TETHYS INC

ALPHEUS 3.0
TECHNICAL REPORT

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Abstract

Established in 2017 and operating out of Tiyan High School in Barrigada, Guam, Tethys Inc. is an environmental engineering company with the mission to improve the quality of oceans, seas, lakes, and rivers that have been marred by natural and artificial causes. As a three-member company in 2021, Tethys Inc. built Alpheus 3.0, an upgrade to their 2019 model.

Alpheus 3.0 is an underwater remotely operated vehicle designed to navigate bodies of water to investigate marine life, repair underwater structures, and collect samples. To accomplish these, the ROV utilizes several motors, cameras, sensors, servos, and microcontrollers.

A demanding 12-month project for Tethys Inc., Alpheus 3.0 is a product of hard work, effort, and passion. The following document reflects the philosophies and challenges of the company in relation to Alpheus 3.0 and its missions.

From left to right
Koji Bilbao: Engineer, Co-Pilot, Mission Strategist
Lexis Sablan: CEO, CFO, Electrical Engineer
Benjamin Kim: Engineer, Pilot, Safety Coordinator

Project Management

Alpheus 3.0 is a continuation of the company's 2020 project that was halted due to COVID-19. Upon returning after a 10-month break, there were a few restrictions that made proceeding with the project difficult. For the first 3 months, the company could only meet once a week which forced them to strategize and work virtually on tasks that did not call for physical attention and to capitalize on the 6 hours allotted during that week.

With only 3 members working on this demanding project, duties were distributed among the team based on each member's skillset. Sablan designed and assembled the custom Printed Circuit Board (PCB), Kim constructed the main ROV, and Bilbao engineered the micro-rov and its components. The team consulted and communicated with each other at every development or whenever a question or issue arose.

Design Rationale

Every aspect of Alpheus 3.0's design, from the chassis to the electronics, was carefully constructed to ensure functionality, ease-of-use, and safety. Buying new versus reusing old materials were among the many decisions the company had to make during the engineering process. The following sections detail the rationale behind these decisions that led to the ultimate design of the ROV.

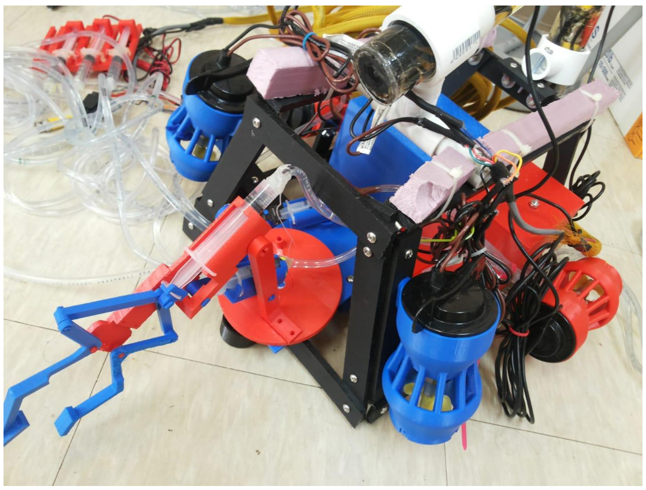
➔ Chassis

Past renditions of Alpheus' chassis have used either PVC pipes or High Density Polyethylene strips. However, the company decided to stray away from these familiar materials. The HDPE strips called for too many joints and the PVC pipes seemed "elementary". Acrylic sheets were the best alternative. The shape of the chassis could be easily replicated from a single sheet with little cutting and no need for any joints.

The hallowed body allowed for various space-consuming components such as the micro-rov housing and claw. The shape also provided a more enclosed chassis in which these parts can be secured. Holes were cut into the top panel to feed the tether through and relieve excessive drag that can occur with the broad surface area of the chassis's top panel.

