ECHO
TECHNOLOGIES

IDEAS WORTH HEARING

SYSTEMS PERFORMANCE SPECIFICATIONS

"Design of a product, development of a person."

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COMPANY PROFILE

MISSION STATEMENT

ECHO Technologies seeks to surpass industry standards and achieve excellence as an engineering business by promoting student led discovery in the development of technical solutions, education of communities, and the growth of individual persons.

VISION STATEMENT

To create ideas worth hearing that inspire the communities we serve, through the products we develop, and the leaders we cultivate.

JOB DESCRIPTIONS

PROJECT MANAGER (PM)

Ada Saing

The Project Manager leads the team in completing the overall mission. They spearhead in delegating tasks and keeping the team on schedule throughout the year. The project manager helps fulfill all the department's needs for the mission, and brings the multiple aspects of the company together. They are responsible for being the main authority of the company and addressing any concerns of the company to CARPA.

DEPUTY PROJECT MANAGERS (DPM)

Catherine Horkay (Aerial DPM)

The Aerial Deputy Project Manager is the head of Subsystem 1. This DPM must oversee all flight above water, federal regulations for the aforementioned, and the complete development of the machines' aerodynamics. The Aerial DPM is also one of the Megalodon's pilots. In tandem with the Aquatic DPM and the Project Manager, the Aerial DPM works as a member of upper management.

Celia Yu (Aquatic DPM)

d

The Aquatic Deputy Project Manager is the head of Subsystem 2. Responsible for overseeing the function of the Megalodon's performance underwater, this individual spearheads the development of the machine's hydrodynamic efficiency. In tandem with the Aerial DPM and the Project Manager, the Aquatic DPM works as a member of upper management.

CHIEF SCIENTIST

Michael Nightingale

The Chief Scientist oversees the use of the Design Process. This includes recording all ideas and ensuring professional documentation of proprietary information. This individual works closely with the Systems department to ensure the technology used on the solution addresses all constraints and specifications. Ultimately, the Chief Scientist is responsible for the final design solution.

DIRECTOR OF MEDIA

Leo Tafoya

The Director of Media is responsible for the development of the ECHO Corporate identity (logos, branding, badges, etc.). They are tasked with overseeing the presentation of all company documents, formal presentations, and the Trade Expo display. They also must produce a nine to ten minute documentary film that outlines the development of the project in a chronological fashion.

DIRECTOR OF PUBLICATIONS

Phuong Uyen Nguyen

The Director of Publications is in charge of the development and formation of all official company documents and publications. These include but are not limited to the Systems Performance Specifications Document and the Proof of Concept Document. They are tasked with aiding in all written materials and acting as a final editor.

CHIEF FINANCIAL OFFICER

Nikki Hasson

The Chief Financial Officer manages ECHO Technology's budget, manages the financial team, acts as a liaison between ECHO and the CAMS Administration, researches supply companies, determines the most cost efficient resources, processes reimbursements, organizes fundraisers, provides monthly financial reports, and approves all company purchases.

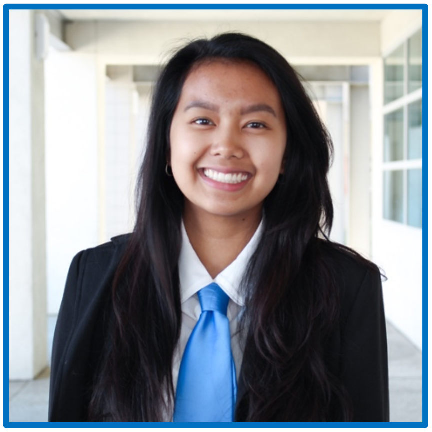
FINANCIAL OFFICERS

Alondra Jacinto, Katie Thoi

The Finance Team is tasked with assisting the Chief Financial Officer (CFO) with producing budget lists, ensuring financial documentation, and presenting proposals to companies and investors. These tasks aid in the development and execution of fundraising and sponsorship events that support the team financially.

DIRECTOR OF OUTREACH

Joachim-Anne Aguilar



The Director of Outreach is in charge of executing community outreach and representing the company at elementary and middle schools. They are tasked with planning STEAM-based events made to educate the youth through interactive presentations and collaborative activities.

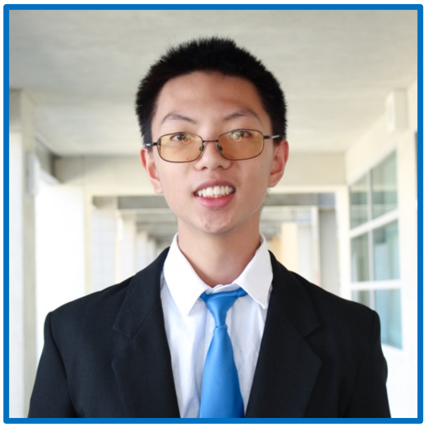
OUTREACH OFFICERS

Beverly Biscocho, Martin Perez

The Outreach team educates middle and elementary school students through STEAM-based activities to encourage them to pursue a future in those fields. The team provides students across the South Bay area an interactive & hands-on experience with robotics, engineering and technology.

DIRECTOR OF SYSTEMS ENGINEERING

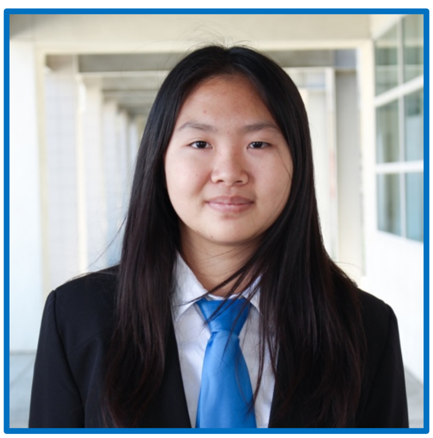
Sean Sng

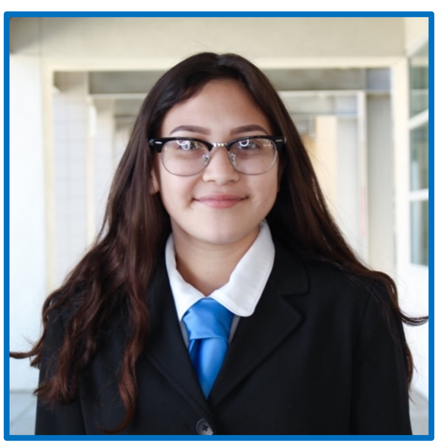


The Director of Systems is responsible for leading the Systems Team and providing the system architecture of the proposed design solution. This individual selects and controls parts and specifications in order to achieve coordination of multiple system components.

SYSTEMS ENGINEERS

Cynthia Lin, Alondra Martinez

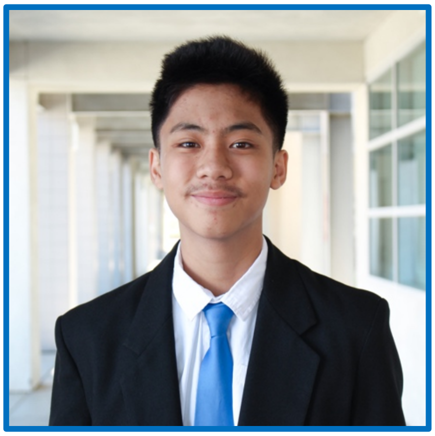




The Systems Team supplies the system architecture of the suggested design solution. This team selects the components that will be used in the mechanism and provides technical specifications data to support these choices. They are also responsible for the provision of a systems architecture chart to illustrate the hardware systems and how they interlink with the affected components.

STRATEGIST

Brad Biscocho



The Strategist is responsible for devising the plans for approaching the tasks and mission parameters. This person coordinates with the Chief Scientist, to develop the best strategy and approach to the mission. They are tasked with working closely to the Systems Department to understand the Megalodon and its full functions and capabilities in regards to the mission.

QUALITY ASSURANCE OFFICER

Adrian Mazas

The Quality Assurance Engineer works with the Test Engineer as well as the Systems Engineers to devise adequate testing procedures for the components used, as well as the mechanism itself. Quality Assurance will verify that all components, mechanical and electrical, will function as intended for the task. This individual will also work with mechanical team and review all technical drawings produced by the team and is responsible for checking all manufactured parts for quality and accuracy.

RISK MANAGEMENT OFFICER

James Runia

The Risk Management Officer is responsible for researching and implementing practices for identifying potential risks and hazards to the success of the project build. This individual is also responsible for the reviews and implementation of safety protocol and ensures the documentation and mitigation of workplace accidents and unsafe practices.

TEST ENGINEER

Jason Chang

The Test Engineer is responsible for the testing and reviewing of all individual components to ensure they function under certain conditions in the field. Working with the Systems Engineer and Chief Programmer, they create procedures and testing environments to evaluate durability, speed, longevity, and other aspects of the product.

DIRECTOR OF MECHANICAL ENGINEERING

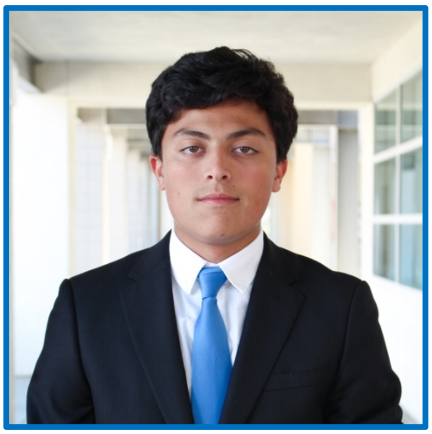
Marcello Cubillos

The Director of Mechanical Engineering is responsible for ensuring the design ideas come into fruition by translating concepts into realistic mechanical systems. This individual leads his Mechanical team by delegating tasks including computer-aided design (CAD) modeling and assembling of the proposed design solution.

MECHANICAL ENGINEERS

Bryan Tran, Caleb Bryson, Fidel Martinez, Yoseline Prado

The Mechanical team is responsible for the design of the robot's individual mechanical systems, including but not limited to: the additive ballast system, the drone/ROV frame, the thrusters, and the central control and computing capsule (CCCC). To design these systems, these individuals implement CAD across multiple software suites. They thoroughly implement the design process as specified in the Society of Automotive Engineers (SAE) standards to ensure that the robot is designed for maximum efficiency and holistic execution.



DIRECTOR OF ELECTRICAL ENGINEERING

Isaac-Neil Zanoria

The Electrical Director is mainly responsible for the designing, wiring, and documenting the Megalodon's onboard electronics, including all sensors, programming boards, locomotion, articulation, and power. They are directly tasked with deciding what source of power will be the most efficient for the mission, considering each task needed to be completed.

ELECTRICAL ENGINEERS

Christina Kim, Marinel Jorgensen

The electrical team is responsible for determining how the Megalodon will be powered. This team works closely with the Director of Electrical to decide which components will work best for the robot under multiple conditions. The electrical team must coordinate how to provide power to the Megalodon in both aquatic and aerial mediums. Team responsibilities also include creating electrical schematics of the system, wiring the electronics, and collaborating with the programming team to produce communications protocols.

DIRECTOR OF MANUFACTURING

Jesse Leal

The Director of Manufacturing is primarily responsible for organizing and executing standard manufacturing procedures to complete the mission. Working closely with the Chief Scientist and Director of Mechanical Engineering construct machining procedures and aid in design development of all products at industry-level standards.

MANUFACTURING ENGINEER

Joshua Rosario

The Manufacturing team is tasked with finding the optimal materials for use in the project. The Manufacturing Team works closely with the Director of Manufacturing to determine methods of machining necessary components. The team will take into account the viability of using different machining styles in order to deliver components. The team additionally communicates with members of other teams, especially the Mechanical team members, to provide a coherent and stable build.

DIRECTOR OF PROGRAMMING

Ted Lin

The Director of Programming organizes the development of software for the robot and communicates with the Chief Scientist and Systems engineers to ensure that the strategy is feasible and the overall design solution is controllable. Working with the Electrical team, they ensure that the Programming team has the necessary hardware, including processors and sensors, to implement the robot software.

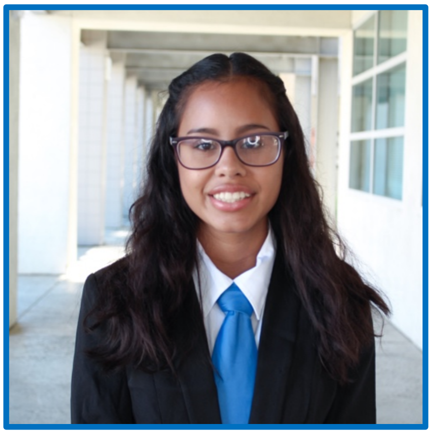
PROGRAMMING ENGINEERS

Itohan Ero, Yajiara Ramos, Sammy Umezawa

The Programming team develops the robot's central operative core. The team is responsible for coordinating the control of individual components to help the robot achieve its ultimate goal. This includes communications with mission control, interfacing with hardware, calculation of the robot's position and orientation in 3D space relative to the field elements, and high-level control algorithms. The Programming team is also responsible for development of the official Echo Technologies website.

