WhaleTech Robotics

Technical Document

North Paulding High School
300 N Paulding Dr #6675, Dallas, GA 30132, USA

Jason Lees (12th) CEO, Lead Engineer, Pilot
Andy Griggs (12th) Marketing Lead, Electrical Engineer, Co-pilot
Drew Boles (11th) 3D Designer, Engineer, Payload Manager
Tony Brozowski (11th) CFO, Safety Officer, Marketing Specialist
Graham Joonsar (10th) Software Engineer
Mentors: Nicola Lees, Geoff Gardener

ABSTRACT

Underwater Remotely Operated Vehicles (ROV) have been designed to perform different tasks in extreme conditions at depth in oceans all over the world. The purpose of this paper is to demonstrate the unique design and stability of “Whale II”, the ROV built by Whale Tech Robotics, located outside of Atlanta, GA. The company was founded in 2012 with the mission of building ROVs that will operate in the marine environment and aid in finding solutions to the impact of climate change on our marine ecosystem.

To meet the global community’s Request for Proposal (RFP), we are excited to bring this innovation of “Whale II” to the ROV industry. The “Whale II” is the complete package:

- The light weight, compact, and robust frame allows the ROV to be deployed and recovered quicker by one, or two, people.
- The lightweight design of the manipulator allows for quick, easy movements, making it easier for the ROV to replace damaged sections of inter-array cables, removing a ghost net from a wind turbine, and removing marine growth from unwanted areas.

Reliability, form, and function were key design principles for “Whale II”, however we understand that the public has choices of products and services. Whale Tech Robotics not only offers a state-of-the-art ROV that can exceed the RFP requirements, but we are also committed to class-leading customer service and support. You can be confident that our Company cares about our community, and we stand at the forefront of efforts to save our oceans.

Figure 1: Whale Tech Robotics Company Members with their latest innovative ROV, Whale II

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DESIGN RATIONALE

Design Evolution

WhaleTech utilizes the iterative design process to develop a product that is both effective and reliable. Each year, we begin with an initial planning phase that lasts around two weeks. During this phase, the mission requirements provided by the Marine Advanced Technology Education Center (MATE) are analyzed, and the corresponding feature to complete each objective is determined and conceptualized. Our company considered last year's ROV, evaluating what worked and what did not. The company then brainstormed and discussed the new design, keePing in mind the size, weight, cost, complexity, safety, and ease of manufacturing the ROV in a timely manner, for the requirements outlined in the request for proposal.

Once this is complete, a provisional budget and timeline are established which guide and help determine the use of research and development costs during the design process. The past analysis allows a more effective feature to be created from the first prototype, thus saving on costs. Once a prototype is created, it is tested in the testing phase. The feature is then evaluated on how it performed during testing and what changes could be made to improve the design. If the design passes the team evaluation, it is reviewed by the entire company to determine how well the feature will mesh with the overall ROV, and if its performance is acceptable. If the design passes company evaluation, a final product is created, and the feature is implemented to the ROV design.

Our company underwent a structural change, relocating to new premises and downsizing in the number of members. As a result, this year's build started later than normal. Because of this, the company decided to keep the mechanical design from last year, as the modular design of Whale proved to be effective in the previous demonstrations. As the company upgraded to the Explorer class, modifications in the onboard control box were needed to meet the MATE safety and operational guidelines.

Mechanical Design and Manufacturing Process

Mechanical Components

Frame

When designing the ROV frame, the company was presented with new opportunities that provided us with more flexibility in design through the improved access to 3d printing and Computer Numerical Control (CNC) machinery. A prototype of the frame was designed around the main components such as the thrusters and onboard control box. It was vital that the onboard control box was positioned in the top half of the frame, to ensure the center of mass was at the correct point on the ROV for maximum stability. Another necessary component consideration was the six T200 thrusters. The implementation of four horizontal thrusters allows the ROV to move forwards, backward, and turn in place simultaneously. These thrusters are mounted at 45-degree angles on each corner of the frame and inset slightly to keep the frame compact in size.

The additional two thrusters are centrally mounted on either side of the frame for stable, vertical thrust. The design resulted in an agile and lightweight frame that utilized aluminum metal sheeting that was donated to us by Kennesaw State University (KSU). The CNC material was created with machined holes spaced at precise intervals for mounting and easy adjustments when needed. Each component can easily be moved and switched allowing for reconfiguration of the frame when needed. The frame’s dimensions measured 38cm in length, 32cm in width, and 20.5cm in height with a weight of 1.36 kg without thrusters, tether, electronic housing, and payloads.

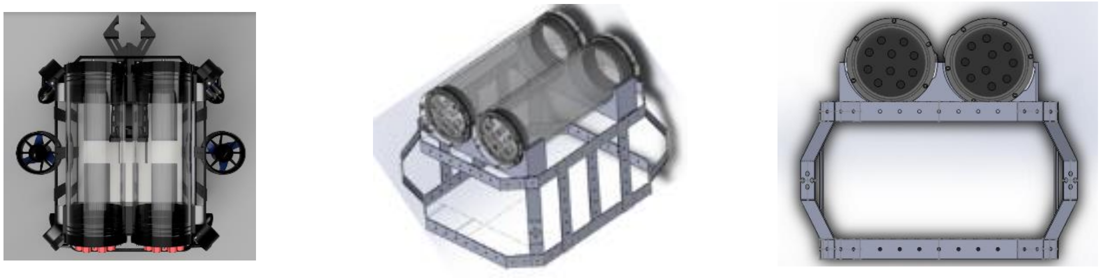


Figure 2: Frame design of Whale ll showing placement of onboard systems and thrusters.

Thrusters

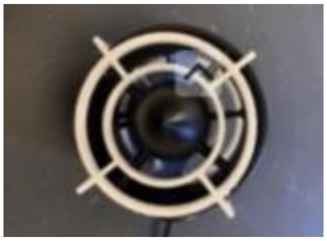
The proposal requested that the ROV be capable of maneuvering quickly and effectively in confined spaces. The company built an ROV that is equipped with six T100 Blue Robotics thrusters. We selected this model of thruster over the T200 model because of it being $87 lower in price and drawing 11.5 amps less current. Each thruster measures 11.3cm in length with a diameter of 9.7 cm.

