LED represents every module is ready and the ROV is ready for launch. Whichever yellow LED comes on, it represents the ROV is ready for launch with limited functionality. If red, there's a critical failure in a subsystem, so don't launch the ROV.

Mechanical Testing

To ensure that it is isolated, two stages of confirmation should be completed. As a first step, a vacuum pump is inserted through the M10 Enclosure Vent and plugged to test the pressure inside the tubes. After 60 minutes of emptying the air from the tube, if the pressure is stable, the tube is perfectly isolated. Second, the ROV is submerged for ten, twenty, and thirty minutes and the enclosures are inspected for leaks and water.

Figure 24 - Vacuum Pump & Vent Plug

To ensure the 6 degrees of freedom are maintained, the thrusters and their directions are checked in a dry test. The grippers are also tested and measured in dry conditions to determine the stresses and the diameter they can withstand.

Buoyancy Test

Following the release of Alboom into the water, a few steps are followed to check buoyancy. Once it is determined that Alboom is inclined, the ballast should be added to achieve maximum stability and then check whether it has sunk due to excess weight. Several bouncy foams would be necessary for this scenario.

Challenges

Mechanical:

- As a result of the pandemic, there was a massive supply shortfall, affecting the provision of various materials and forcing alternate designs and techniques.
- There was a shortage of epoxy which led to a waterproofing problem, and then we went for alternatives.

Electronics:

- While raising the speed of thrusters, Alboom Raspberry PI4 disconnected immediately due to BMF because the PSU reset itself. We added a large Capacitor to compensate for the50ms duration of the power loss and prevent the Raspberry Pi4 from Restarting.

Software:

- Implementing an AI model was new to all of us, we implemented YOLO to detect dead fish, but the installation was a little bit tricky, and the pre-processing step was quite arduous especially annotation, so we created our neural network that makes annotations automatically.

- Our team had difficulty extracting the width without calculating the distance aspect ratio; however, it was solved by clicking on a point and saving it to a point cloud.

Non-technical:

- As a result of the COVID-19 and shelter-in-place restrictions, Wildcats Engineering was not able to use its meeting space, which resulted in cancellations and delays of scheduled work. In this situation, finding a way to work remotely to continue design and development work efficiently and effectively was the greatest challenge.
- Furthermore, implementing new technologies and manufacturing processes required extra training and testing hours.

Lessons Learned

- We have collaborated with each employee's sub-team and learned valuable technical skills from them. Most of these skills were learned from the training sessions conducted by the mentors. Mechanical workshops include presentations on SolidWorks® and manufacturing programs, among other CAD/CAM programs.
- On the electrical side, the Department of Electrical Engineering conducted workshops on EasyEDA, Soldering, and Embedded C. On the software side, the Department of Software Engineering conducted workshops on machine learning, deep learning, and control.
- Peer-to-peer engagement is critical for good team interaction, as Wildcats Engineering understands. Also, one of the most significant lessons we learned as a company this year is that you can be invincible if you have passion, major compromise, and effort for what you do.

Future Improvements

As a firm that promotes the development of high-impact technology with a high reputation, we believe that improvement is critical, thus we will endeavor to do more in this area next year:

- We would like to employ fiber-optic cable to transmit video and control signals
- Given enough budget and laborious abilities to build a carbon fiber or fiberglass frame because of their heavy-duty nature and lightweight.
- A larger budget will be allocated to the electronics section to engage in a training program to build our electronics.
- Conducting VR system to the pilot as we were not able to conduct it this year.
- A mechanical scanning imaging sonar is known as a lidar scanning sonar. It's primarily intended for use on the BlueROV2 and other ROVs for low-visibility water navigation. Inspection, obstacle avoidance, target finding, tracking, and the development of autonomous systems are all possible uses.
- Improve the arm's perception of rotation such that the gripper can rotate.

Safety

Philosophy

MATE's primary purpose is safety. We take safety extremely seriously at Wildcats Engineering Company, and we work hard to keep our employees safe, protected, and pleased so that they may manufacture high-quality goods and master their trades without fear of exploring higher technological depths within their skill ranges. Our business guarantees that the Job Safety Analysis (JSA) is followed in the launch, recovery, operation, and waterside safety of Alboom before and after it is deployed underwater.