DIRECTOR OF INTERNS

Ivonne Munoz



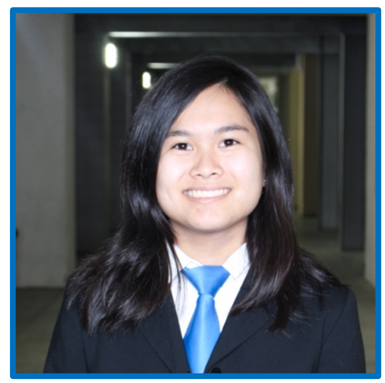
The Director of Interns is responsible for ensuring that the interns complete all tasks essential to their part of the mission. The Director of Interns must articulate the objectives, plan schedules, and delegate tasks. In addition, the Director is required to work collaboratively with Echo Technologies and the company interns in order to ensure that the Remora and Megalodon efficiently work in tandem with one another.

INTERNS

Echo Technologies has tasked company interns to aid in Project Azorian. The interns are responsible for the design and the development of a waterproof Remotely Operated Vehicle (ROV) also known as "Remora" capable locating the wreckage sight, signaling the Megalodon, and detecting "radioactive" objects during the mission. The intern team is required to work collaboratively with Echo Technologies to effectively complete their robotic suite.

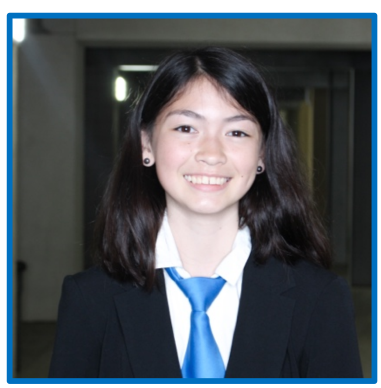
Tuan Ha

Kyle Takata



Kaitlyn Lee

Silas John



Kira Williams

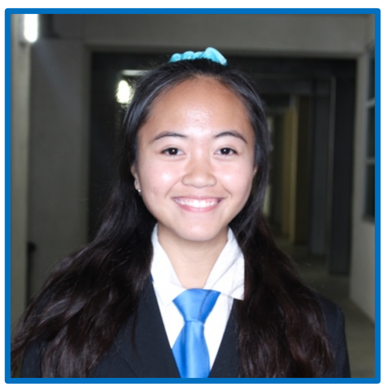
Josef Kirkman

Shohan Ramesh

Tommy Pho

Sean Yamaguchi

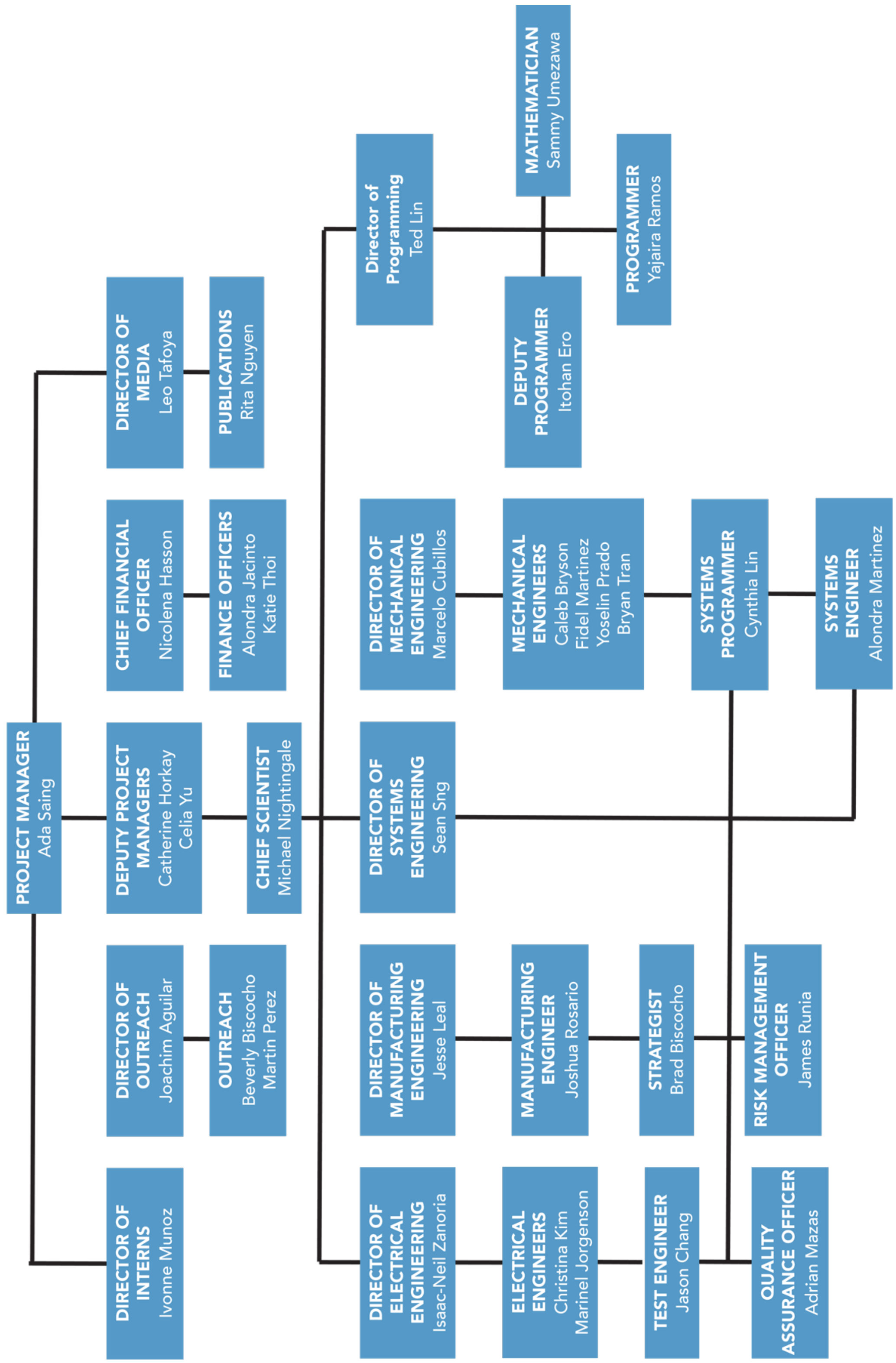
Ashley Son



Giannka Picache

Ellie Matsuno

COMPANY ORGANIZATION CHART



TASK DYNAMIC ASSESSMENT CHART

NAME	SYSTEMS	CAD	MASTERCAM	3D PRINTING	MECHANICAL	MANUFACTURING	ELECTRICAL	PROGRAMMING	FINANCE	MEDIA
Aguilar, Joachim									■	■
Biscocho, Beverly									■	■
Biscocho, Brad	■	■			■	■				
Bryson, Caleb		■			■					
Chang, Jason		■		■	■					
Cubillos, Marcelo		■	■	■	■	■				
Ero, Itohan			■					■		
Hasson, Nikki									■	■
Horkay, Catherine		■							■	■
Jacinto, Alondra									■	■
Jorgenson, Marinel					■		■			■
Kim, Christina					■		■			■
Leal, Jesse		■	■	■		■				
Lin, Cynthia								■		
Lin, Ted								■		
Martinez, Alondra	■	■	■		■				■	■
Martinez, Fidel		■			■					
Mazas, Adrian	■	■			■				■	■
Munoz, Ivonne		■	■		■					
Nguyen, Rita										
Nightingale, Michael	■	■		■	■	■			■	■
Perez, Martin										
Prado, Yasolin		■			■					
Ramos, Yajaira		■						■	■	■
Rosario, Joshua		■	■			■				
Runia, James	■	■	■							
Saing, Ada									■	■
Sng, Sean	■	■								
Tafoya, Leo									■	■
Thoi, Katie									■	■
Tran, Bryan		■	■		■					
Umezawa, Sammy								■		
Yu, Celia	■	■			■		■		■	■
Zanoria, Isaac-Neil		■			■		■			

MISSION OVERVIEW

PROBLEM STATEMENT

The primary objective of ECHO Technologies is to develop a vehicle capable of flight and underwater control that can be deployed autonomously and wirelessly to inspect and collect items from the ocean floor.

Previous ocean floor inspections, sampling, and recovery operations have been done by deploying a ship with a tethered vehicle to dive to the ocean floor. However, this method cannot be done without drawing unwanted attention to a potentially proprietary mission given a large ship is visible for all to see. Today's technology still has not yet offered a solution as radio waves fail to penetrate the water to any useful depth.

ECHO Technologies intends to design and build a UAV/UUV that can be deployed autonomously and wirelessly by using cutting edge sensors and programing along with a stable drone platform that can be used to secretively inspect the ocean floor.

DESIGN BRIEF

CAMS Advanced Research Projects Agency (CARPA) Initiative has tasked ECHO Technologies to design and build a UAV/UUV vehicle named Megalodon that can recover the items of interest from the K-129 crash site after pinpointing a signal from a UUV vehicle named Remora that located those items of interest and recovered the radioactive items.

This mission is an attempt to recover the leftover parts from a nuclear capable K-129 crash that the CIA failed to completely recover the ocean floor. As a ship was raising the K-129 from the ocean floor, it broke apart and part of the submarine was lost.

The mission will begin with the Megalodon picking up and placing Remora into the water to locate the crash site. Once the crash site is located, Remora will recover the radioactive items after inspecting the crash site with a UV light and then rise to the surface to signal for the Megalodon. The Megalodon will then transition to underwater, and swim to the crash site to recover the remainder of the K-129. The Megalodon will deposit the parts it collects before coming back for Remora where it picks Remora up and travels back to land.

CONSTRAINTS:

- Funding **(under $10,000)**
- Time **(263 days as of 9/6/18)**
- Weather **(wind, temperature)**
- FAA Regulations
- Need pool for testing
- Megalodon cannot use a tether

DELIVERABLES:

- **The Megalodon mechanism must:**
  - Be completely waterproof
  - Be capable of flight, in dual fluid mediums
  - Fly 201.9 feet in the air to the pool, locate the pool, and dive into the pool, swimming to the wreckage
  - Manipulate recovery articulation
  - Be able to detect the beacon of the Remora, and retrieve it, once the salvage operation is complete
- **The Remora mechanism must:**
  - Be completely waterproof
  - Be able to locate the wreckage site through a live video feed
  - Provide a beacon for the Megalodon device
  - Recover the radioactive items of interests

    - Be able to detect radioactive activity, with UV light

- **Additional Deliverables:**
    - Development of a communication method that will work between 100-3000Hz

EXECUTIVE SUMMARY

ECHO Technologies is currently developing recovery vehicle technology that will allow salvage operations to be done in the safest manner with minimal damage. We have designed a hybrid multi-purpose Aerial Assault Vehicle/Unmanned Underwater Vehicle system (codenamed Megalodon) that is capable of flight in multiple fluid mediums. In addition, company interns will design and develop a Remotely Operated Vehicle (codenamed Remora), capable of locating the wreckage site and signaling the Megalodon. In this simulated mission "Project Azorian", Megalodon and Remora will work collaboratively to locate and recover the objects of interest.

The objects of interest will be placed in an unknown location underwater. Using signals and live feed provided by the Remora, Megalodon will be able to locate the wreckage site. Then, Megalodon will use a dustpan like mechanism to obtain the objects of interest, fly them out of the water to safety, and drop the salvage atricultation to pick up the Remora, and return to base.

ECHO Technologies is fully responsible for raising funds and managing financial assets throughout the process of completing the mission. In order to meet funds necessary, third party companies will be contacted and various fundraisers will be held. The financial team will keep a record of all expenses and will make certain that all financial matters are properly executed and authorized.

In addition, our company will conduct outreach events for future STEM students in elementary and middle schools. These events will allow for students to participate in STEM related activities, and through these activities, we hope to challenge and inspire new generations of engineers.

ECHO Technologies strives to improve the general quality of life. We seek to surpass today's technological innovations. This project will motivate us to create ideas worth hearing, and inspire the communities around us.

ENGAGEMENT MANAGEMENT PROCEDURE

Throughout the course of the project, ECHO Technologies is subject to the following performance reviews set by the CARPA Initiative:

IN PROCESS REVIEW (IPR)

Informal weekly reports within the company to assess the progress of the project. This is done in order to ensure that the company stays on schedule to complete the project by the projected mission date.

PERIODIC DESIGN REVIEW (PDR)

Formal monthly meetings held with the customer to demonstrate the progress of individual subsections within the company. Management is responsible for reviewing all work done by the subteams in order to ensure it meets company standards.