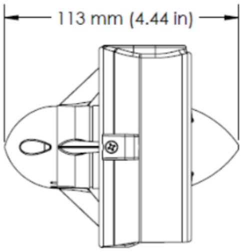
The thrusters operate at a maximum power of 150W and can operate effectively at a depth range of 150 meters. Each thruster provides 9.4 N of thrusting power, and as the ROV is equipped with 6 thrusters, we calculated the total thrust as:

Vertical thrust: $9.4\ N * 2\ \text{thrusters} * \sin 90^{o} = 18.8\ N$

Horizontal thrust: $9.4\ N * 4\ \text{thrusters} * \sin 45^{o} = 26.59\ N$

All six thrusters have protective shrouds and custom 3D printed thruster guards to enclose the propellers, ensure operator safety, and meet the safety MATE requirements.





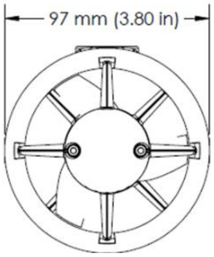


Figure 3: T100 Thruster with custom designed propeller guards.

Tether

Whale ll is equipped with a custom detachable tether that serves as the interface between the ROV and the surface control box. It provides the ROV with the electrical power and control commands while providing the Pilots with video and data feeds during operation. The tether consists of CAT 5e Ethernet cables and two14 gauge wires (one main power and one ground). The cables are neatly bundled using a TechFlex braided sheathing, which protects the wires inside and makes transportation easy.

Figure 4: Whale ll detachable tether reel

The tether weighs 3.52kg and has a total length of 20 meters allowing the ROV to maneuver with ease during the missions. The tether is secured both on the ROV side and the surface control box side with a strain relief to prevent the tether connections from being damaged. The team opted to construct their own tether rather than purchasing a commercial tether due to the expense, thus allowing funds to be utilized in other areas of the ROV build.

Tether Management

With previous builds, company members have struggled with bulgy coils of tether when transporting and deploying the ROV. As a result, company members brainstormed ways better to store and transport the tether of Whale ll. As a solution, the tether is coiled around a custom constructed reel, allowing it to be deployed pool side when needed. The reel holds the 20m detachable tether, with a handle that allows the tether to be coiled and uncoiled when needed.

Submersible Connectors

Whale II uses a combination of Bulgin sealed waterproof connectors as they offer secure, watertight connections that can withstand harsh environments during the testing and use of the ROV. Utilizing the connectors allowed for a detachable tether and for the two onboard control boxes to be compartmentalized without interfering with the communication aspect of thrusters and signals. Utilizing the connectors allows the teams to disconnect the onboard control box during troubleshooting with ease and minimizes downtime and loss of practice. In addition, the connectors were donated, minimizing additional expenses for the company.

Figure 5: Bulgin connectors used for power distribution.

Buoyancy

One of the benefits of our two onboard control boxes is that they serve as our main source of buoyancy. By having two airtight tubes spaced out on top of the ROV, the ROV will have a relatively flat source of buoyancy that keeps it upright. Using Archimedes' principle, along with the measured volume of the ROV, the calculated buoyant force was 93.017N. Since the ROV only weighs 86.044N, an additional 7.0266N of weight had to be added to make the ROV neutrally buoyant.

Total ROV Volume	0.0096m^3
Density of Pool Water	992.72 kg/m^3
Total Buoyant Force of ROV	93.071N
Total Buoyant Force of Onboard Control Boxes	66.94N
ROV Weight	86.044N
Added Weight	7.0226N
Added Mass	717g

Table 1: Buoyancy calculations to determine how much weight needed to be added to ROV frame.

Electrical Systems

Onboard Electronics

Whale II is equipped with a two-box design for our onboard electronic system. The two onboard control boxes hold different components allowing technical issues to be isolated and fixed quickly, reducing repair time. The left box contains one Raspberry Pi 4, Pixhawk, fathom x and an array of 6 ESCs (Electronic Speed Controllers) that take 12V inputs directly from 2 of 3 voltage regulators in the adjacent housing. The last regulator is shared by the former to supply 12V among the non-ESC components. The right box contains the three previously 48V to 12V regulators along with the stepper controller that controls the movement of the manipulator stepper motors. This controller also shares the same supply as the first components of the left box.

The on-board control box needed reliable and strong watertight enclosures for the electronics on board, so the team opted to use two Blue Robotics 4inch series watertight enclosures with custom built acrylic caps to accommodate the Bulgin PX 0747/8 connectors. Both end caps can be disconnected from enclosures to allow for easy access for troubleshooting and repairs. Each tube measures 30cm by 11cm by 11cm. The inner diameter of the enclosure is 10.5 cm. Once the wires were fed through the vent hole, it was epoxied to prevent water leakage.

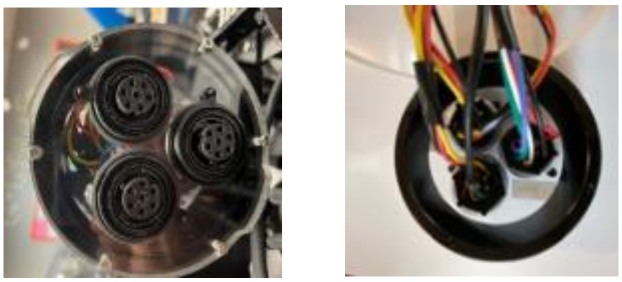


Figure 6: Bulgin PX 0747/8 mounting connectors onboard control box.

Figure 7: Bulgin PX 0747/8 power connectors between the two onboard control boxes.