ROV chassis designed from a single sheet of bent acrylic

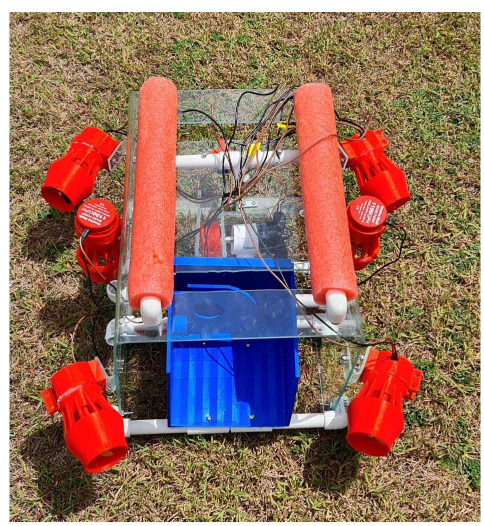
The shape of the ROV was formed largely to accommodate the necessary camera angles in front of, behind, and beneath the ROV while minimizing drag that interfered with surge, pitch, and yaw movements hence the open front, back, and bottom panels and two large rectangular indents along the horizontal at the bottom of the ROV. The closed top panel additionally served to create slightly higher levels of pressure along its underside thus aiding the ROV to maintain an upright orientation alongside the buoyant plastic foam . As an ulterior motive, the rectangular indents function as a convenient and adjustable mounting post for the micro-rov retraction device.



2019 Alpheus 2.0's HDPE chassis (left) vs. Alpheus 3.0's acrylic chassis (right)

➔ Motors

Alpheus 3.0 utilizes six 1100 GPH bilge pumps to maneuver through the water. Four of the motors are oriented at a 45 degree angle at each corner to achieve a vectored drive. Such positioning of these motors allow for more precise movement than can be made by a two-motor linear drive. Precision is important during the product demonstration because of the nature of the missions—retrieving props with the claw—and to avoid knocking over any props that may lead to a penalty. The final two motors are at the center of either side for up/down movement.



Motors oriented at 45 degrees for vectored drive

For safety reasons, all motors are enclosed in 3D-printed Kort Nozzles. These Kort Nozzles also provide additional output thrust. They were designed by "sthone" on Thingiverse.com and licensed under creative commons. Borrowing this design rather than creating custom shrouds was made on the basis of efficiency, convenience, and aesthetic.

Modified bilge pumps with propellers

➔ Cameras

Alpheus 3.0 utilizes three cameras: two on the main ROV and one on the micro-rov. Camera A on the main ROV is mounted on the front with a slight angle downwards. This camera is essentially the "eye" of the ROV to provide sight for the pilot to navigate the waters and perform tasks. The camera's particular position also offers an unobstructed view of the claw for precise retrieval and release of mission props. Camera B is located in the center of the ROV facing downwards. Its sole purpose is to provide sight for flying the transect line and identifying the species. Camera C is mounted on the top front of the micro-rov. As the main rov has no back-facing camera, the micro-rov camera will be used to position its housing in front of the drainpipe, navigate itself towards the sample, and determine if the sample has been secured.

➔ Gripper

The parallel gripper, Alpheus's primary appendage for interacting with the world, is a 3D printed claw managed by an RG SG90 9g servo. The company found it more convenient and less consuming of time and resources to utilize a premade claw design from the Internet (mybotic on instructables.com). The servo that controls the claw is connected to the surface control board via an ethernet cable. It utilizes an Elegoo Mega microcontroller programmed to transmit signals from a SPDT switch to the servo. The two positions on the switch translate to either an opened or closed state.