CRITICAL DESIGN REVIEW (CDR)

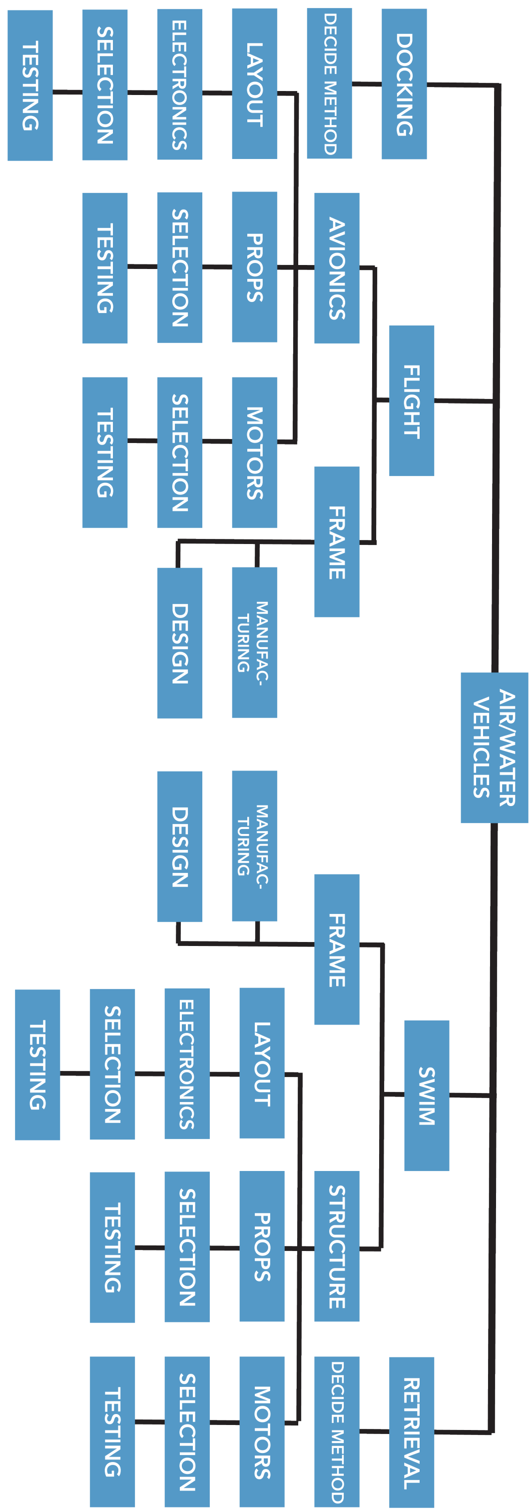
Major design review period occurring a total of five times throughout the course of the project. These reviews are the times in which deliverables will be graded, and a panel of 3rd party representatives evaluate the solution proposed.

The five CDRs that will take place are:

1. Systems Performance Specification **(SPS)** and Presentation
2. Proof of Concept **(POC)** Presentation and Demonstration
3. First Article and Technical Data Package **(TDP)**
4. Mission Performance
5. Engineering Design & Development **(EDD)** Expo and Presentation

TIMELINE

WORK BREAKDOWN SCHEDULE



SCOPE OF WORK

There will be five Critical Design Review (CDR) periods where the major deliverables will be presented and reviewed. Based on the assessment of each team's proposals, there will be a designated winning team for each CDR. The team that amasses the most points during the CDRs will be awarded the "contract" and determined to be the overall winner for the 2019 CARPA Challenge.

SOFT DELIVERABLES

CDR 1: Systems Performance Specifications (SPS) (11/15/18)

- SPS Proposal Document
- SPS Proposal Presentation
- Year Long Schedule
- Work Breakout Structure Diagram
- Proposed Budget/ Bill of Materials
- Professional Input Survey
- Test Schedule and Procedures

CDR 2: Proof of Concept (POC) Presentation and Demonstration (01/24/19)

- Proof of Concept Document
- Proof of Concept Presentation
- Prototype Demonstration
- Revised Test Schedule and Procedures

CDR 3: First Article & Technical Data Package (TDP) (04/18/19)

- Technical Data Package
- Final Design and Bill of Materials
- Test Requirements

CDR 4: Mission Performance (05/11/19)

- Mission Execution Off-Campus

CDR 5: IDP Trade Expo and Presentation (05/30/19)

- Functional Product
- Team Portfolio: Digital Documentary
- Engineering Notebook
- Computer Science: "Demo" Firmware Program
- User Manual

HARDWARE DELIVERABLES

CDR 3: First Article & Technical Data Package (TDP) (04/18/19)

- Megalodon (UAV/UUV)
- Remora (ROV)
- Packaging
- Accessory Components

YEARLONG WORK SCHEDULE

	NOT COMPLETE
	IN PROGRESS
	COMPLETE

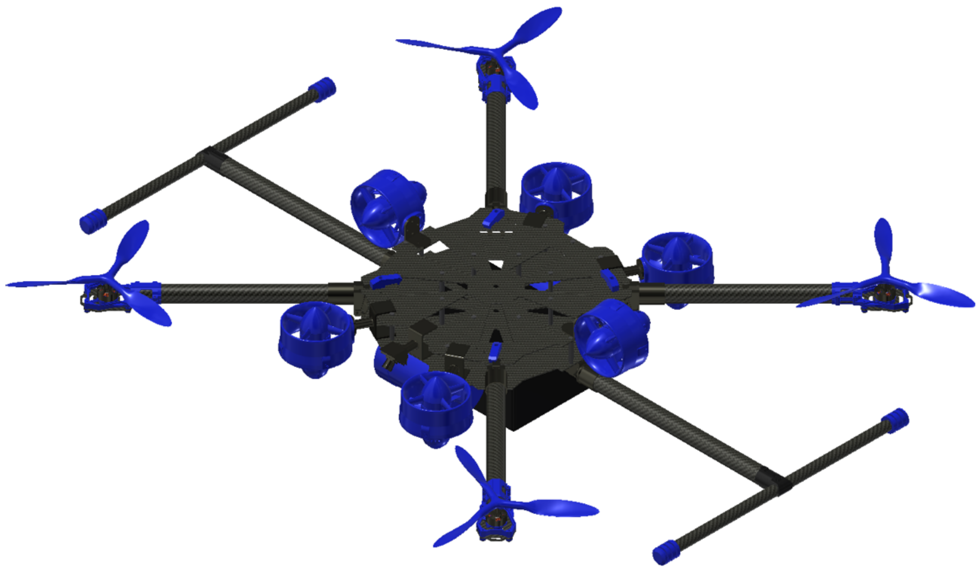
ITEM	TASK		% COMPLETE	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.
1	**CDR 1: SPECIFIC PERFORMANCE SPECIFICATIONS (SPS)**		**100%**									
	COMPANY PROFILE	MISSION & VISION STATEMENTS										
		JOB DESCRIPTIONS										
		COMPANY ORGANIZATION CHART										
	MISSION OVERVIEW	PROBLEM STATEMENT										
		DESIGN BRIEF										
		EXECUTIVE SUMMARY										
		SCOPE OF WORK										
		RISKS & ASSUMPTIONS										
		ENGAGEMENT MANAGEMENT PROCEDURE										
	TIMELINE	WORK BREAKDOWN SCHEDULE										
		YEARLONG WORK SCHEDULE										
	PROPOSED DESIGN SOLUTION	DESIGN OVERVIEW										
	QUALITY ASSURANCE	TESTING & PERFORMANCE										
		RISK ASSESSMENT CHART										
	RESEARCH	MARKET SURVEY										
		PATENT SEARCHES										
	FINANCING	BILL OF MATERIALS										
		FUNDRAISING REPORT										
		BUDGET REPORT										
	CARPA APPROVAL											
	SPS ROUGH DRAFT											
	SPS PRESENTATION											
2	**CDR 2: PROOF OF CONCEPT (POC)**		**10%**									
	FINAL COMPUTER AIDED DESIGNS											
	PROTOTYPE: MEGALODON											
	PROTOTYPE: REMORA											
	SUBSYSTEMS TESTING											
	PROCEDURES											
	TEST DESIGNS											
	ANALYZE RESULTS											
	REVISIONS TO DESIGNS											

ITEM	TASK		% COMPLETE	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.
	TEST REVISED DESIGNS											
	ANALYZE & SUMMARIZE RESULTS											
	FINAL REVISION											
	POC ROUGH DRAFT											
	POC FINAL DRAFT											
	PREPARATION											
	PRESENTATION											
3	**CDR 3: TECHNICAL DATA PACKAGE**		0%									
	FINALIZED MEGALODON DESIGN											
	FINALIZED REMORA DESIGN											
	ASSEMBLY											
	FINALIZE PART DRAWINGS											
	FINALIZE BILL OF MATERIALS											
	TEST REQUIREMENTS											
	ROUGH DRAFT OF DATA PACKAGE											
	FINAL DRAFT OF DATA PACKAGE											
4	**CDR 4: MISSION PERFORMANCE**		0%									
	SCENARIO											
	COMPLETION											
	SENSOR EXPO											
5	**CDR 5: TRADE EXPO**		0%									
	MEGALODON											
	REMORA											
	ENGINEERING NOTEBOOKS											
	PERFORMANCE											
	SCENARIO/STRATEGY											
	PACKAGING											
	USER MANUAL											
	SOFTWARE PROGRAMS											
	DOCUMENTARY											
	TEAM PORTFOLIO											

PROPOSED DESIGN SOLUTION

DESIGN OVERVIEW

Project Azorian requires two vehicles working together to locate and recover remains of a K-129 submarine on the ocean floor. Echo Technologies is developing two separate underwater vehicles to accomplish this task. The first is named Remora which will be able to locate the crash site on the ocean floor signal for the second vehicle and collect the radioactive parts of the K-129. The second vehicle is named Megalodon which will carry the Remora near the crash site and drop it into the water. After receiving a beacon from the Remora, it will enter the water and collect the non-radioactive parts at the crash site. The Megalodon will then leave the water to pick up Remora and fly back to land to deposit the objects of interest.



[FIGURE 1: Megalodon UAV/.UUV Design**]**

(FIGURE 1) ECHO Technologies' approach for the Megalodon is to use a carbon fiber frame that serves as a durable, large, and lightweight platform to mount four air motors, six underwater motors, an ABS watertight enclosure, as well as an articulated mechanism to recover the objects of interest. When picking up the objects of interest off the ocean floor, it is likely our vehicle will become negatively buoyant. For this reason, the Megalodon will be equipped with C02 cartridges that feed into two ballast tanks, ensuring the Megalodon will be able to reach the surface. This design gives us the performance we will need to meet the mission deliverables. The mission will be completely autonomous through use of environmental sensors as opposed to constant communication, given that today's technology does not permit communication with the Megalodon deep on the ocean floor.

The Megalodon will implement an aerial quadcopter drone and a 4 motor underwater ROV system. The quadcopter design consists of four motors with a low center of gravity which is proven to be a stable and maneuverable platform while carrying significant payloads. The six motor ROV system is a popular and simple option for underwater control as it is a neutrally buoyant design, with four motors controlling up and down, roll and pitch, and two forward mounted motors with differential thrust for control on the horizontal plane. Both of these subsystems, aerial and underwater, will provide sufficient power for a lightweight vehicle that can carry a large pound payload.

The watertight electronics enclosure is the heart of the Megalodon. It will hold the batteries to power the Megalodon, various Raspberry Pi processors, orientation sensors for the air and underwater, and a programmable flight controller. The programmable flight controller allows the Megalodon to be operated autonomously with a pilot in a position to override the system in case there is loss of control. In addition, the electronics enclosure will provide a minimal of buoyant force, making it appropriate for the weight requirements of our vehicle.

The C02 canister ballast system works by opening valves on the top of the ballast tanks to let water in, thus becoming neutrally buoyant to dive to the ocean floor. When the Megalodon needs to resurface, a servo actuated C02 valve will blast the water out of the tank through holes located on the bottom of the ballast tanks. The buoyant force will be enough to rise the Megalodon to the surface and lift the aerial propellers and motors out of the water which will then take over, allowing the Megalodon to fly. This will also act as failsafe mechanism incase the Megalodon becomes stuck or is unresponsive on the ocean floor. A timer will be set that can initiate the C02 cartridges.

The objects of interest are of unknown sizes but it is predicted the hull of the K-129 is about 15 inches long with a diameter of 3 inches. Missiles scattered along the ocean floor are expected to be 8 inches long with a one inch diameter. In order to accommodate the uncertain sizes and weights of the various objects, Echo Technologies has developed a unique approach to the recovery mechanism. This approach is similar to that of a dustpan scraping along the ocean floor with a large rotating paddle pushing the different sized objects further back and securely into the Dustpan. This mechanism has a durable yet lightweight aluminum frame with a metal screen allowing water and air to pass through but not the missiles and hull of K-129. In addition, the Megalodon will be equipped with a camera providing vision to identify the parts on the ocean floor allowing the Megalodon to approach and collect these objects of interest. As a result, this will be a simple yet effective, lightweight solution to collecting different and unknown sized objects.

REMORA

The Remora designed by ECHO Technologies follows a simple UUV design using six motors. Four motors supply power to keep the Remora at a certain vertical position while the other two motors give the vehicle a differential thrust capability allowing movement in the horizontal plane. To communicate with Remora, Echo Technologies will use a tether that will allow for live video feed through two cameras, one mounted forward and the other mounted backwards. The recovery mechanism to retrieve the objects of interest will have two claws side-by-side to minimize the twisting once it grabs onto a missile. The missile will then be stored in a protected area onboard the Megalodon so it can recover multiple missiles at a time. A day-brite UV light located near the claw will allow us to see which missiles are radioactive and need to be recovered. The Remora will also have ballast tanks similar to the Megalodon allowing it to easily resurface after collecting all of the radioactive missiles.