Surface Control Box

This year, WhaleTech took a small, sleek, minimalistic approach on its surface control box due to its burden of responsibility being heavily shifted to the onboard control box. The surface control box acts as a connection point between power and the robot, the laptop and joysticks, and the tether. The housing of the control box is a pelican box measuring 29cm in length, 21cm in width, and 9cm wide, with a PVC platform base inside for mounting. On the platform, a power switch and a USB hub are mounted. The switch is wired to power with Anderson connectors and a fuse 16cm away from the positive connector. The switch and the USB hub are then both wired to the panel mount on the box using a PX0735/6 Bulgin connector allowing for the tether to detach. The detachable tether and the small size make the control box, and thus the robot, easier to transport than ever before.

The surface control system consists of two main subsystems: the control system and the communication system. The control system consists of two Logitech Extreme 3D Pro flight sticks which are used to Pilot the ROV. With eleven buttons, a trigger, a hat switch, and three axes of movement, these highly customizable controllers are tailored to the preferences of the Pilot. One joystick is customized to control the movement and camera angle of the ROV and the other controls the manipulator. By using two joysticks, each Pilot can focus on their specific task and complete the missions more efficiently.

Figure 8: Tether connection to surface box

Figure 9: Surface control box

Figure 10: Warning labels on surface box and tether restraint.

This communication system consists of the laptop and the peripherals connected to a USB hub housed within the surface control system. The laptop reads the USB signal from the joysticks and converts this data with the surface code. It then communicates this data back through the USB hub and through the tether to the onboard Arduinos.

Each of the subsystems for the surface control system is neatly integrated into a singular surface control box. This control box takes one positive and one ground wire and splits them with a bus bar to power everything within. All connections housed within the surface control box are properly secured to reduce the risk of pulled wires and electrical shorts. The control box also contains a power switch so that the entire ROV can be quickly powered off in case of emergency.

Fuse

To meet the safety requirements of the MATE competition, the company incorporated a Littelfuse 30 Amp fuse into the main power line. This small safety device will stop the ROV from working if the electric current exceeds the required amount, preventing fires, electrical shock, and

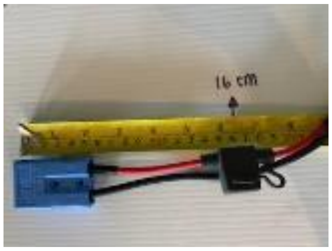


Figure 11: 25 Amp Fuse 16 cm from main power.

damage to the main control box. The fuse is located 16 cm from the main point of connection to meet the safety requirements put forward by MATE.

Pneumatics

Software

The software that runs the ROV consists of code written in C++ that is running on a Raspberry Pi 4 in the robot and external code written in Python running on a laptop. The code that is running on the Raspberry Pi is for the low-level control of the robot, using motors, servos, and receiving input from cameras. The code written in Python on the laptop oversees the higher-level functions, such as image recognition, following a transect line, and stitching images. The laptop is significantly more powerful than the Raspberry Pi, so it is ideal for these performance intensive applications.

The manual mode of the robot's control scheme takes in input from two Logitech joysticks that are connected to the laptop. The input from these controllers is processed by the laptop into a form that the Raspberry Pi can easily receive and comprehend. These controllers also have a variety of buttons that allow for the Pilots to perform intricate actions not possible with lesser controllers.

The data is then transferred from the laptop into the Raspberry Pi, where it is deciphered by the Raspberry Pi back into usable values. The Raspberry Pi then sends signals to its GPIO Pins that are connected to our robot electronic components, like the thrusters, used to maneuver, and the motors on our arm. The model of Raspberry Pi we are using, the Raspberry Pi 4, has 4 gigabytes of ram, allowing for raPid code execution and precise movements.

Mission Specific Tools

Cameras

The WhaleTech robot uses three Explore HD 2.0 Underwater ROV/AUV USB cameras to provide visual information to our Pilots and our autonomous programs. These cameras are positioned with one always facing forward, one pointing downward, and one placed on our arm. Since these cameras are USB, we are more easily able to process the camera data for autonomous programs, as these cameras can directly interface with our onboard Raspberry Pi. The Raspberry Pi is then able to send the camera data up to our computer on land, ready for the autonomous programs that require the camera, such as flying the transect, creating the photomosaic, and mapPing the fish pen.

Figure 12: Explore HD 2.0 camera and side view showing measurements.

The Explore HD 2.0 cameras have a waterproof rating of IP69K, can operate at depths of 400 meters, and measures 4 cm in diameter and weighs 80 grams. The company opted to purchase these cameras after technical issues where the old cameras were losing feed during practices. In addition, The Explore HD 2.0 offers clearer feedback in low light conditions, providing the Pilot with accurate colors and clear images for the inspection and mapPing of the transect lines, as seen in figure below.

Figure 13: The Picture on the left was taken with the Explore HD 2.0 camera, the one on the right, with our old fish-finder cameras.

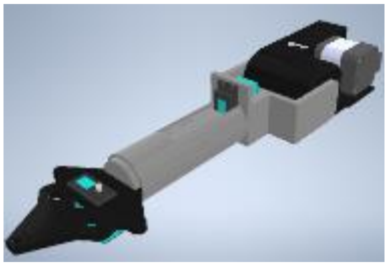
To prevent leaking when mounting the camera wires to the onboard control box, the company opted to use the WetLink penetrator from BlueRobotics to prevent linking. The cable and rubber seal inside the bulkhead of the penetrator are compressed, which creates a high-pressure seal preventing water from entering the housing. The high-pressure seal acts as a strain relief and prevents the cables from being pulled out. The penetrators are rated to 950 meters depth.

Figure 14: WetLink Penetrator showing O-ring and rubber seal located inside the penetrator.

Manipulator

Due to the relatively high number of tasks that require fine maneuvering of subsea items, such as replacing a damaged section of an inter-array cable and repairing the damaged area of the offshore aquaculture fish pen, WhaleTech Robotics opted to develop a manipulator, that is both reliable and versatile.