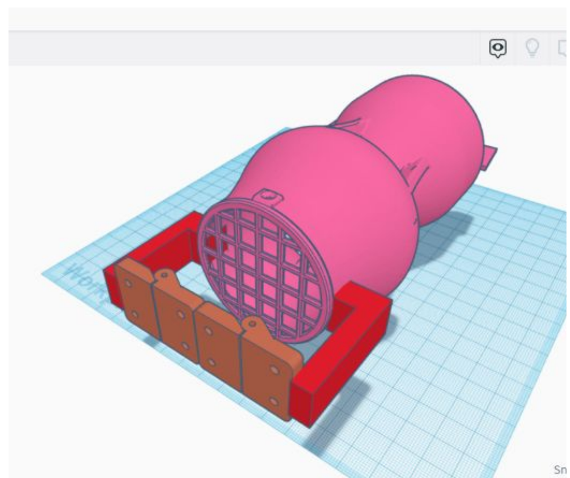
Claw design from mybotic on instructables.com

Use of a servo bears stark contrast to the original and more rudimentary "hydraulic" system of Alpheus 2.0 as the servo was not subject to potential leakage, did not require a proportional amount of strength for actuation, or constant maintenance. Based on the nature of the tasks that require retrieval of certain props, a horizontal orientation of the claw was deemed most appropriate.

➔ Micro ROV

The micro-rov is composed of a single shrouded motor, a camera, and a hinged mechanism for "grabbing" the sample from within the drain pipe. The motor is one of the 500 GPH bilge pumps provided with the Triggerfish kit. Because of the small space in which the micro-rov needs to fit, all degrees of freedom excluding surge were eliminated, as enabling any more would have required at least one other motor in addition to the forward/backward motor. With lack of such movement, a simple hook mechanism would have not been reliable enough to retrieve and return the sample. With limited resources, a remotely controlled mechanism—such as a servo claw—would have created an additional and unnecessary dimension of complexity, requiring us to feed a tether to it and create accommodations on the PCB. Instead, the micro-rov is equipped with a hinge in the front that opens when pushed against the rope handle of the sample. The hinge does not open in the other direction, effectively "trapping" the handle so that the sample can be retrieved.

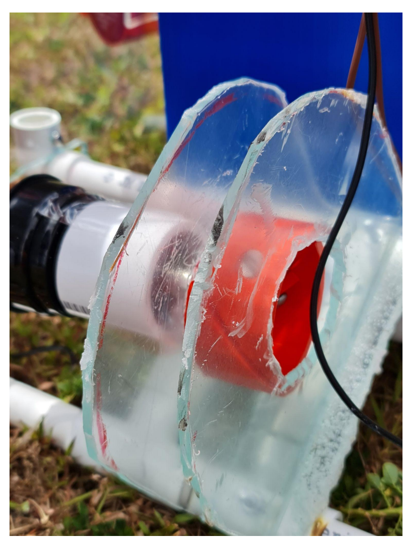
3D-printed Micro ROV Housing



CAD of Micro ROV shroud and hinge mechanism

■ Retracting Mechanism

To facilitate the micro ROV's return to its housing, a 500 GPH motor attached to a 3D-printed wheel retracts and coils the tether. The two motors are controlled by the same sabertooth motor controller and joystick. As the micro ROV thrusts forward, the coil simultaneously releases and vice versa for when the micro ROV thrusts backwards. The coiled tether also acts as a stabilizer for the micro-rov while it sits in its housing. Otherwise, with the housing opened to the water, a loose tether would allow for the micro ROV to slip out and move freely while the main rov is in motion.



Wheel with acrylic guard attached to motor

➔ Control Box

In the previous 2 years Tethys Inc. has been engineering ROV's, the company has used the MATE provided Triggerfish 3.0 control box. Entering the 2020/2021 season with refined experience in constructing ROVs and newfound ambition to go beyond familiarity, the team decided to dedicate focus to designing a bigger and better control box to accommodate improvements made to the ROV itself.

■ Monitors

Housing the PCB, controls, and monitors is a 35 inch rolling Husky toolbox. While the inside of the box is more than enough space for the small PCB and minimal controls, it is the size of the lid on which the monitors would be mounted, that prompted us to choose such a big box. Previous experience with the triggerfish control box proved that the 7 inch TFT monitor was too small and too low quality for the pilot to navigate the ROV accurately and with ease. To resolve this, the company opted in using a donated 24-inch VGA monitor for the main camera display—powered via a wall outlet rather than the MATE power supply—accompanied by the same 7-inch Triggerfish monitor for supplemental and micro-rov camera feeds.