FRAME STRUCTURE DESIGN

The drone frame is constructed of hollow carbon fiber tubes, connected to a central carbon fiber frame. It has four arms extending in each direction, each of which will hold a motorized propeller. To ensure maximum maneuverability of the Megalodon in the air and water, our material used must have the following general criteria:

- Impact resistant
- Lightweight
- Water resistant
- Durable

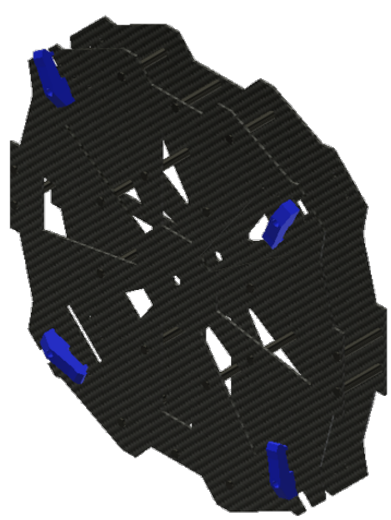
During our initial design process, we concluded that the drone's material must be strong enough to carry all the retrievable parts out of the water onto land **(FIGURE 2)**. After placing each type of material through the decision matrix, we narrowed the material choice for the frame down to carbon fiber and High-Density Polyethylene (HDPE).

[FIGURE 2: Frame Material Decision Matrix**]**

MATERIAL	COST	WEIGHT	DURABILITY	WATER RESISTANCE	MELTING POINT	MACHINABILITY	TOTAL
CARBON FIBER	0	2	2	0	1	-1	4
HDPE	1	1	0	1	-1	0	2
PVC	1	1	0	1	-1	-1	1
ACRYLIC	1	-1	-1	1	-1	-1	-2

Ultimately we chose to use a carbon fiber drone frame, because carbon fiber is lighter and more durable than HDPE. We also considered using a tricopter as opposed to a more expensive quadcopter, but from our research we found that a quadcopters are easier to balance when in flight, and are more impact resistant than tricopters.

As opposed to completely constructing a quadcopter frame from scratch, we decided to buy and assemble a commercial quadcopter frame **(FIGURE 3)**. A commercial frame can potentially provide us greater precision, but most importantly, it can save time and money. In order to machine a carbon fiber frame ourselves, our mills would require specialized tools, potentially costing hundreds of dollars and lots of time to learn how to set up properly and prepare.



[FIGURE 3: Commercial Quadcopter Frame**)**

WEIGHT

After deciding on our drone's material, we began to research drone designs with one, two, three, and four motors. From our research, we found out that quadcopters usually have a four to one power to weight ratio, which means that the thrust from the motors should be four times the weight of the of the quadcopter.

Since some of the objects that our drone will pick up will potentially weigh several pounds, we decided to direct our research to drones with three and four motors. We found that using three motors is cheap and light, however, a three motor system limits some of our maneuverability options, such as rotation.

Although four motors might not be as light or as cost efficient as opposed to using three motors, it will allow easier piloting and maneuverability of the drone, easier balance, and simpler designing and building. For these reasons, we decided to use a drone with four aerial motors.

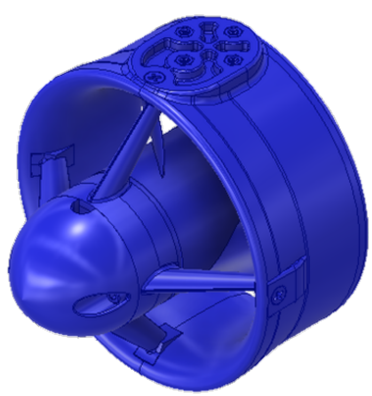
FLIGHT

Since our drone will have to be both aerial and subaquatic, the drone motors need to be effective in both the air and water. Either that, or we use two sets of four motors, each set of which is effective in the air, or the water.

When looking at motors we had to keep in mind that motors used in the water require enclosures to waterproof the mechanical and electrical components. We also had to keep in mind that when motors are in the air, they need less torque than when they are in the water.

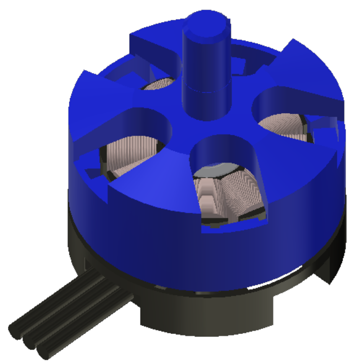
Looking back to our research about how many motors we should have, we decided that it would be a good idea to have four working motors in the air and six working motors in the water. Because the motors used in the air and in the water are different, we decided to use ten motors total, four aerial motors and six underwater motors.

For underwater flight, we compared the Blue Robotics M100/T100 Thrusters to the M200/T200 Thrusters, eventually realizing not enough thrust could be generated to allow maximum maneuverability. Next, we compared M200 Thrusters and T200 Thrusters, which includes motor mounts and an epoxied encasing. After thorough analysis, we decided to use six T200 Thrusters **(FIGURE 4)** for underwater movement. These thrusters are designed for underwater robotics, and each produce over five pounds of thrust. The T200 Thruster uses brushless electric motors, so it can be used for aerial or underwater mobility. In this scenario, we are specifically using these thrusters for underwater maneuvering. The thrusters are plastic, UV resistant, and non-corrosive.



[FIGURE 4: T200 THRUSTER**]**

For our aerial flight, we decided to use the Tarot 6115 High Power brushless motors **(FIGURE 5)**, because they're recommended and easily attached to the drone frame and can give us the thrust we need given the right propellers. These brushless motors fit perfectly with our Tarot quadcopter frame. Because these motors are only meant for the air, we will use professional epoxy to waterproof the motors, creating an IP69K rating.



[FIGURE 5: Tarot 6115 High Power Brushless Motor**]**

MOTOR PLACEMENT

The span between two aerial motors on the Megalodon is almost a meter ensuring that the drone is large and stable to carry the payload required. In addition, the motors are located above the center of gravity meaning the drone is even more stable.

For the underwater motors, the four facing vertically will be located next to the arms of the quadcopter. This will be a strong design that allows for enough torque to maneuver the Megalodon and make adjustments when the center of gravity changes if we pick up an object of interest, for example. The two hoizontal facing motors will be located on the landing mechanism, ensuring a strong design with enough torque to turn the drone on the horizontal plane.

BALLAST SYSTEM

The drone will use canisters of CO_2 as ballast. When the Megalodon initially lands in the water, it will have positive buoyancy making it float on the surface. A servo actuated valve will open on the top of the two Acrylonitrile butadiene styrene (ABS) plastic ballast tanks allowing the air held inside to exit and the water to enter, thus making the vehicle neutrally buoyant. The ballast tanks will be made of two 4-inch diameter ABS plastic tubes with aluminum end caps. The ballast tanks are strategically placed above the center of gravity ensuring the Megalodon will not tip over. When the Megalodon collects the objects of interest on the ocean floor, it is likely the Megalodon will no longer be neutrally buoyant and will require a significant amount of force to reach the surface again. Because of this, the C02 cartridges will be opened by a servo actuated valve and allow the C02 to enter the ballast tanks and push the water out of the ABS plastic tubes. This will be enough buoyancy to lift the Megalodon to the surface and the aerial propellers out of the water so they can make the Megalodon fly. The servo actuated valve is a modified bicycle valve intended for use with C02 canisters making this a proven concept.

RECOVERY MECHANISM

ECHO Technologies has a unique approach to the recovery mechanism. Rather than using a claw like device, the Megalodon uses a dustpan like device that scrapes along the ocean floor with a large rotating paddle pushing the different sized objects further back and securely into the Dustpan. It was clear that this approach would require a rather large mechanism so weight was an immediate concern. For that reason, ECHO Technologies will use an aluminum frame with a metal screen allowing water to pass through but not the objects of interest. This recovery mechanism is also relatively wide, meaning the Megalodon does not need perfect precision when grabbing these objects. Instead, the Megalodon can approach form an angle and still have success recovering these objects of interest.

CAMERA PLACEMENT

Since the Megalodon is an autonomous vehicle, it relies on cameras for sensing its environment and detecting nearby objects. There will be two cameras placed on the vehicle. Both cameras have a wide view. The first camera will be placed at the bottom of the vehicle in the center. This camera will look straight downwards, and will be used for aligning with the Remora to pick the Remora up. The second camera will be angled 45 degrees downwards and placed near the front of the vehicle. This camera enables automatic vision target tracking to autonomously pick up objects of interest underwater.

STRATEGY

The Megalodon will fly over 200 feet to the Remora with a precalculated trajectory. Crash prediction from our sensor suite, as well as crash prevention failsafes, will be integrated into pre-programmed flight. The Megalodon will line up with and pick up the Remora using automatic vision targeting and proceed to drop the Remora in the pool with another precalculated trajectory.

The Remora will be equipped with the necessary sensors to perform localization relative to its starting position. Once the Remora successfully locates the wreckage and drops the beacon, it will send its coordinates to Mission Control, which will then send the coordinates to the Megalodon. The Megalodon will fly over to the wreckage and perform a controlled diving sequence.

The Remora will act as a third-person camera during the Megalodon's time underwater. A communication system will be developed such that simple open-looped commands (forwards, backwards, turning) can be sent from mission control to the Megalodon during underwater operation. The pilots will control the Megalodon to reach the general vicinity of the objects of interest. Because of challenges with real-time communication, human-piloted control will be limited. An underwater vision system to autonomously orient the Megalodon to pick up the objects of interest will then activate.

ENERGY SOURCE

POWER

In order for the Megalodon to move underwater, it is supplied with four brushless motors. For the flight subsystem, the Megalodon is also equipped with four brushless motors. All of the motors are powered by LiPo (Lithium Polymer) batteries with the help of a pair of power distribution boards. Some smaller boards and sensors (including the 3 Raspberry Pi 3 Model B boards that will be controlling the robot) will receive power through a voltage transformer; lowering the 22.2 V output of the battery to their operating voltage of 5 V. Several of the other sensors will receive power directly through the Pi's USB ports.

CONTROL SYSTEM

The robot is controlled by 3 Raspberry Pi 3 Model B programming boards. One will be attached to a flight controller, which will connect to aerial motors through 4 Electronic Speed Controllers (ESC's). The flight controllers, which monitors the orientation of the robot using an integrated Inertial Measuring Unit (IMU), controls the pitch, yaw, and roll of the aerial aspect of the robot, keeping it level and moving it according to commands sent to it from the its attached Pi's, controlling the speed of the motors using the ESC's. The underwater M200 brushless motors that will propel the robot underwater will be attached (through ESC's) directly to one of the Raspberry Pi's. The robot will receive information about its surroundings by use of several sensors, including an additional IMU, a pressure sensor, and two cameras. These will be attached to the Pi's.

CURRENT AND WATTAGE

It is necessary to understand the power that is able to be produced by each component being relied on to produce energy for the robot. **FIGURE 6** contains information on the voltage, current, and wattage of each of the Megalodon's energy components.

[FIGURE 6: Megalodon energy components**]**

COMPONENT	VOLTAGE (V)	CURRENT (A)	WATTAGE (W)
RASPBERRY PI 3 MODEL B	5.0	2.5	1.25
IMU	3.6	0.0061	0.02196
ELECTRONIC SPEED CONTROLLER	5	60	300
M200 BRUSHLESS MOTORS	6-20	22	350

BATTERY

An estimate for the battery that would power the vehicle is a 10000mAh 6S 22.2V LiPo battery. With a discharge rate of 12C, the battery can be discharged up to 120 Amps continuously. We predict that this battery will be sufficient to power the vehicle based on our 15-pound estimation of the Megalodon's weight. This type of battery has been used by our Chief Scientist and proved to be sufficient in supplying power to a model airplane.