Lab Protocol

Wildcats Engineering is concerned about its employees' safety. As a result, job-specific personal protection equipment such as glasses, gloves, goggles, masks, and earplugs are necessary, as well as an emergency eyewash, fire extinguisher, and first aid kit in the workplace. All worksites were outfitted with caution signs and stickers. Furthermore, experienced team members followed the workshop norms without missing a beat. Electrical professionals also try to identify and prevent hazards by implementing proper controls.

Safety Features

The body fillets were designed to avoid sharp edges, and all bolts and connectors were properly covered to prevent any problems with the electronics underwater. The thrusters in Alboom were all shrouded by surrounding each propeller with a T200 nozzle and using a thruster guard that completely encircles the propeller and has a sized ring that meets the IP-20 standards, which equates to a mesh size of >12.5mm. All the electronics in Alboom were waterproofed by placing them inside a tube made of acrylic, a non-conducting material capable of withstanding pressure to a depth of 8 meters. Cables were connected to the control tube via the end cap's rubber O-ring to provide strain relief, prevent cable breakage, and seal the control tube to prevent water leakage, The vehicle can be carried by its tether to prevent it from slipping or losing control, and everything is securely fastened to protect fragile or coated materials during preparation and achieve perfect edge retention.

As for the electrical safety, a water detection sensor module is introduced interior of the tube, which would caution the pilot to close down the framework in the case of occurrence of any water leakage, and a temperature sensor for getting a consistent perusing of the temperature inside and remotely, a gyro and accelerometer to recognize whether Alboom is out of balance, and continually alter its level under-water, a compass to play down the deviation as much as conceivable, a humidity sensor to measure the condensation inside the Acrylic tube and notify the pilot when it reaches a critical level so that they can decide their course of action accordingly and a current regulator to supply all the LEDs in Alboom with a constant current supply and prevent any sudden current changes that may lead to any malfunction or hazardous damage.

Acknowledgments

This is the first year that Wildcats Engineering would enter the MATE ROV, and a haze of uncertainty surrounds our capability. This being so it would be understandable if those we asked to back us were to be hesitant to invest a large sum into our endeavors, yet despite that our company has been blessed to have such a supportive foundation behind us that has allowed us to operate with complete financial and logistical freedom. We are first and foremost truly grateful for all the support we received from American Baccalaureate Schools by funding our company's new vehicle Alboom and supporting us all the time and supplying us with their facilities for manufacturing, testing, and training. No expense had been spared, no request unfulfilled they have been a great boon to Wildcats Engineering, and we are greatly indebted to their services.

The members of Wildcats Engineering are incredibly grateful to Mr. Mamdouh and Mrs. Eman for being mentors and providing an environment where the team was able to learn and grow abilities to meet the many challenges presented throughout competition preparation. Other huge thanks should be mentioned to Ms. Kayla Johnson who had helped plan the logistics of the company’s trip to Los Angeles without her endeavors we would not have been able to participate in the competition Lastly, Wildcats Engineering is very appreciative of MATE for hosting this competition and providing this competition to stimulate all the young and aspiring minds around the world!

Lastly, Wildcats Engineering is very appreciative of MATE for hosting this competition as it provides amazing educational opportunities for many.

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Appendices

Appendix A: Safety Checklist

Pre-power checks		**In water check**	
	All crewmembers are wearing safety gear.		Power up the system and check the warning lights.
	Power is disconnected before conducting a safety check.		Check internal pressure is stable at the surface.
	Propellers, shafts, and manipulators clear of obstructions	**Recovery checks**	
	Cables are tied down and the electrical connections are waterproofed.		Check ROV is at the surface, facing away from the pool wall.
Pre-water checks			Two crewmembers and a tether man lift the ROV from the water onto land.
	Connect tether to control station and power the system.	**Entering the lab or workshop**	
	Check the video system.		Sign and timestamp Employee Sign Sheet.
	Check internal pressure reading at the control station is correct for the dive.		Wear company Issued facemask and PPE.
	Power down the system and call out “Water Ready”.	**Operating Power tools**	
	Two crewmembers and the tether man lower the ROV into the water.		Wear all required PPE per tool.
	Call out “In Water”.		Always keep hands away from the tool head.