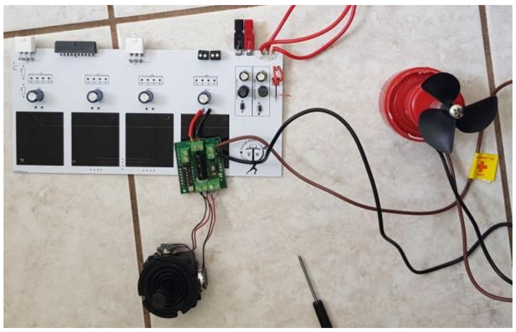
3 monitors mounted onto the lid of the control box

The 35 in. Husky rolling toolbox housing the ROV controls

■ Custom Printed Circuit Board

Inarguably the most challenging aspect of reimagining our own control box was designing the Printed Circuit Board that would bring the entire system to life. Each member had little to no experience or knowledge in electrical engineering. However, the ambition to do something never achieved before by a Guam team was enough to disregard that fact. Deconstructing the Triggerfish control box and referring to the assembly guide document provided by MATE provided a deeper understanding of how the familiar control box and its components functioned. This supplied the necessary foundation to jump start further research via the Internet.

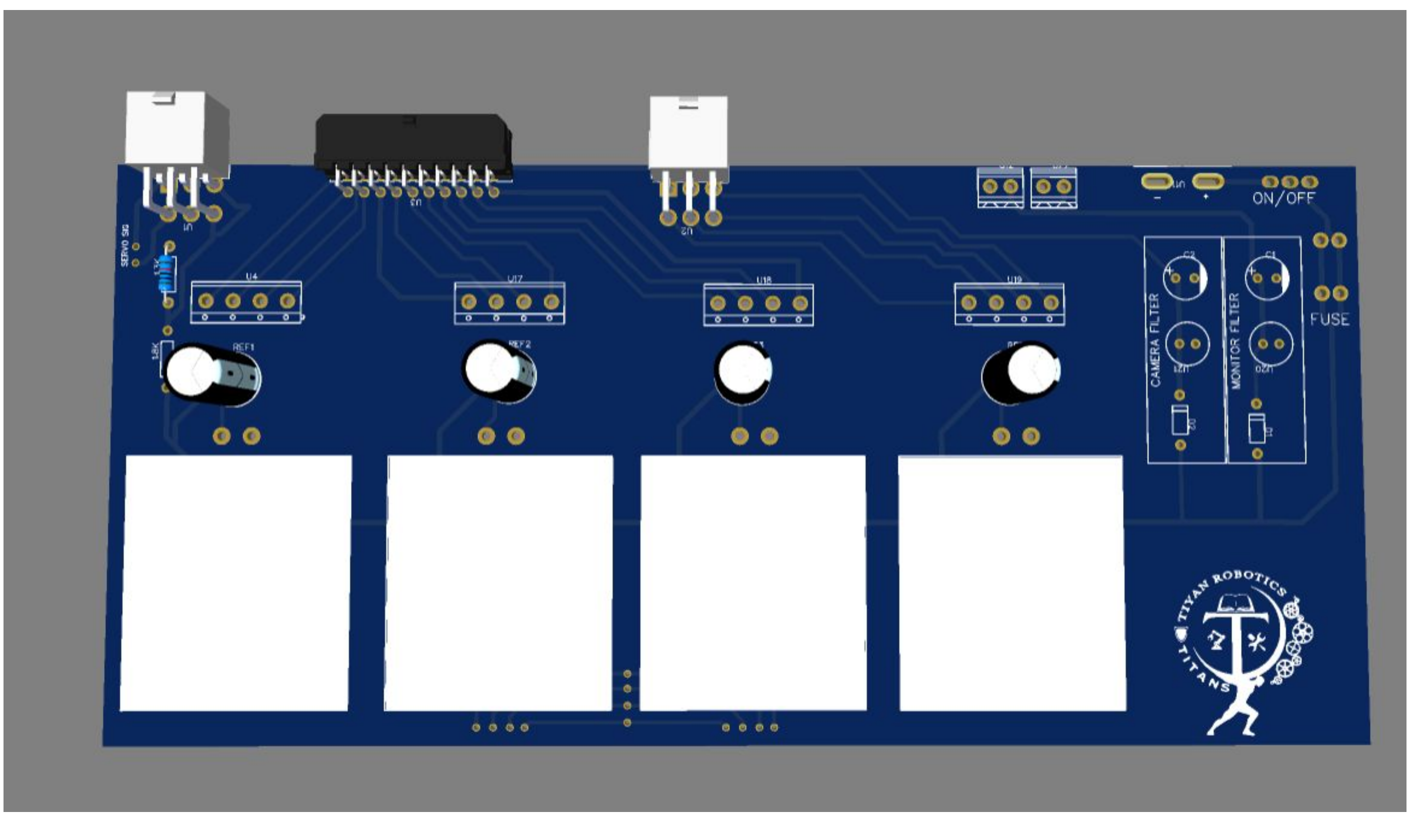
The company used EasyEDA to design the PCB Gerber file as well as its sister companies: JLCPCB for the manufacturing and LCSC for the electrical components. The PCB takes in—via crimped housing terminals—8 motors, 2 TFT monitors, 3 cameras and 2 servos. Efficiency, usability, and adaptability were all considered when designing the PCB. It needed to allow for easy assembly and troubleshooting, hence using screw terminals for most external components rather than committing them to the board via soldered wires. To make most of the effort and money that went into it, the control box also needed to be able to be used in the upcoming years rather than a single season. For this reason, the PCB takes in more monitors and servos than is used on Alpheus 3.0 should future ROVs call for such.