With help from a former member of 404 Engineering, the manipulator design was originally able to be based on the use of two NEMA 17 stepper motors (Automation Direct: STP-MTR-17040W). These stepper motors are capable of 0.43 Newtons per meter of lift force which was unfortunately lower than the optimal lift force for competition.



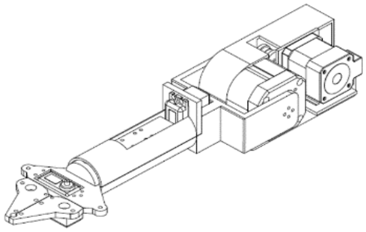


Figure 15: Inventor design of Whale ll manipulator.

Due to this, a custom speed reducing gearbox was required. With this holding, torque capacity, during initial testing, was determined to be inadequate for our company's needs. Testing proved that the utilization of a speed reducer gearbox provided the needed results to prove useful. With the utilization of a v-belt system (gear ratio of 3:1) along with the dual speed reduction gearbox, which was a 25:1 gear ratio, the holding torque of the NEMA 17 was increased to 32.31 Newton-meters. This combination of the v-belt system (the silver portions of the Picture below) and the speed reduction gearbox allowed for a 75:1 gear reduction of the NEMA 17. While this improved the overall torque capacity of the motor, it lessened the speed of the overall tilt.

Figure 16: Stepper motor that allows the arm to tilt up and down

However, after research into our former team's manipulator designs it was shown that the angular speed of the tilt body was only slightly slower than the servo-based design used previously. Further research into the newly designed manipulator showed that the overall lifting capacity of the newly designed tilt was 9.08 kilograms at the overall length of the manipulator.

For example, at 0.3 meter, the newly designed manipulator achieves a lifting force of 120.02 Newtons and a weight capacity of 12.25 kilograms. A stepper motor without any gear reductions or v-belt systems, it can only achieve a lifting force of 1.6 Newtons and a weight capacity of 0.163 kilograms.

Mounted to this gear box is the 25.4 cm shaft which includes our manipulator camera mounting bracket and our servo-based gripper. A servo-based gripper allows for far more accurate movement compared to a stepper motor. This movement of the gripper allows for our ROV to safely retrieve and replace subsea items during operation.

GO-Float

One of the missions tasked by MATE Robotics this year requires teams to replace an existing Go-BGC Float with one prepared by the company. WhaleTech Robotics created the replacement float, which has been dubbed "Remora" by the company, out of a variety of materials, including two submersible pumps, an acrylic tube, a custom printed electronics board, an Arduino nano, two relay switches, a balloon functioning as a bladder, a depth sensor, and two blue robotics O-ring flanges with fitting caps. Remora functions as a buoyancy engine, pushing air from inside the control box to an outer bladder using one of the two pumps, changing the density of the float, causing it to rise. The Arduino constantly receives values from the depth sensor, and when it detects that the value is no longer changing, it toggles the relays, activating the second pump. This brings the air from the outer bladder back to the control box, once again changing the density, only this time, it causes the float to sink. Remora will repeat this process until it successfully completes two vertical profiles. Remora measures 22 cm in length and 7.6 cm in diameter, meeting the size requirements set forward by MATE.

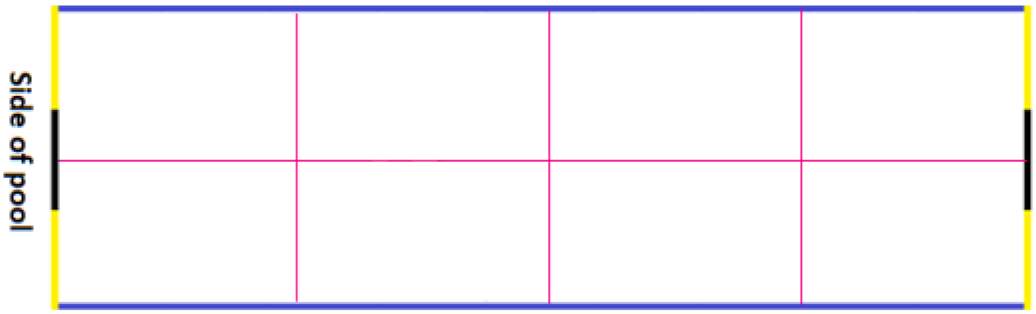
Figure 17: GO-BCG float

Image recognition Tools

Photomosaic of wreck site

To fly over the wreck, our Pilots can utilize our robots bottom facing camera to stay inside the transect boundary. The bottom facing camera is much more useful than any other camera would be because it is facing straight down, not angled downward like other cameras would be.

While one of our Pilots is flying the transect described above, our other Pilot will be making note of the rectangles that the wreck is contained in for the following task of mapPing the wreck. After finishing the transect, our Pilots will open image editing software to draw the ship onto the correct rectangles that were recorded during the flying of the transect. The image our Pilots will draw the wreck onto is shown below.



For our photomosaic of the wreck, we decided to achieve it autonomously due to the extra points it would give with little modification to our robot. The process of creating our photomosaic is quite simple. Our Pilots position the robot over each tile in a certain order, and due to our downwards facing camera, we are easily able to take Pictures of the full square. Once the Pilots have taken 8 Pictures, our autonomous program activates. It uses OpenCV library functions to concatenate our images onto each other. All the horizontal pairs are stitched together first, then each of those pairs are stitched vertically, resulting in the final photomosaic.

Measuring of shipwreck and Mort's

The company was employed to measure aquatic life and a sunken ship. To accomplish this task without burdening Pilots by bringing down a physical measuring tool, software was created to achieve the same results digitally. As the objects needing to be measured were known beforehand, an equation was able to be formulated for each object to quickly measure the object at the swipe of a mouse.

The equation

$$L_u = \frac{L_k}{P_k} \times P_u$$

Where L_k is the length of the known segment, P_k is the Pixel length of the known segment, P_u is the Pixel length of the unknown segment, and L_u is the length of the unknown segment. The Pixel lengths of the known and unknown segments are found by the Pilots drawing lines across the segments, and the known length is stored as a literal. Once the three values are found, the program will output the length of the unknown segment in centimeters. The known length of the objects varies case by case, In the case of the mort, many segments of the fish will remain consistent between adults of its species. One such segment is the distance between the caudal fin and the anal fin at approximately 10 cm.