Appendix B: Budget Sheet

			Reporting Period	
School Name:		American Baccalaureate School	From:	11/01/2021
Instructor:		Mamdouh Ali	To:	05/01/2022
Income				
Source				**Amount**
ABS Grant round 1				$3,500
ABS Grant round 2				$3,600
Expenses				
Category	**Type**	**Description**	**Projected Cost**	**Budget Value**
Sensors	Purchased	Low Light USB Camera	$150	$150
Electronics	Purchased	Onboard Raspberry Pi4B+	$200	$200
Electronics	Purchased	Onboard Pixhawk 4	$150	$150
Electronics	Donated	PlayStation Dual Shock 4 Controller	$60	-
Hardware	Purchased	PVC Pipes, Connectors (Mission Props)	$250	$250
Hardware	Purchased	Misc. Screws and Nuts	$100	$100
Hardware	Purchased	3D printed body Parts	$600	$600
Hardware	Purchased	Gripper Linear Actuator	$200	$200
Electronics	Purchased	Power Distribution PCBs	$50	$50
Hardware	Purchased	Pelican Cases	$1,000	$1,000
Electronics	Purchased	T200 Thrusters and ESCs	$2,000	$2,000
Hardware	Purchased	14mm Rubber O-rings	$20	$20
Sensors	Purchased	Bar 30 Depth/Pressure Sensor	$100	$100
Electronics	Purchased	Laser Modules	$25	$25
Electronics	Purchased	Meanwell Power Supply	$200	$200
Electronics	Donated	Lenovo Laptop	$750	-
General	Purchased	Marketing Materials, Flyers etc.,	$300	$300
Travel	Purchased	Round Trip to Los Angeles, CA	$10,000	$10,000
Accommodation	Purchased	5 nights stay at Courtyard by Marriot	$3,500	$3,500
			Total Income:	$7,100
			Total Expenses:	$19,655
			Total Expenses - Donations:	$18,845

Total Fundraising Needed: $11,745

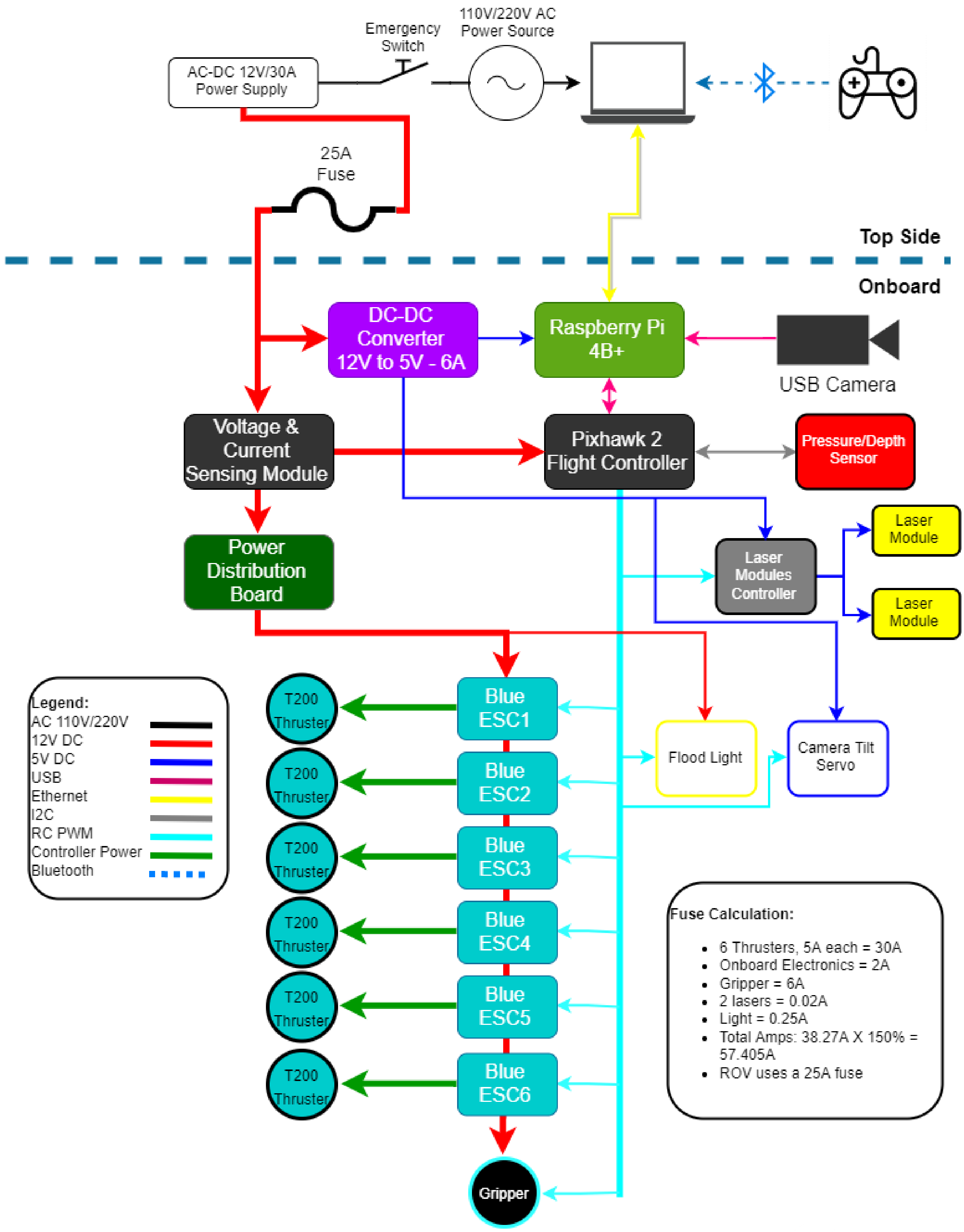
		Reporting Period
School Name:	American Baccalaureate School	From: 11/01/2021
Instructor:	Mamdouh Ali	To: 05/01/2022