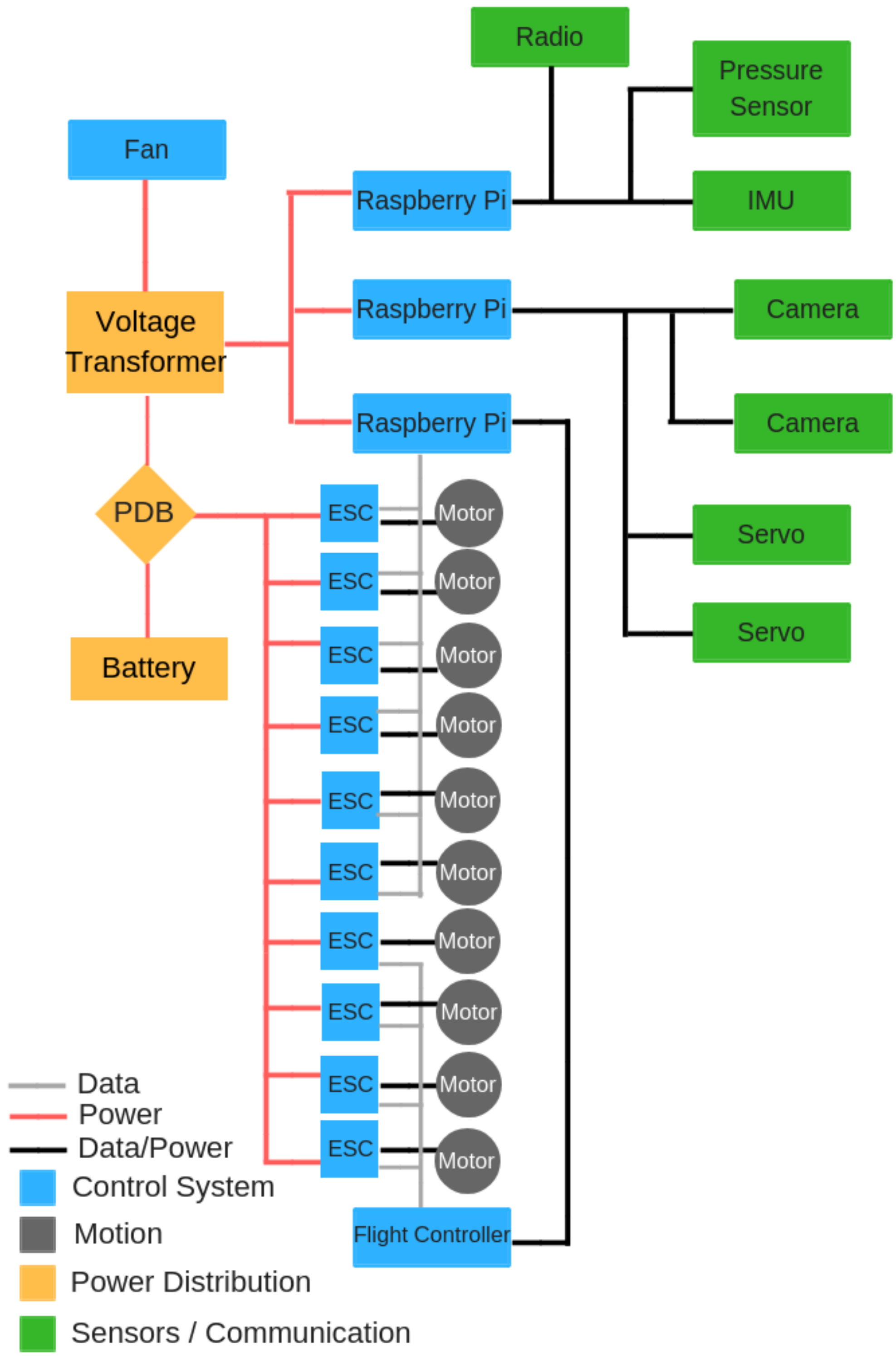
WIRING AND CIRCUITRY

The electrical system of the Megalodon begins with the LiPo battery as the main power source. The battery will be connected to the power distribution board (PDB). The PDB will distribute power to the ESC's which will control the motors and then connected from the PDB are the ESC's. The brushless motors for both aerial and underwater movement are controlled by the ESC's. Four of the ESC's for the underwater subsystem are directly connected to one Raspberry Pi. As for the remaining six ESC's for the aerial subsystem, they are connected to a flight controller, which is then connected to the same Pi. Another component that is connected to the PDB is the voltage transformer that lowers the output to an operating voltage of 5 V. The fan is connected to the voltage transformer to circulate the air within the box and parts that are also connected to the voltage transformer are the 3 Pi's. One of the two remaining Pi's are linked to a radio, pressure sensor and an IMU, while the other Pi is connected to cameras and two servos.

In order to save vertical room inside the robot's electrical housing, the Raspberry Pi's will be modified. By desoldering and removing the ethernet ports and reducing the number of USB type A jacks on the board from 4 to 2, the width of the Pi can be cut almost in half. This saves a lot of room when arranging Pi's, which will be stacked on top of each other using aluminum standoffs.

SENSORS AND COMMUNICATION

A radio receiver (RX) will receive commands from the drone controller. A pressure sensor will be used to measure data about the Megalodon's y-position, making it easier to calculate automated movement underwater. An inertial measuring unit (IMU) can be used as an accelerometer and gyroscope to measure the robot's speed and orientation underwater, which will make it easier to navigate underwater autonomously. Two high-pixel density cameras will be used by the drone pilot to survey the Megalodon's surroundings while in the air, and used underwater with the robot's vision system to help the robot to navigate and identify objects autonomously underwater. A visual representation of the Megalodon sensors and communication network can be seen in **FIGURE 7** as a wiring schematic.



[FIGURE 7: Megalodon Wiring Schematic)

MANUFACTURING

In order to manufacture the necessary components for both robots, Megalodon and Remora, Echo Technologies intends to use several manufacturing techniques and will outsource to external machine shops when needed.

After extensive research we have highlighted the weaknesses and strengths of several materials in order to determine which material would best suit our use. We have decided to work primarily with Carbon Fiber because of its lightweight and strength. The Megalodon Robot frame will be made out of Carbon Fiber, which will be machined with an exterior resource. In order to prevent water exposure from within the frame epoxy will be used in many areas of the Megalodon robot. On the other hand, for components that will not undergo large amounts of stress will be manufactured from due to its ease of use and affordability.

Some of the most used manufacturing setups will be consisting of additive and subtractive fabrication. Additive manufacturing such as 3D printing will be utilized to manufacture prototype components or more cost-efficient components of the robots. Additionally, manufacturing will utilize several Computer Aided Design (CAD) produced designs in order to fully plan out the project. Similarly, several components of the project will be fabricated via Computer Numerical Control (CNC) machining with our available Haas milling machines and lathes for precision

SOFTWARE AND COMMUNICATION

PROCESSING

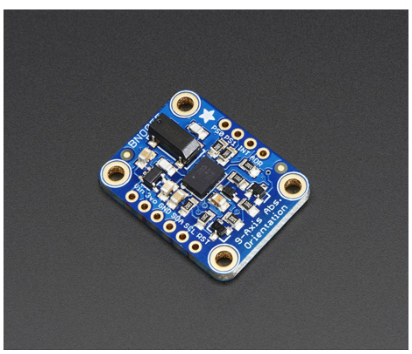
The main processor of the Megalodon is a Raspberry Pi 3 - Model B **(FIGURE 8)**. This processor was chosen due to its high processing speed of 1.2GHz with 32kB Level 1 and 512kB Level 2 cache memory , compatibility with the planned waterproof materials to be used, and its adaptability. There will be three Raspberry Pis used. The first Pi is intended to receive data from the sensor and convert it into messages that can be understanded and programmed. The second Pi will be programmed with a control loop that commands the Megalodon to move. The third Pi will be receiving information from the camera.

[FIGURE 8: Raspberry PI 3-Model**]**

The Raspberry Pis will communicate using a serial connection programmed with Python. The PI cereal packet, enable serial communication by editing config dot text in the root directory, open it using nano director modify its value to 1, download serial monitoring software and open USB to TTL Converter then run the python script using command sudo python, enable local echo to see what data is being sent.

SENSOR STACK

The Megalodon will be equipped with Adafruit 9-DOF Absolute Orientation Inertial Measurement Unit **(FIGURE 9)** (IMU Fusion Breakout Model-BNO055; this sensor has 9 degrees of freedom and the ability to output the following sensor data: absolute orientation (Euler and Quaternion), angular velocity, acceleration, magnetic field strength, linear acceleration, gravity, and temperature. The robot will also have an underwater pressure sensor. The Bar02 is a shallow depth, ultra-high resolution, waterproof pressure and temperature sensor **(FIGURE 10)** that comes in a Blue Robotics penetrator which provides a waterproof seal for the enclosure. This sensor measures depth of 0-10m with resolution of 0.16mm and altitude in air with a resolution of 13cm. The sensor communicates over I2C. It operates on 3.3V I2C voltage but can accept power input up to 5.5V. It comes standard with a 4-pin DF13 connector that will connected to a board that will be connected to to the raspberry pie. The robot will also receive information from the flight controller which has its own integrated IMU.



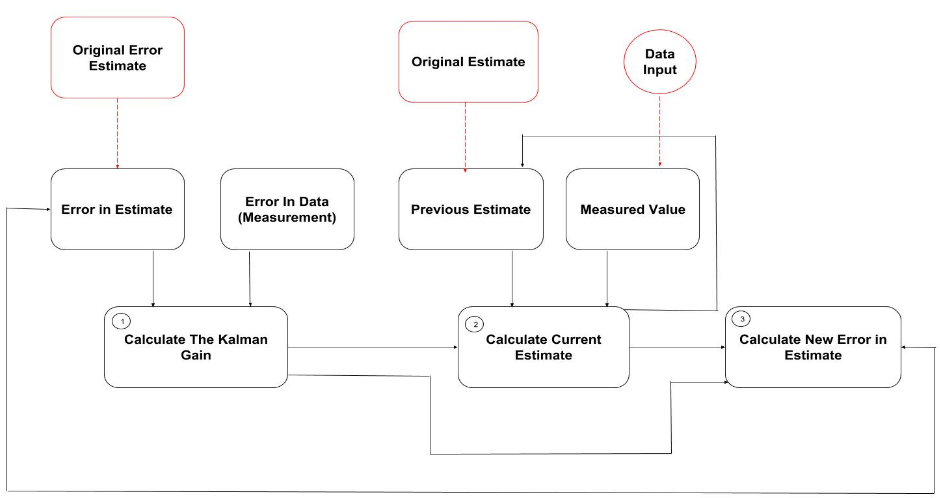
[FIGURE 9: Raspberry PI 3-Model B]

[FIGURE 10: Bar-02 Ultra High Resolution Sensor**]**

STATE ESTIMATION: THE KALMAN FILTER

A Kalman filter is an optimal estimation algorithm. We will be using this tool in addition to the sensors to minimize the estimated error covariance through a predictor-corrector type estimator. We particularly need it for the double integration of acceleration from the Adafruit 9-DOF IMU. The use of the Kalman filter will make sure our data is accurate, remove the noise from the data set, and smooth the data. The Kalman Filter will allow us to extract the necessary information from the data and ignore everything else.

An overview of the process of the Kalman Filter is shown in **FIGURE 11**. The Kalman filter will take current measurements and use estimates of error from the estimates and measurements to get closer to the true and accurate measurement.



[FIGURE 11: Kalman Filter Diagram**]**

The Kalman Filter constantly takes inputs from the sensors on common intervals. The first step is to calculate the Kalman Gain which will be used to measure how much of the prediction and measurement will be inputted into the updated Kalman Filter estimate. To calculate Kalman Gain the original error of the estimate is needed and the error in the measured value. In a single dimension, the formula to calculate Kalman Gain is shown below:

$$K_n = \frac{p_{n,n-1}}{p_{n,n-1} + r_n}$$

The second step is to calculate the current estimate for the Kalman Filter which is based off the Kalman Gain. This step updates the previous estimate given from the Kalman Filter.

$$\hat{x}_{n,n} = \hat{x}_{n,n-1} + K_n \left(y_n - \hat{x}_{n,n-1} \right)$$

The final step is to determine the error the calculated estimate, so a new Kalman Gain can be calculated with a new and smaller error in the estimate is calculated. The Kalman Filter is an iterative process that quickly finds accurate values of data.

$$p_{n,n} = \left(1 - K_n \right) p_{n,n-1}$$

The Megalodon will need to filter values for linear position, angular position, and velocity in multiple dimensions. The equations shown above are for a one-dimensional system and we will be implementing the

Kalman Filter for multi dimensions which takes into account process noise and inputs from the x,y,z dimensions.

SOFTWARE FRAMEWORK

Typically, standard synchronous programs will execute statements sequentially and one by one. However, given the high input/output (I/O) that the program must process and the single-threaded process it runs in, it is critical that the program does not remain idle while waiting for certain tasks to complete. Therefore, the program will implement of this concurrency through the Python asyncIO module **(FIGURE 12)**, which utilizes coroutines, tasks, and a main event loop to improve efficiency. Unlike generators, which generate sequences of values for iteration, coroutines are generators that consume and pipe out data sent to it. The event loop, which works similarly to a central executor, iterates over tasks -- schedulers for coroutines -- in a queue and runs them. In the event that a particular coroutine calls another coroutine, the current coroutine will be suspended for a context switch; similarly, if a coroutine must execute blocking code, it will be suspended so that the event loop can run other tasks in the queue and return to it after the other tasks have finished executing. Ultimately, utilizing asyncIO allows the program to run non-blocking I/O, which will be a great benefit to the program that processes a high amount of I/O.