Troubleshooting and Testing Techniques

Testing and troubleshooting are the main steps in fabricating a robot after the design and budget phases as stated by the company's rationale. The process starts in the design phase with the construction of prototype components. These prototypes are then thoroughly tested to give proof of the concept. The prototypes allow for troubleshooting the components while saving funds by using cheaper components while testing functionality and water tightness. The most important part of the prototype phase is iteration. During this phase, a prototype will go through many failed or sub-par designs so that when a design makes it out of the prototype phase, it meets the rigorous standards of WhaleTech. The iterative process does not stop at this point, however. Should a problem with the component occur after its implementation, certain steps are taken to swiftly eliminate the problem and potentially make the component better performing than before. When troubleshooting, the first step is identifying the problem. This starts by gathering teams relevant to the component or components in scrutiny. If the problem is local to a singular component, one team will work diligently to remedy the situation. If a problem occurs involving two or more components, the parties needed will work together to inspect the problem's source. If the problem's remedy affects the overall design of the Whale ll, the entire company is gathered and debriefed and cooperates to identify the next steps.

This method of troubleshooting avoids unwanted downtime of people not relevant to the issue, and the avoidance of confusion between members of WhaleTech, by ensuring any design changes are known by every member. This method of troubleshooting combined with WhaleTech's iterative process ensures an ROV that exceeds the standards set by WhaleTech and the risk of failure while in use.

SAFETY

Safety Philosophy

WhaleTech's Corporate goal is to provide a safe work environment for its employees and customers. It's at the forefront of everything we do. Our commitment to safety is evidenced by the stringent proactive approach the company believes all accidents are preventable, and that safety is the responsibility of every employee, all the time. Here at WhaleTech, our workplace is maintained at high standards, following, and always operating in compliance with, MATE safety regulations. Our employees are orientated and trained on how to perform their jobs safely, efficiently, and effectively by implementing safety processes through efficient communication and continuing safety education to all our personnel.

Workshop Protocols

WhaleTech's safety committee is trained to identify hazards and unsafe work practices, prevent accidents by removing any known obstacles, and evaluate the company's ongoing efforts to achieve an accident and injury-free workplace. On the committee there is also a safety officer who is tasked with updating the Job Safety Analysis (JSA) and Safety handbook, throughout the year as our employees design, test, and work on the ROV. These documents suggest the safest way to complete a task by identifying potential hazards before the task is started and recommends the safest way for the task to be completed. The safety coordinator documents any changes to the forms during the manufacturing process. The Whale Tech Robotics safety handbook was readily accessible for review and training throughout the build year. As our company relocated to new facilities this year, one of our most significant challenges during the transition is that our equipment and machine tools are dispersed between multiple rooms. This transition requires continuous planning, ongoing monitoring, and testing of equipment to ensure all employees are working in a safe environment.

Training

The structure of our company is continuously evolving. WhaleTech adopted a policy that training is essential for the company's success, as it leads to higher production, and fewer accidents. WhaleTech adopted a mentor-to-mentor program, where veteran employees teach new and untrained members skills that they will need to be successful within the company.

All employees are retained at the beginning of the build year to refresh safety protocol and use of tools. The company emphasizes that the program can only work when everyone involved feels comfortable discussing concerns, making suggestions, and reporting injuries, incidents, and hazards. In doing so, the company can be successful moving forward knowing that safety is their number one concern.

Vehicle Safety Features

The company designed the ROV for raPid deployment and simple operation without sacrificing quality and versatility. To accomplish this, the company integrated special safety features to keep the crew, work environment, and ROV safe during operation and testing. At the start of every year, Whale Tech develops a plan for the

ROV that is compliant with the MATE safety handbook. The ROV frame does not have sharp edges that could cause injury during the deployment and transportation of the ROV. The ROV thrusters are housed within the aluminum frame preventing objects from contacting the propellers, ensuring the safety of the thrusters and the surrounding marine environment. Safety labels are placed on the surrounding casing of the thrusters, indicating that the moving propellers could cause harm.

The control box is clearly labeled to prevent wires from being switched or connected incorrectly. The clear canisters housing the onboard electronics allow for easy detection of water leakage during the operation of the ROV. All cables inside the frame are secured away from the moving propellers. A fuse is attached to prevent the ROV from exceeding the maximum operation value of 25 amps. All connections are waterproofed with liquid tape. The control system is constructed from watertight 6-inch acrylic tubes with watertight end caps. The ROV is free from any chemical substances or pollutants that may affect or harm the marine environment.

Figure 18: Safety features include safety on/off switch, shroud, guards, and danger stickers on all thrusters.

Figure 19: All exposed wires are waterproofed, covered with heat shrink and all sharp edges on frame removed.

Operational and Safety Checklist

The company's Operational and Safety Checklist (Appendix A) has proven repeatedly to organize and manage tasks, reduce errors, increase productivity, and ensure all steps in any given task are completed correctly. In addition, employees follow operational JSA’s to identify potential hazards that should be addressed before launching, operating, and recovering the ROV during pool testing.

LOGISTICS

Company Organization and Assignments

Our company consists of five members who have been designing and building ROVs for over 7 years. The company is divided into three divisions, electrical, mechanical, and engineering. Company meetings began with a detailed description of what work has been accomplished in each member's own time, as well as what needed to be done moving forward in the build. Our CEO subdivided and assigned roles and the responsibilities to each department that needed to be completed. Each department was responsible for specific tasks throughout the week, allowing a five-man team to complete the job of what had previously taken ten or more people in the same amount of time. The CEO would document the progress of the build and ensure collaboration across each department. This increased efficiency allowed for more time to practice with the ROV and for any new issues to be noticed before competition.