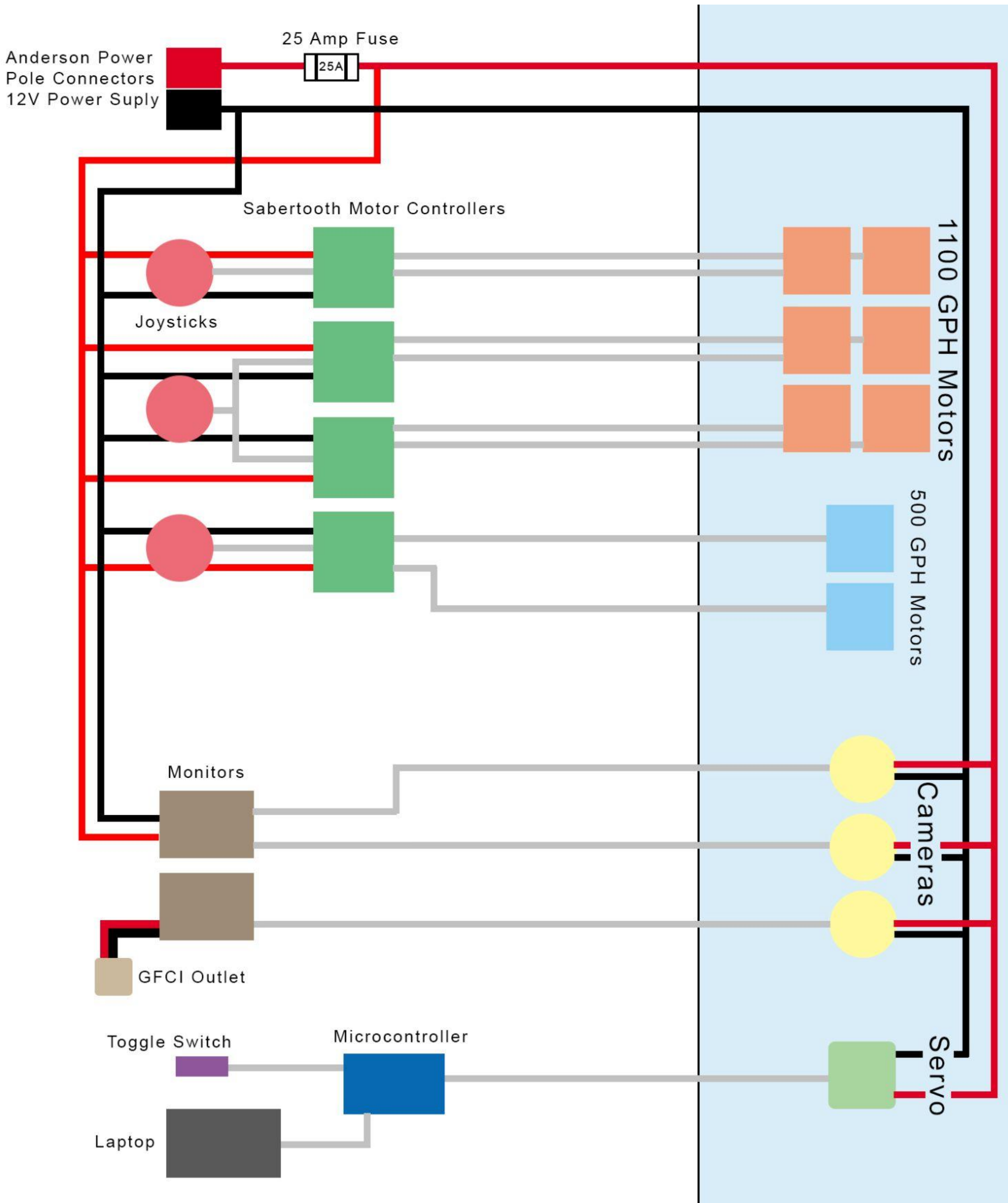
Beginning of the testing phase

Final, printed circuit board

3D CAD of PCB design



System Interconnected Diagram



Fuse Calculations
1100 GPH Motors: 3A*6
500 GPH Motors: 2.5A*2
Cameras: .0.5A*3
Servo: .5A

Total 25 Amps
25A * 150% = 37.5A

> 25 Amp Fuse

Safety

During the engineering process, multiple considerations were made to ensure all components of the ROV are safe for use. These considerations include but are not limited to: shrouded motors, strain relief on the tether, hot-glued and heat-shrinked electrical connections, and adequate fuse on the electronics.

Prior to any use of the Alpheus 3.0 ROV, the demonstration team conducts a visual and tactile inspection of the ROV, the tether, and the control box. The team checks that all joints and connections are secure, wires are unexposed, and there are no loose parts. To ensure that no safety inspection step is missed, the team will refer to the following checklist.

- All joints, bolts, and nuts are tight and secured
- Motors are completely enclosed by the shrouds
- No exposed wiring on the ROV, tether, or control box
- The appropriate fuse is included in the power connection
- Tether and other wiring is untangled and manageable
- Deck team is following the dress code (close-toed shoes and no loose-fitting clothing)
- No power is running through the system until ready for launch

Troubleshooting and Challenges

➔ Technical

With very little experience in designing custom PCBs, issues were bound to arise. Upon receiving and attempting to assemble the PCB, the team discovered that while all other areas were functioning, once the camera filter components were added, voltage throughout the entire system ceased to exist. After conducting further research and comparing the camera filter on the Triggerfish circuit board to Alpheus' board—which in hindsight should have been done prior to finalizing the design—the issue was clear. The tracing for the inductor was done incorrectly. While it would have been an easy fix to change the orientation of the inductor on the manufacturer file, ordering a new set of boards would have been a costly expense.

Rather than starting anew or scraping the idea of a custom board altogether, the electrical engineer came up with the idea to reroute the camera filter system to a blank circuit board and then back to the PCB, which worked and allowed the company to proceed with the project.