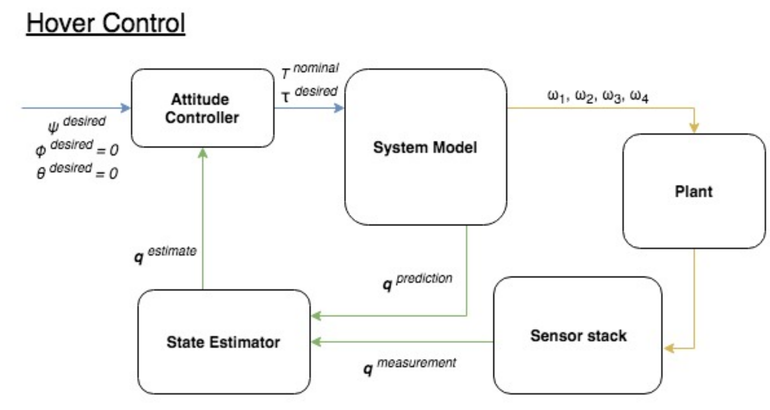
```python
# asyncio demonstration
import asyncio, datetime

# define main event loop
loop = asyncio.get_event_loop()

# send coroutine - sends a message after a blocking delay
async def send(msg, delay):
    await asyncio.sleep(delay)
    print(msg, '@', datetime.datetime.now().strftime('%H:%M:%S'))

# end coroutine - ends  mainloop after a blocking delay
async def end(delay):
    await asyncio.sleep(delay)
    print('ending loop @', datetime.datetime.now().strftime('%H:%M:%S'))
    loop.stop()

# create and add tasks to the queue
loop.create_task(send('starting loop', 0))
loop.create_task(send('hello 1', 3))
loop.create_task(send('hello 2', 1))
loop.create_task(send('hello 3', 8))
loop.create_task(end(7))

'''
expected behavior:
coroutines with shorter blocking delays will be executed first.
- "hello 2" will be sent before "hello 1" because of its shorter delay.
- "hello 3" will never be sent because the loop will be ended before its delay is over.
'''

loop.run_forever()
loop.close()

'''
Output:
starting loop @ 19:45:00
hello 2 @ 19:45:01
hello 1 @ 19:45:03
ending loop @ 19:45:07
'''
```

[FIGURE 12: AsyncIO Code Snippet**]**

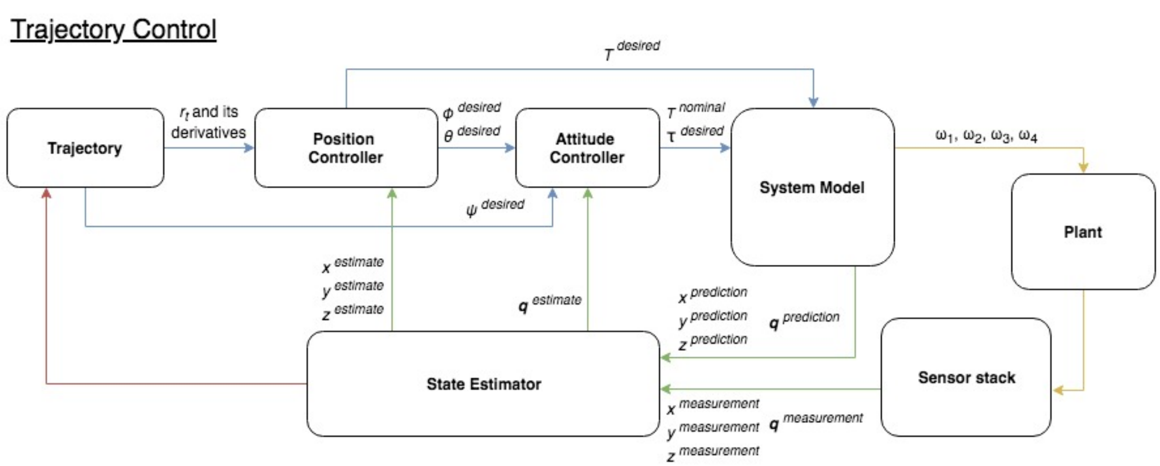
The robot software framework will be developed such that the low-level components will run asynchronously at a faster rate than the high-level components. This hierarchical structure minimizes latency and interference between different controllers and ensures that all of our high-level commands will be properly executed. The position controller / estimator and attitude planner will run at 20 Hz. The attitude controller / estimator will run at 200 Hz. Our motor controllers will run at upwards of 500 Hz to ensure optimal response time.

FLIGHT CONTROL

The Megalodon's flight control system consists of multiple control loops at different levels, as described in the "Software Framework" Section (Page81). **FIGURE 13** and **FIGURE 14** below show the control loop diagrams being used to model the Megalodon's flight control systems while the robot is hovering and moving along its path of trajectory.



[FIGURE 13: Hover Control loop diagram**]**



[FIGURE 14: Trajectory Control loop diagram**]**

SYSTEM MODEL

The model of the quadrotor consists of 4 forces that are the result of controlled motor speeds. The relationship between the thrust force T from a rotor and the speed of the rotor is quadratic, shown by the equation in **FIGURE 15.** The reaction torque Q produced by the rotor can also be represented by a quadratic relationship, shown by the equation in **FIGURE 16**. We can add these forces and torques to create an accurate model of the system, which will help with state estimation, the creation of feasible trajectories, and overall quadrotor control.

$$T_i = c_T \varpi_i^2$$

[FIGURE 15: Equation – relationship between rotor thrust force and speed**]**

$$Q_i := c_Q \varpi_i^2,$$

[FIGURE 16: Equation – reaction torque**]**

The fundamental model of the quadrotor can be represented by the equation in **FIGURE 17.** The constant matrix includes the thrust constant C_T, the torque constant $C_{Q,}$ and the distance d from the center of the vehicle from to the center of a rotor. Using this equation, we can solve for rotor speeds to be sent to motor controllers given desired net thrust force and torques.

$$\begin{pmatrix} T_\Sigma \\ \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix} = \underbrace{\begin{pmatrix} c_T & c_T & c_T & c_T \\ 0 & dc_T & 0 & -dc_T \\ -dc_T & 0 & dc_T & 0 \\ -c_Q & c_Q & -c_Q & c_Q \end{pmatrix}}_{\Gamma} \begin{pmatrix} \varpi_1^2 \\ \varpi_2^2 \\ \varpi_3^2 \\ \varpi_4^2 \end{pmatrix}$$

[FIGURE 17: Equation – fundamental model of quadrotor)

Attitude Tracking

The Megalodon's three-dimensional orientation will be represented internally by a quaternion, shown in the equation in **FIGURE 18**. Quaternions were chosen because they only require 4 elements to fully represent attitude, as opposed to 9 elements needed for rotation matrices. Since we are dealing with tracking the orientation of a rigid body, we are chaining rotations together. For chained rotations, quaternions offer a reduction in computational memory needed compared to matrix representations. Quaternions also solve the gimbal lock problem presented by traditional euler angle (yaw, pitch, roll) representation.

$$\begin{aligned} \boldsymbol{q} &= q_0 + q_1\boldsymbol{i} + q_2\boldsymbol{j} + q_3\boldsymbol{k} \\ \boldsymbol{q} &= \begin{bmatrix} q_0 & q_1 & q_2 & q_3 \end{bmatrix}^T \end{aligned}$$

[FIGURE 18: Equation (quaternion) – three-dimensional orientation)

Since quaternions are not intuitive to visualize, we will convert them to euler angles to be sent to human operators using the equation in **FIGURE 19.** This conversion will take place in a separate thread as to not interfere with our internal algorithm.

$$\begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} = \begin{bmatrix} \operatorname{atan2}(2(q_0q_1 + q_2q_3),\ q_0^2 - q_1^2 - q_2^2 + q_3^2 \\ \operatorname{asin}(2(q_0q_2 - q_3q_1)) \\ \operatorname{atan2}(2(q_0q_3 + q_1q_2),\ q_0^2 + q_1^2 - q_2^2 - q_3^2) \end{bmatrix} \quad (5)$$

[FIGURE 19: Equation – quaternion to euler angle conversion)

Because of the computational advantages of quaternions, our internal algorithm will still use quaternion-based tracking and control. Quaternion multiplication can be done by using Kronecker products, as shown in the equation in **FIGURE 20.**

$$\boldsymbol{p} \otimes \boldsymbol{q} = \begin{bmatrix} p_0q_0 - p_1q_1 - p_2q_2 - p_3q_3 \\ p_0q_1 + p_1q_0 + p_2q_3 - p_3q_2 \\ p_0q_2 - p_1q_3 + p_2q_0 + p_3q_1 \\ p_0q_3 + p_1q_2 - p_2q_1 + p_3q_0 \end{bmatrix}$$

[FIGURE 20: Equation – Kronecker products used for Quaternion multiplication)

Attitude Controller

The attitude of the quadrotor will be controlled by some variation of a cascaded PID controller. The error can be calculated by multiplying the desired pose quaternion (taken from the trajectory) and the conjugate of the estimated pose quaternion, as shown in the equation in **FIGURE 21**. Elements of this error quaternion can then be integrated into a controller as shown in the equation in **FIGURE 22**, which is an example of a cascaded P controller that outputs desired torque. This desired torque matrix will be passed to the system model. When not being used in conjunction with a position controller, the attitude controller will also output the nominal thrust force needed to maintain the Megalodon's height.

$$\boldsymbol{q}_{err} = \boldsymbol{q}_{ref} \otimes \boldsymbol{q}_m^*$$

[FIGURE 21: Equation – Quadrotor attitude margin of error)

$$\tau = -P_q \cdot \begin{bmatrix} q_1^{err} \\ q_2^{err} \\ q_3^{err} \end{bmatrix} - P_\omega \cdot \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

[FIGURE 22: Equation – cascaded P controller [outputs desired torque]]

TRAJECTORY GENERATION

Translational motion of a quadrotor can be achieved by manipulating the roll and pitch of the vehicle. We chose to use minimal-snap (4th-derivative of position) trajectories because the motor commands and accelerations of a vehicle in flight are proportional to the snap of the vehicle. Minimizing the snap will increase the gracefulness of flight, which is necessary to maintain control over the vehicle. Since stability matters more to us than speed, we will also set a conservative hard value for maximum pitch/roll. The 3D trajectory will be computed as a series of position, velocity, and acceleration vectors (notated as r_T , r_T dot, and r_T double dot, respectively). All of this will be done offboard before the mission.

TRAJECTORY FOLLOWER AND POSITION CONTROLLER

The trajectory follower consists of a higher-level position controller and the inner attitude controller.

The sequence for following a trajectory will be as follows:

1. Stiff hover control to desired starting position and yaw.
2. Intermediate trajectory following makes up the bulk of the movement.
3. Attitude control to stable zero roll and zero pitch.
4. Soft hover control to desired end position.

The intermediate trajectory follower will first determine the trajectory point closest to the Megalodon's position. A PID controller on position (with added an acceleration feedforward component from the trajectory) will then calculate a command acceleration vector notated as r des double dot, as shown in the equation in **FIGURE 23**. By linearizing the equations of motion for the quadrotor, we can obtain a relationship **(FIGURE 24)** between the command acceleration vector and the desired roll, pitch, and net force. We will convert the desired roll and pitch into a quaternion to pass into the altitude controller.

$$(\ddot{r}_{i,T} - \ddot{r}_i^{\text{des}}) + k_{d,i}(\dot{r}_{i,T} - \dot{r}_i) + k_{p,i}(r_{i,T} - r_i) + k_{i,i}\int(r_{i,T} - r_i) = 0,$$

[FIGURE 23: Equation – command acceleration vector]

$$\begin{aligned}
\phi^{\text{des}} &= \frac{1}{g}(\ddot{r}_1^{\text{des}} \sin\psi_T - \ddot{r}_2^{\text{des}} \cos\psi_T) \\
\theta^{\text{des}} &= \frac{1}{g}(\ddot{r}_1^{\text{des}} \cos\psi_T + \ddot{r}_2^{\text{des}} \sin\psi_T) \\
F_B^{\text{des}} &= m(\ddot{r}_3^{\text{des}} + g).
\end{aligned}$$

[FIGURE 24: Equation – relationship between command acceleration vector and desired roll, pitch, and net force]

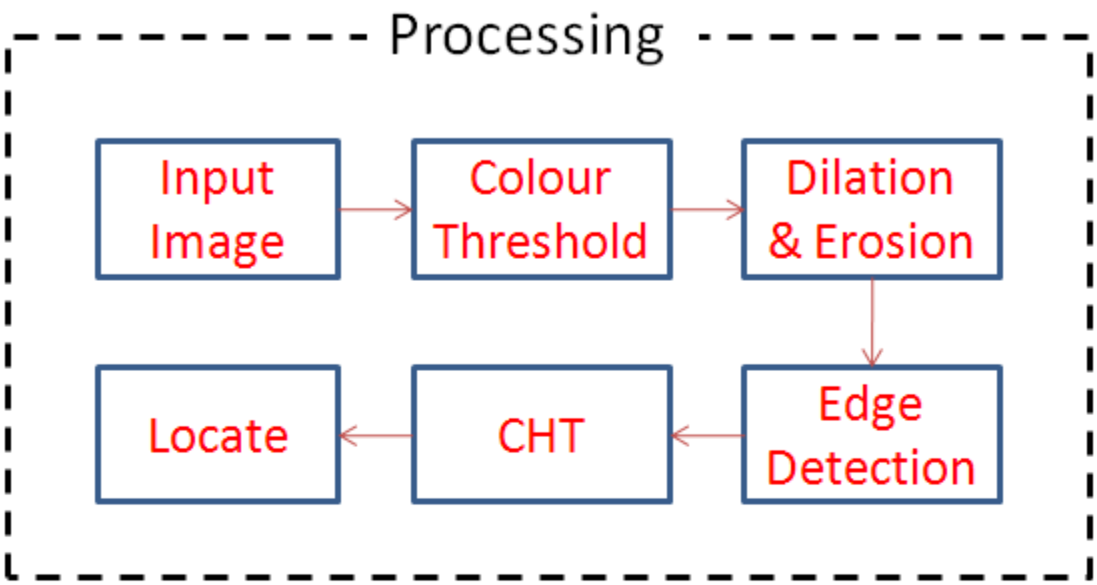
VISION

As the general strategy of the game requires a vision system that can autonomously orient the Megalodon to aid in the retrieval of the objects of interest, the vision system must AT LEAST be able to perform these two functions:

1) Continuously capture and store images. There must also be a process where specific images are translated into arrays. Conversion of image data to an array is a standard procedure executed to enable further mathematical operations to be made on the image. Transfer of arrays is easier and more practical than the transfer of the raw image itself.