One of our biggest goals this year was to improve cross training within our company. When a member with a special skill graduate, our company struggles to fill the gap. This year we implemented a policy that each member learns one new skill. By developing knowledge in other areas, employees benefit a big Picture perspective, allowing them to contribute more to our company.

Scheduled Project Management

WhaleTech consists of four departments: design, manufacturing, electrical and programming. Company members were assigned into these departments at the beginning of the year based on their understanding of the tasks, as well as the strengths, skill-level, experience, and interests of each company member. Team members collaborated with the CEO, Jason Lees, and voiced their concerns, keePing the CEO on track and aware of any potential delays or changes in the build to ensure a successful construction of the ROV. The CEO tracked the progress of the ROV build using the Gantt Chart Figure (20). This allowed the company to finish the designated jobs at a much higher level of efficiency.

We met twice a week and always began with a review of what work has been accomplished in each member's own time, as well as what needed to be done moving forward in the build. Each member was responsible for specific tasks throughout the week. The focus on efficiency allowed for more time to test the ROV and for any new issues to be identified and resolved.

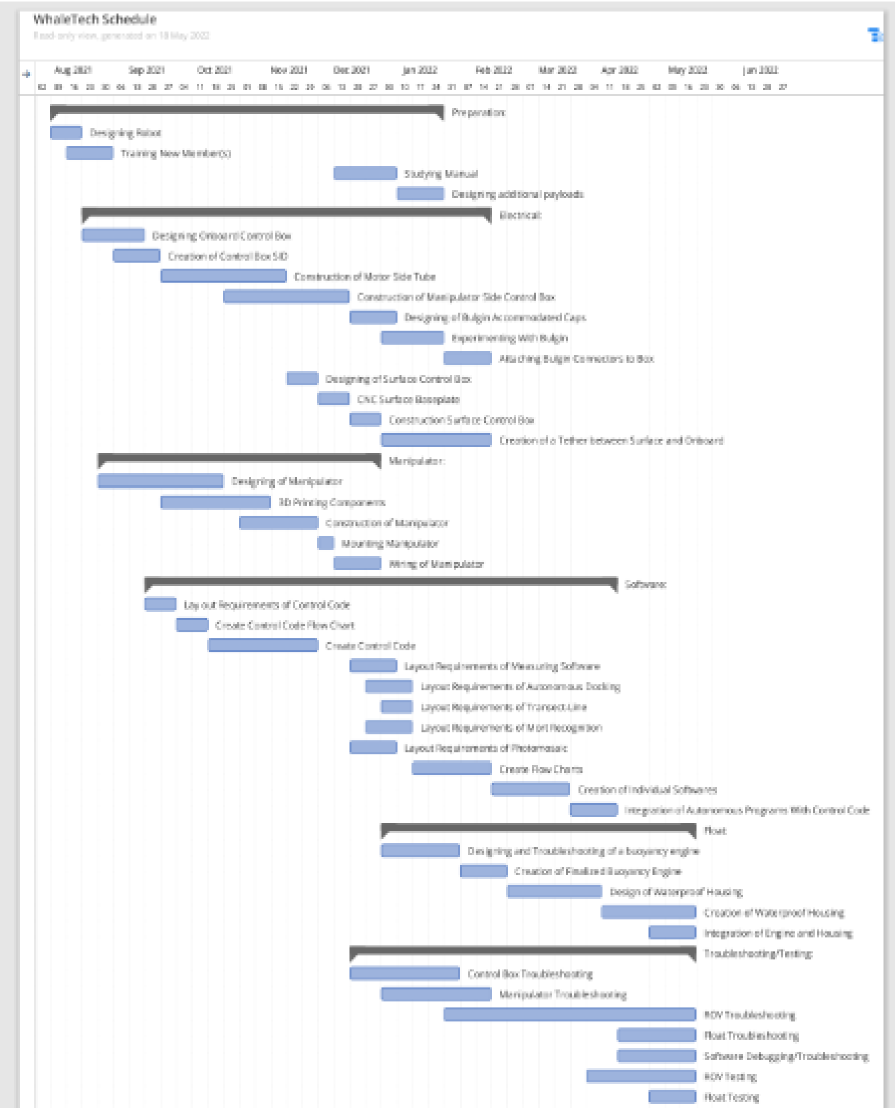


Figure 20: Gantt Chart for 2021-2022 build year.

Collaborative Workspace

WhaleTech Robotics utilizes a collaborative cloud system to store all files. This provides the team members the opportunity to access, communicate and provide feedback with others, without being in the same location. In addition, team members communicate with each other through zoom and Discord, allowing the team to track progress, place orders for parts, anticipate delays and monitor tasks that still need to be completed. Utilizing the cloud system and discord allowed the company to meet mission objectives and solve day to day operational problems, avoiding delays in the build of their ROV.

Code Management

This year, WhaleTech Robotics started using a version control system called Github to manage software development and deployment. Github allows programmers to make changes to code that can be reviewed by others before being merged into the final control code. Also, since Github stores repositories of code on their servers, if program files are accidentally deleted or if the programming laptop is rendered unusable, code can quickly and easily be recovered from the internet. In addition, since our code is stored online, it can be accessed from any authorized device, letting our company have access to our programs anywhere, while maintaining confidentiality. To write source code, our company employs the use of the Visual Studio Code IDE, for its variety of extensions that-make development much easier, and because it is lightweight and loads very quickly.

Budget and Cost Planning

Our company proposed a budget for vehicle development after reviewing the requirements for the 2022 MATE competition and the expenses incurred from previous builds. The company pledged $4,000.00 for vehicle development and $9,000.00 for operating expenses including travel and accommodation. Actual vehicle development costs totaled $4,304.29 and operating expenses totaled $8,780,00. The company remained on budget with a remaining balance of $290.71. To keep track of expenditures and money raised through sponsorships and fundraising, the company maintained a budget sheet which kept track of all transactions made throughout the ROV build. This allowed all company members to stay on track and within budget. The budget and costing sheets can be found in Tables 2 and 3.