This was not the only issue that arose regarding the PCB but it was the one that made the entire project come to a halt. To address other minor issues, troubleshooting methods were employed: adding each component one by one, using different components, using a multimeter, etc.

➔ Non-Technical

During the 12 total months Tethys Inc. has worked on Alpheus 3.0, two main challenges were presented. The first was funding. To achieve the aforementioned ambitious improvements would require a larger expense than reusing old materials would. With the limited manpower and opportunity to fundraise, a large portion of the funds had to come out of team members' pockets.

The second challenge was scheduling and meeting up during a global pandemic. In the first few months after returning to competing, the team could only meet once a week for 6 hours. This posed a substantial threat to the productivity potential, especially given the fact that majority of the work needed to be done in person. In order to capitalize on the short time allotted each week, the team would strategize and distribute specific goals for the day.

Company Reflection

Committing over 100 hours of work on campus and even more at home, Tethys Inc has practiced resilience against adversity. The company managed their time well and worked together to overcome obstacles with their critical thinking, innovation, and compromise. The company has improved from last season's poor time management and team communication. By stepping out of their comfort zones and risking easier routes, they have learned valuable electronic and engineering skills that may be advantageous in future endeavors, if not day-to-day life.

Future Improvements

Learning from mistakes is a vital part of the company's continuation into the next seasons. Future improvements can help improve the chances of success. Such improvements include: managing time more efficiently; being more diligent and comprehensive of online sources; and being more mindful and understanding of the science behind the project rather than pure guesswork.

Acknowledgements

At this point, Tethys Inc. would like to acknowledge and appreciate the following individuals and organizations: Coaches Mrs. SND and Mr. Borja for their immeasurable support and guidance; fellow Tiyan Robotics Club members for their help in fundraising efforts; the Guam Department of Education for the materials provided; and the Marine Advanced Technology Education for the opportunity to compete.

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Budgeting

Tethys Inc 2020-2021 Budget				
Income				
Source				**Amount**
Jamaican Grill Plates Fundraiser				$200
Chuck E Cheese Night				$130
Expenses				
Category	**Type**	**Description**	**Projected Cost**	**Budgeted Value**
Hardware	Reused	500 GPH Motors	$70	-
Hardware	Purchased	New Motors	$120	$120
Hardware	Purchased	Acryllic sheet	$60	$60
Electrical	Purchased	Custom PCB and parts	$200	$200
Hardware	Purchased	Control Box	$40	$40
Attachments	Purchased	Servos	$20	$20
Sensors	Reused	Cameras	$180	-
Hardware	Donated	PLA Filament	$90	-
		Total Income		$330
		Total Expenses		$780
		Total Reuse/Donations Expenses		$340
		Total Fundraising Needed		$440

Project Costing

Tethys Inc 2020-2021 Project Costing				
Income				
Source				**Amount**
Jamaican Grill Plates Fundraiser				$140
Fright Night				$225
Holiday Festival				$212
Titans Live				$209
Chuck E Cheese Night				$123
Expenses				
Category	**Type**	**Description**	**Notes**	**Amount**
Hardware	Reused	500 GPH Motors		$70
Hardware	Purchased	1100 GPH Motors	New Motors	$96
Hardware	Purchased	Acryllic sheet	2x for chassis and control box	$76
Electrical	Purchased	Custom PCB and parts	Including shipping	$151
Hardware	Purchased	Control Box		$60
Attachments	Purchased	Servos		$20
Sensors	Reused	Cameras	Reused	$180
Hardware	Donated	PLA Filament	For 3D printing	$90
Electrical	Purchased	Microcontroller		$30
Hardware	Purchased	500ft Cable	Motor Tether	$90
Hardware	Purchased	100ft RCA Cable	Camera Tether	$17
Hardware	Purchased	100ft Cat6	Servo tether	$20
		Total Raised		$908
		Total Expenses		$900
		Total Reuse/Donations Expenses		$340