2) Continuously pass filters, and process arrays into meaningful information. Common filters used in general image processing include Gaussian filters that reduce noise. (More research on edge detection, underwater condition filtering, orientation detection will be done in the immediate future.) A process should also be ready to identify the presence of the object, create a contour, identify the centre of the object, and be ready to send final information to the main control.

FIGURE 25 below reflects the general steps that the Megalodon vision system's image processing function will follow.



[FIGURE 25: Megalodon Vision processing diagram]

It is best for the vision subsystem to follow several of the ASync protocols found in the main control system to compartmentalise the aforementioned functions listed 1 and 2. Like the general Megalodon software framework that is planned to run asynchronously, the vision subsystem is likely to be similarly compartmentalised so that there is minimal idle time and latency between the different stages of image processing. The rate at which images are captured and made into arrays will not be the same as the rate at which vision algorithms could filter the arrays and make calculations.

The camera that will be utilised for this robot must have a relatively sufficient frame rate and resolution so that the raw image needed for processing is high enough for effective filtering, but low enough for the Raspberry Pi to be able to handle well. The camera will be preferably small (roughly one cubic centimetre, no bigger than three cubic centimetres). A smaller camera is preferred as waterproofing the camera is made easier, and there is greater flexibility in the positioning of the camera on the Megalodon. The USB cameras we choose must be compatible OpenCV, the primary library we are going to use to manipulate the raw image into useful information for the main control. We will decide on the camera(s) to use after testing two candidate cameras.

There is a possibility of using a separate language just for image processing, namely C++, a faster alternative to Python. Both languages are supported by OpenCV.

COMMUNICATION

The majority of our systems will be autonomous, however for testing and in case of failure we plan to employ two sets of communication. For communication in the aerial system, we will be using 2.4Ghz communication system. For the underwater system we will use a piezoelectric transducer, in which we will be taking advantage of the piezoelectric effect. We will be taking advantage of the direct piezoelectric effect which produces a voltage based on a mechanical strain. Different mechanical strains will produce different voltage outputs. We plan to use sound waves as our input and the voltage will be our output. an underwater speaker will be used. The sound input will be varied based on frequency, so certain frequencies will output different voltages. However it is very likely that the frequencies that we attempt to produce and the frequencies that are actually produced will vary slightly. In order to account for this there will a range of output voltages will produce the same output. For example if the input is a frequency of 1000hz then there will be a corresponding voltage that will produced due to that frequency. Let's say that corresponding voltage is 10V. However through water and due to error of the speaker that frequency may vary slightly and become 990Hz or 1005 Hz. These frequencies might produce a voltage of 9.9V or 10.05V. So the range we might establish could be between 9.9V and 10.1V. So that all voltages between these two values still have the desired effect.

REMORA DESIGN OVERVIEW

MECHANICAL

FRAME STRUCTURE DESIGN

The ROV's frame will be constructed out of ABS plastic, based around a center receptacle. It be will connected with screws and 3D printed gussets. It has an arm with 2 sets of claws extended at the front of the vehicle. The arm will have a servo-motorized joint which will allow the arm to pick up and place the collected missiles in the receptacle.

During our initial design process, we concluded that the underwater vehicle's material must be strong enough to carry all the retrievable parts and structured in such a way to keep them from falling out. Using a design matrix, the two options were high density polyethylene (HDPE) and ABS plastic. Ultimately, we chose to use ABS plastic, because it had better manufacturability and is stronger than HDPE.

We decided the laser cut the majority of the frame as it would be easier and more efficient to make the frame from scratch. Parts with looser constraints will be 3D printed. Though this may seem costlier, it will allow the ROV's design to be more flexible to changes in the Megalodon's design due to its simple design.

For underwater movement, we use four T-200 Blue Robotics Brushless Motors, with motor mounts included. They will be angled slightly to enable full control of the movement of the ROV. The T-200s provide more security and ease of manufacturing as opposed to another motor like the M-200s since it does not come with shrouds on the motors.

BUOYANCY

In order to solve the issue of submerging and rising, we decided to make an attempt to implement a ballast tank. Our intention was to create a capsule that had the capability of intaking and releasing water. This would allow the ROV (aka the Remora) to change its buoyancy by increasing/decreasing the overall mass. Our idea was to use a mechanical valve to allow water in (and prevent it from escaping) and, when it is necessary to increase buoyancy and decrease mass, the use of pressurized air would allow for the swift and efficient pressurization of the capsule. We intend to place the buoyancy capsule (ballast tank) on the exterior of our ROV with sufficient distance from the other components.

CLAW MECHANISM

The intake mechanism that scored the highest on a decision matrix was a four pronged, ABS plastic claw. There will be two sets of claws arranged on top of each other to ensure that during the course of the mission, the radioactive materials will not twist out of the claws' grips. We had based the idea on how fingers easily grip cylindrical objects using x and y axis movement. This will help the Remora collect the radioactive missiles efficiently.

MISSILE INTAKE SYSTEM

By way of the claw mechanism, the Remora will pick up radioactive missiles and deposit them in a central receptive tank. This intake system was scored the highest amongst other ideas because it is projected to be easily waterproofed, low cost, lightweight, efficiency, and quick building time. Similar to a dump truck, the claws will pick up the missiles and store them in a container in towards the middle, inward area of the ROV.

BEACON

For the Megalodon to easily locate the Remora underwater, we decided to use an ultrabright LED beacon that can be detected with a camera. The strong flashes of light are visible from half a mile away. In addition, this beacon is completely waterproof, lightweight and it is also at a low cost.

MOTORS

In order to provide the greatest amount of thrust, we decided that the use of six T100 Motors would be best. Its ability to create 5 lbs of thrust makes it an ideal choice to push, maneuver, and steer the Remora. We intend to place four motors directed to the y-axis and two directed to the x-axis as this will allow the Remora to provide the largest amount of upward/downward thrust which is a necessity when submerging and emerging.

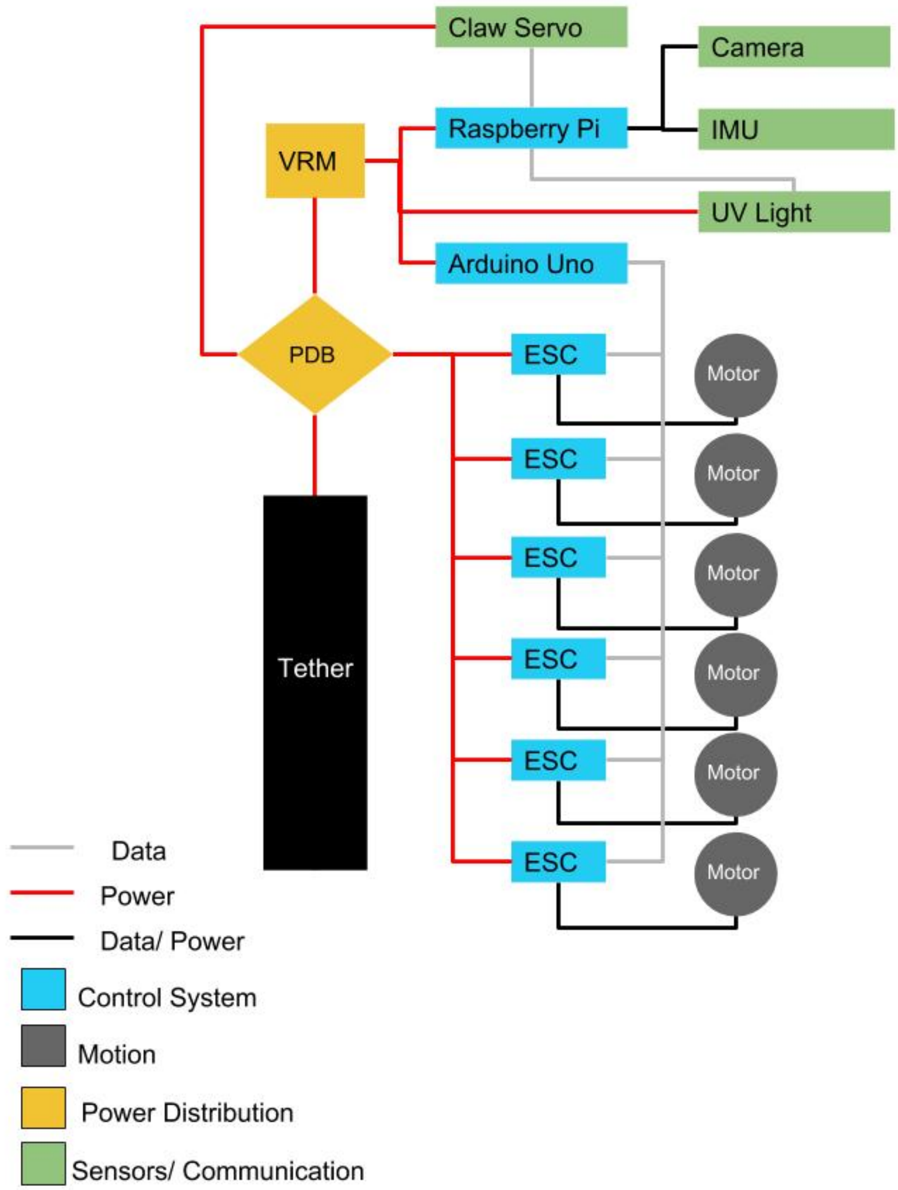
ELECTRICAL

POWER SYSTEM

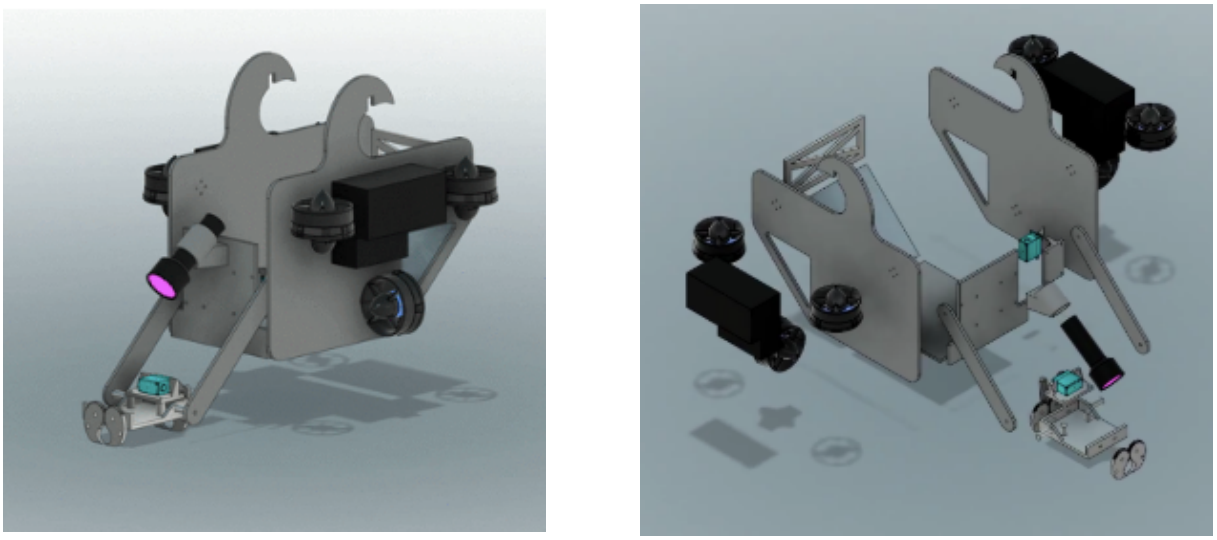
The Remora will be powered from an external power source, which will send power and data through a tether to the onboard electronics of the ROV. The power from the tether will be sent to an onboard power distribution panel (PDB) which will disperse the power through the system. The Remora has a set of 6 T100 motors which supply 5 pounds of thrust each. Each motor will be connected to an Electronic Speed Controller (ESC) which in turn is connected to the PDB. In addition, a servo assembly for the claw actuator system will be connected to the PDB. The ESC's and servo will be connected directly to the PDB, while the onboard Raspberry Pi Model A+, Arduino Uno Rev 3, and UV Light will be powered from the PDB through a 5V voltage regulator module (VRM); lowering the output of the tether to their operating voltage of 5V. A camera and IMU will receive power directly through the Pi's USB ports.