Operating Income 2020-2021		
Fees	Company member's fees ($475 per company members, total 5 members)	$2,375.00
Donations	Donations/ STEM Days/ Fundraising	$3,000.00
Sponsor Donations	EY, Automation Direct, Think GA Homes	$8000.00
	Total operating income	$13,375.00
Operating costs 2020-2021		
Travel	Hotel costs, transport, food for 5 members for 4 nights stay in CA	$7,780.00
Registration fees	MATE registration fee, printing, shipPing	$1000.00
Total operating costs		$8,780.00
Balance		$4,595.00

Table 2: Operating income for 2021-2022.

2021-2022 WHALETECH ROBOTICS EXPLORER BUDGET

		Reporting Period
School Name:	North Paulding High School	From: 1 November, 2021
Instructor/Sponsor:	Nicola Lees	To: June 21, 2022

ALL COSTS AND INCOME IN USD

	Source	Description/Examples	Amount
INCOME:	Initial	Starting Balance Payed By Fees	2375
	Fundraiser	Sold Hot Chocalate And Cookies	1000
	Fundraiser	Sold Bed Sheet	2000
	Sponsors	EY, Automation Direct, Think Homes	8000

Expenses

Category	Type	Description/Examples	Unit Cost	Quantity	Total Cost	Category Total
Frame	Purchased	PVC Base Plate	62	1	62	362
	Reused	Meatl frame material	200	1	200	
	Purchased	Epoxy, fasteners	100	1	100	
Propulsion	Purchased	Blue Robotics ESC's	35.5	2	71	659
	Purchased	T100 thrusters	210	2	420	
	Purchased	Blue Robotics ESC's	35.5	4	142	
	Purchased	3D filament for shrouds	26	1	26	
Manipulator	Purchased	Double Metal Seal Bearings 5x16x5mm	10.69	1	10.69	558.08
	Purchased	Deep Groove Ball Bearing 30x42x7	9.62	1	9.62	
	Purchased	100PCS 12mm Allen Bolts	9.62	1	9.62	
	Purchased	Double Rubber Seal Bearings 4x12x4mm	11.67	1	11.67	
	Purchased	Savox Waterproof Coreless Digital 7.4V Servo	103.78	3	311.34	
	Purchased	20 Ball Bearings 8x22x7mm	11.76	1	11.76	
	Purchased	8x16 Rubber Ball Bearings 10 8x16x5	10.58	1	10.58	
	Purchased	Stepper Motor Mounting Bracket	16.04	1	16.04	
	Purchased	Manipulator Prototype Gears	40.33	1	40.33	
	Purchased	Prototype Manipulator Bearings	22.34	1	22.34	
	Purchased	SparkFun Logic Level Converter	12.84	2	25.68	
	Purchased	5mm Diameter, 1ft long Aluminum Rod	30.7	1	30.7	
	Purchased	Spark Fun PowerBoard	19.19	2	38.38	
	Purchased	100PCS 20mm Hex Socket Screws	9.33	1	9.33	
Pilot system	Purchased	Micro Hdmi cable	11.62	1	11.62	534.62
	Purchased	TV monitor	165	1	165	
	Reused	LogiTech Controllers	46	2	92	
	Resued	Laptop	220	1	220	
	Purchased	LogiTech Controllers	46	1	46	
Tether	Purchased	Loctite Multi Purpose Repair Putty, 2oz, White	6.41	1	6.41	244.81
	Purchased	Dispenser Gun kit, 50mL	23.53	1	23.53	
	Purchased	Tether Connectors	152.84	1	152.84	
	Purchased	100ft 1/4 inch PET Expandable Sleeving	14.97	1	14.97	
	Purchased	32oz Epoxy Resin kit	32.09	1	32.09	
	Purchased	180PCS Heat Shrink	14.97	1	14.97	
Control Box Electronics	Purchased	iFlight 48V to 12V DC Converter	20.67	3	62.01	514.98
	Purchased	Breadboard, Fan Kit, USBC Power Supply	81.83	1	81.83	
	Purchased	DC-DC Step Down Regulator	15.89	1	15.89	
	Purchased	18AWG Wire Kit	18.18	1	18.18	
	Purchased	5-Pack DC-DC Step Down Volt Regulator	15.98	1	15.98	
	Purchased	Rasperry Pi 4GB	192.59	1	192.59	
	Purchased	Single Fathom-X Tether Interface Board	128.5	1	128.5	
Control Box Electronics					0	858.8
	Reused	Cast Acrylic Tube	90	2	180	
	Reused	Acrylic sheeting for custum cut end caps	60	1	60	
	Purchased	O-rings	69	1	69	
	Donated	Bulgin connectors	350	1	350	
	Purchased	48 V converters	49.95	4	199.8	
	Purchased	3D printed custom mount	9	2	18	711
	Purchased	Explore 2.0 USB camera	235	2	470	
Surface Electronics	Purchased	Pelican case	58	1	58	245
	Donated	Bulgin connectors	165	1	165	
	Purchased	Tether restraint cable	22	1	22	
					0	
					0	
Payloads GO-BGC Float	Purchased	Pressure sensor, arduino, 9V battery, relay	147	1	147	428
	Purchased	Blue Robotix acrylic tube 22 cm	90	1	90	
	Purchased	Gikfun Mini DC 6v to 12V R385 Pump	17	2	34	
	Purchased	End caps for housing	62	2	124	
	Purchased	on/off switch	33	1	33	
	Total	5116.29				
	Total Cost Reused and Donated Items	812				
	Total Project Cost	4,304.29				

Table 3: Project costing sheet for 2020-2021 ROV build

ACKNOWLEDGEMENTS

Whale Tech Robotics would like to recognize several sponsors and individuals for their continuous support and help throughout the year.