Appendix C: Project Costing

Funds

Date	Type	Category	Expenses	Description	Source/Note	Amount	Running Balance
11/01/2021	Purchased	Sensors	Camera	Low Light USB Camera	Used as the main Camera	$150	$150
11/01/2021	Purchased	Electronics	Computer	Onboard Raspberry Pi4B+	Used to stream the camera signal	$200	$350
11/01/2021	Purchased	Electronics	Flight Controller	Onboard Pixhawk 4	Used to control the thrusters ESCs	$150	$500
11/15/2021	Donated	Electronics	Gamepad	PlayStation Dual Shock 4 Controller	User for control System	$60	$560
11/15/2021	Purchased	Hardware	PVC	PVC Pipes, Connectors (Mission	Used for building the missions probs for	$250	$810
11/15/2021	Purchased	Hardware	Parts	Misc. Screws and Nuts	Used for general vehicle construction	$100	$910
11/15/2021	Purchased	Hardware	3D Printing	3D printed body Parts	Used for general vehicle construction	$600	$1,510
11/15/2021	Purchased	Hardware	Gripper	Gripper Linear Actuator	Used to execute the required missions	$200	$1,710
11/15/2021	Purchased	Electronics	PCB	Power Distrebtion PCBs	Used to organize the control tube	$50	$1,760
12/20/2021	Purchased	Hardware	Cases	Pelican Cases	Used for secure transportation of the	$1,000	$2,760
12/20/2021	Purchased	Electronics	Thrusters	T200 Thrusters and ESCs	Used for general vehicle construction	$2,000	$4,760
12/20/2021	Purchased	Hardware	Penetrators	14mm Rubber O-rings	Used for waterproffing the cable entring the	$20	$4,780
02/15/2022	Purchased	Sensors	Pressure	Bar 30 Depth/Pressure	Used for pilot assisting using the depth hold	$100	$4,880
02/15/2022	Purchased	Electronics	Laser	Laser Modules	Used for measuring under water	$25	$4,905
02/15/2022	Purchased	Electronics	Power Supply	Meanwell Power Supply	User to power the vehicle	$200	$5,105
02/15/2022	Donated	Electronics	Computer	Lenovo Laptop	Used for running the main software	$750	$5,855
04/15/2022	Purchased	General	Printing	Marketing Materials, Flyers etc.,	Printing the marketing display and team flyers	$300	$6,155
04/15/2022	Purchased	Travel	Airfare	Round Trip to Los Angeles, CA	Mentors and team members airfare to	$10,000	$16,155
04/15/2022	Purchased	Accom.	Hotel	5 nights stay at Courtyard by Marriot	Mentors and team members	$3,500	$19,655
04/15/2022	Cash Donated	General		Funds Donated by friends and famlies	Used for travel and accommodation	($10,000)	$9,655
						Total Raised	($10,000)
						Total Spent	$19,655
						Final Balance	$9,655

Appendix D: ROV's SID



Appendix E: NRD SID (GO-BGC Float)