- MATE Center and Gray's Reef National Sanctuary for creating the 2022 missions and organizing the competitions.
- Bulgin for their generous donation of connectors.
- MATE sponsors (Marine Technology Society, Marine Technology Society ROV Committee, National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Oceaneering, Kingsport Aquatic Center, Marine Technology Society, Ballad Health, TVA, Teledyne Marine, Department of Environment and Conservation, Martin Klein and Eastman Foundation.
- Jody Patterson for ongoing support towards our program.
- Automation Direct, for their generous donations of electronic components for the manufacturing of Whale II manipulator.
- EY for the sponsorship and donation for team shirts for the 2022 MATE World Competition.

- Senators Ridge and Seven Hills HOA for allowing us the use of their pool to practice for the event.
- Mr. Gardener, Mr. Leach, and Mrs. Lees for the continuous help and support throughout the year.
- Glen Lewis and Michael Lees, for their assistance and guidance throughout the year.

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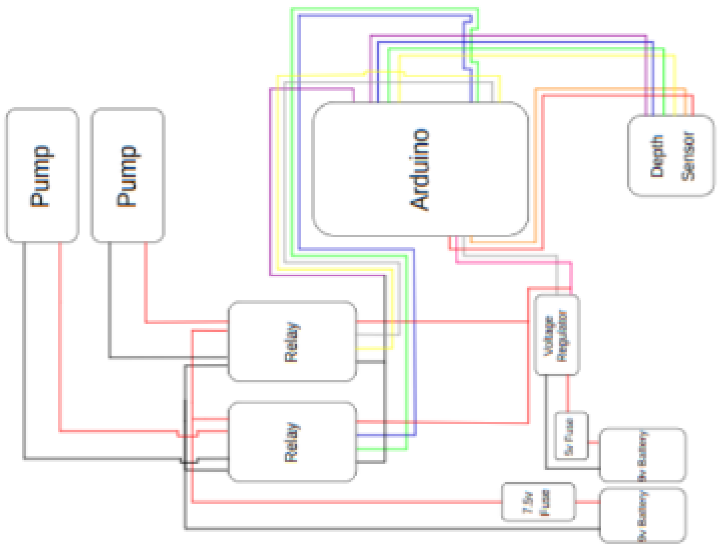
APPENDIX A: OPERATIONS AND SAFETY CHECKLIST

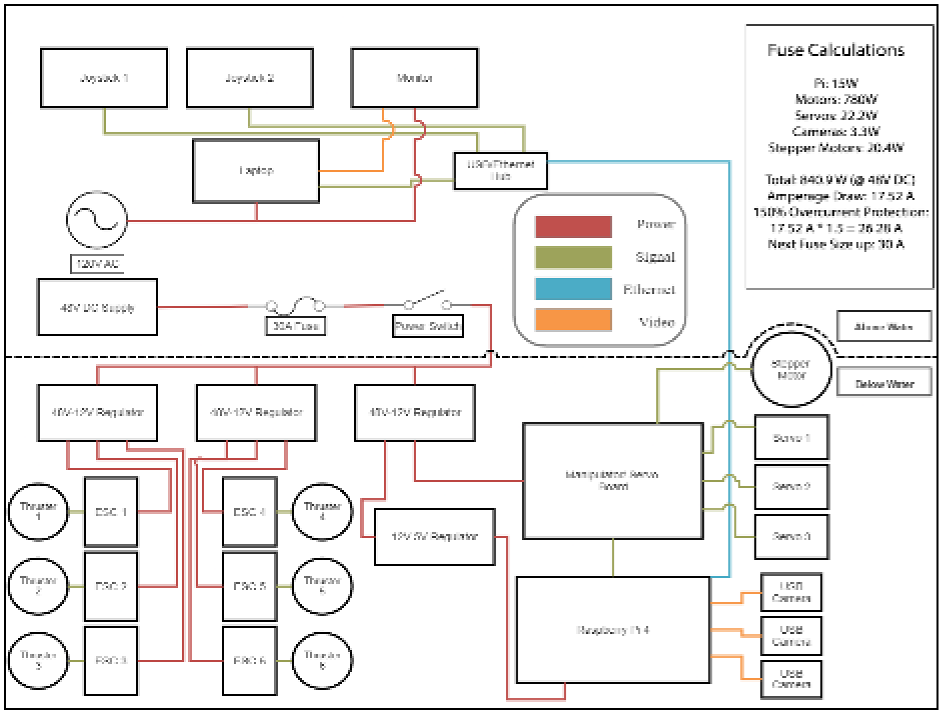
PRE-POWER CHECKS	CHECK
ALL team members are wearing correct attire when poolside.	
Operational area is clear of obstructions	
Check to make sure ROV power is off before conducting safety checks	
Check fuse is in place and operational	
All components of ROV are secured in place (tether, arm, cameras)	
ROV and tether are free of sharp edges	
ROV thruster shrouds are in place and secure	
Manipulator is secure and can move freely	
All tether and cable connections are secured and waterproofed	
Onboard control boxes are secure and end caps are securely fastened	
Call out "Power on"	
PRE-WATER CHECKS	
Connect tether and power cables to power box	
Check operation of cameras and video feed	
Check movement of manipulator and tilt camera	
Call out "Safe"	

IN-WATER CHECKS	
Test up and down thrusters	
Test forward and backward thrusters	
Call out "ROV Ready"	
ROV OUT CHECKS	
Wait for ROV to return to the surface	
Call out "Power off"	
Remove the ROV from the pool, facing the manipulator away from the pool edge.	
Place ROV on pool deck	
WORKSHOP PROCEDURE	**CHECK**
Eye and ear protection worn when operating power tools	
No loose clothing is worn, long hair tied back when working with machinery or moving parts on the ROV	
No open-toed shoes	
Operation of machinery is under adult supervision and only if the member has been trained on how to operate the machine	
Rubber gloves and dust masks/ respirators when sanding or handling chemicals	
All company members will follow workshop rules – no horseplay in the workshop	
Training is mandated before members can operate new machinery	

APPENDIX B: SID OF GO-FLOAT



APPENDIX C: SID MAIN ROV



APPENDIX D: FLOWCHART PROGRAMMING