CONTROL SYSTEM

The robot is controlled by an external control box with a joystick and button system that will send data through the tether to the Arduino Uno which is connected to each of the 6 ESC's which drive the propulsion motors of the robot. In addition, the Raspberry Pi will also receive signals from the tether and will control the camera, image processing, IMU, UV Lighting, as well as the claw servo which will pick up the radioactive missiles. The Pi will process the camera feed and send it to the control box which an operator will be using to control the ROV. The IMU data will be sent to the control box and on towards Megalodon, which will use the data to pinpoint the location of the Remora, in order to pick it up. **FIGURE 26** shows a visual representation of the Remora wiring schematic and **FIGURE 27** shows an assembled and expanded CAD of the remora robot with all aforementioned features.



[FIGURE 26: Remora wiring schematic]



[**FIGURE 22:** Remora CAD]

MISSION APPROACH

To complete this mission two robots will be made. The design of the first UAV, the Megalodon, will be a combination of both a quadcopter and an underwater ROV. It will consist of two seperate systems: an aerial system and an underwater system. The second ROV, the Remora, will only need to be mobile while underwater and will only consist of an underwater system.

1. **Objects of interest include** (All items are cylindrical)**:**
    a. coding machines,
    b. a missing torpedo
    c. (3) R-21 ballistic missiles, possibly tipped with nuclear warheads, and
    d. any possible remainder of the hull.
    e. Part of this new mission is to discover whether the K-129 was armed with nuclear tipped R-21 ballistic missiles, in violation of the 1971 Strategic Arms Limitation Treaty (SALT).
2. **On-board UV light**

The Remora will act as a third-person camera during the Megalodon's time underwater. A communication system will be developed such that simple open-looped commands (forwards, backwards, turning) can be sent from mission control to the Megalodon during underwater operation. The pilots will control the Megalodon to reach the general vicinity of the objects of interest. Because of challenges with real-time communication, human-piloted control will be limited. An underwater vision system to autonomously orient the Megalodon to pick up the objects of interest will then activate.

The aerial system will be responsible for the flight of the UAV. Using this system, and an attachment to the Remora the Megalodon will transport the the Remora from the dock into the water. The Megalodon will fly over 200 feet to the Remora with a precalculated trajectory. Crash prediction from our sensor suite, as well as crash prevention failsafes, will be integrated into pre-programmed flight. The Megalodon will line up with and pick up the Remora using automatic vision targeting and proceed to drop the Remora in the pool with another precalculated trajectory.

From here the Megalodon will return to the dock to conserve battery, while the Remora locates the wreckage. Once the Remora locates the wreckage it will become a beacon for the Megalodon. However the distance from the wreckage to the dock can be large and it may be hard for the Megalodon to see the beacon from the distance. To help with this, in the process of finding the wreckage, the Remora will record relative position from it to the dock. The dock will be considered the home point and once the Remora finds the wreckage it will record relative position. The Megalodon will then use these relative positions to determine a rough area to where the wreckage is located. Once the Megalodon reaches that area it will be much easier for the Megalodon to see the beacon since its looking in a more limited area. Once here the Megalodon will dive and begin recovering items. Starting here the underwater system for the Megalodon will be used.

The Megalodon will recover the coding machines, missiles, torpedo, and any remainder of the hull. The Megalodon will recover as many items as possible per trip, following about the same procedure for each one. First the Megalodon will locate each item and grab onto the item using our articulation system. The Megalodon will then resurface and fly to the dock and place that item/items down. The Megalodon will then dive back into the water and begin looking for the next item.

The Remora has the task to recover ballistic missiles and determine if they are radioactive. In order to limit the possibility of collisions and because the Remora is also being used a third person camera, the Remora will only conduct this part of the mission while the Megalodon is a far distance away, mostly while the Megalodon is in the air. The Remora will have to recover and analyze three missiles and will be able to hold all of them at the same time.

Once the Megalodon finishes recovering all the items and the Remora has recovered all the missiles the Remora will once again attach to the Megalodon and the Megalodon will fly back to the dock.

QUALITY ASSURANCE

QUALITY ASSURANCE STATEMENT

To ensure all aspects of the project work and function properly certain tests are performed. All parts manufactured by the manufacturing department must be inspected using a dial caliper or other precision instruments. A part number is then given to the part and a form is signed, assuring the part was made correctly. All crimped wires must also be inspected before use. A pull test is then conducted using a gage and pliers. All crimped wires must withstand a constant pull of 60 lbs. and a form is then signed by the quality assurance officer. All technical data packages produced by the systems engineer and mechanical team must be approved by the quality assurance officer for proper dimensioning, Geometric dimensioning and tolerance **(GD&T)** standards.

ASSURANCE FACTORS

WATERPROOF PROCEDURE

All components that have the possibility to be exposed to water when diving will go through a basic underwater procedure. Component bought will have to have an IP rating greater or equal to IP67. Although this rating already confirms its ability to be waterproof, it will still be tested in-house to catch any irregularities or defects. It will consist of one trial that will be repeated three times sequentially: the component will be placed at the bottom of a 7ft. pool for ten minutes. Should the component pass within the three trials, it will then be used for prototyping designs. This procedure will also be used for any casing or enclosures made in-house.

MECHANICAL

MOTORS

Not only must they provide enough thrust for flight, but also be waterproof for underwater travel. To test the thrust of motors for air I will create a first class lever where on on end will be an attached motor and the other resting on a weight scale. I will zero the current weight and have the motor go at different throttle strengths: 50%, 60%, 70%, 80%, 90%, 100%. To test the thrust of motors for underwater, I will use a waterproof pull scale and have the motor attached to the end (note it will be powered by an outside source) and test using the same throttle strengths written before.

CLAW

To test the effectiveness of the claw, I would need to test its grip strength and ability to grab different shapes. To conduct this procedure, I will have the specified claw grab multiple cylindrical objects under a set time period and see how well the claw grips while in air.

ELECTRICAL BODY

The electronics of the drone will have to be protected in a waterproof case. Before testing, two different cases were chosen to be used: a 1150 Protector Pelican Case and a ML-58F*1508 ML Series Outdoor NEMA Enclosures Case. The two were each subjected to the Waterproof Procedure: they were placed in a 7ft pool for ten minutes. The Pelican Case survived the test, while the NEMA Case failed. This was due to how each case closed. The Pelican Case used two simple latches while the NEMA Case had to be screwed down: while it was possible for the NEMA Case to pass the test by tightening the screws, it would have risked stripping the screws and make the case unusable.

PROGRAMMING

FRAME

The frame is the centerpiece of our drone: It is what houses and connects everything together. The most important aspect to test the frame would be its stability. While in the air, it must achieve stability or else it will risk stalling. To test this, a rig will be created: it will consist of a linear bearing with at the end of its shaft a ball joint and head. The frame will be able to be attached to the ball joint. With motors attached, programming will able to test their code regarding air movement. They will be able to see how their code plays out in real life with this testing rig.

RISK ASSESSMENT

RISK SCALES

	Severity			
Likelihood	Inconsequential	Insignificant	Noteworthy	Dangerous
Anticipated	Moderate	High	Unacceptable	Unacceptable
Possible	Acceptable	Moderate	High	Unacceptable
Improbable	Acceptable	Acceptable	Moderate	High
Unrealistic	Acceptable	Acceptable	Moderate	High

Risk Management					
Risk	Consequence	Likelihood	Severity	Risk Factor	Action
Testing	Damage to important components	Possible	Noteworthy	High	Testing procedures need to be prepared prior
Accidents that result in injuries	Personnel may need medical attention which may affect the timeline	Possible	Noteworthy	High	Personnel are required to follow many procedures for safety, using protective equipment, and being well informed
Inhalation of lead fumes	Cancer	Possible	Noteworthy	High	Have ventilation, use a fan while soldering, do not stay directly above fumes
Water damage	Timeline is delayed and systems may need to be rebuilt	Possible	Noteworthy	High	Test containment and ensure no water leakage before testing

Damage to parts	Timeline is delayed in order to replace or repair parts	Improbable	Noteworthy	Moderate	Ensure qualified personnel are using the best material in a reasonable time in order to create back up or replacement parts
Unfavorable weather conditions	Flight may be affected and pilots may need cover	Improbable	Noteworthy	Moderate	Reschedule
Lipo battery leaks / damage	Fire, poisonous fumes, severe burns, explosion	Improbable	Noteworthy	Moderate	Use a salt water bath and dispose
Inhalation of dust	Nose bleeds, issues breathing, harm to lungs	Improbable	Noteworthy	Moderate	Wear a face mask when dealing with dust
Electronic malfunction	Failure mid-flight, rewiring, timeline is delated	Improbable	Noteworthy	Moderate	Check all cable connections, and test prior to flight
Manufacturing injuries	Timeline is delayed,	Improbable	Noteworthy	Moderate	Practice safe procedures and

	personnel may need medical attention				follow the rules of the Annex
Errors in communication	Lose drone controls, lose the drones position, have issues completing the mission	Improbable	Noteworthy	Moderate	Test the communication systems extensively in order to ensure they will work when needed
Manufacturing errors	Material and time is wasted, the parts may malfunction	Improbable	Insignificant	Acceptable	Account for possible error and have QA check all measurements twice
Outsourcing to manufacture parts	Deadlines may not be met and shipping may take longer than anticipated	Improbable	Insignificant	Acceptable	Account for shipping times, vet all parts received, and make orders well before parts are needed
Low battery charge	Failure mid-flight, more time to charge	Improbable	Insignificant	Acceptable	Always charge the craft prior to flight, have charging

					available
Camera malfunctions	Cannot detect objects, difficulty piloting	Improbable	Insignificant	Acceptable	Check camera connections and test visuals
Parts arrive late	Personnel are unable to complete work without part	Possible	Inconsequential	Acceptable	Always have alternative work ready to do if parts arrive late
Pieces are not as expected	The claw system may be unable to pick them up	Possible	Inconsequential	Acceptable	Ensure that the claw is over the specifications given for the sizes

FINANCIAL REPORT

FINANCIAL BACKGROUND

ECHO Technologies has been tasked with designing, building, and demonstrating a hybrid, multi-purpose Unmanned Aerial Vehicle/Unmanned Underwater Vehicle (UAV/UUV) systems, code-named "Megalodon", capable of flight in multiple fluid mediums (air and water) and "Remora" which is capable of recovering items of interest. These UAV/UUV systems will be operated no later than May 2019.

In order to successfully accomplish the task at hand, ECHO Technologies' financial team will maintain a formal budget. This budget will include a Bill of Materials, which is a proposed list of materials that serves as an estimate of the anticipated cost of the entire project. In addition to the cost of materials necessary for the building of the robot, the costs of multiple events will also require funding. The Bill of Materials includes essential information such as the vendor, the quantity, and the price of the materials. For clarity, the Bill of Materials is separated into two sections: Systems and Miscellaneous. The Systems section includes a list of parts needed to make the drone function and carry out the commands as dictated by its programming as well as a list of parts that give the UAV/UUV structure and shape. The Miscellaneous section includes materials needed to run and represent the organization as well as propagate STEM education through outreach programs.

FUNDRAISING

In order to produce the UAV/UUV, funding is essential to the project. The finance team intends to raise $10,000 through various fundraisers, donations from generous individuals and groups, and sponsorships from corporations as described in the Funding section. Through fundraising, we have successfully raised $170 from the school event Taste of CAMS, and have scheduled future fundraisers such as a Dippin Dots Fundraiser on November 14, 2018 and more that will take place before the end of this year. We are also in the process of using the crowdfunding site, GoFundMe, to acquire donations from the general public, are in discussion with LA Galaxy and are currently waiting for response for potential sponsorships.

BUSINESS CASE

1. COMMERCIAL APPLICATIONS

The systems and strategies being developed by ECHO Technologies have a broad range of applications in the modern market outside of its confines in the lab.

1.1. Search, Rescue, and Recovery

Recovery, inspection or observation tasks are often unscheduled and unpredictable. The Megalodon responds well under these conditions as it is built for these same principles. Having an ROV to assist in search and recovery operations without furthering human risk, will be a huge asset and a commodity that consumers will be highly interested in.

2. FINANCIAL APPRAISAL

2.1. Affordability

The entirety of the project is projected to cost around $10,000. Learning from the history under the CARPA Initiative, ECHO Technologies knows that projects like these cost more than what they seem, and $10,000 is reasonable when compared to its previous companies. This number includes extra funds to cover any mishaps, design changes throughout the process, and funds needed to sustain the company.

3. FUNDING

3.1. ECHO Technologies currently receives funding from a diverse range of sources. In the future it could be contracted to help work towards any of the plans described in the "Commercial Applications" section.

3.2. Independent and Partnered Fundraisers

Our company has set up and is planning to set up independent fundraisers selling food or at different events to raise small amounts of money to be used for our expenses such as purchasing parts or decorative pieces for events we host. Some of these fundraisers include the California Academy of Mathematics and Science's annual Taste Of CAMS event on October 26, 2018 as well as a partnership with Dippin Dots to sell different flavored ice cream on November 14 2018.

During these fundraisers, either the Project Manager, Deputy Project Managers, or the CFO oversee the event, keep track of the money, and delegate the volunteers who are employees of ECHO Technologies.

3.3. Company Sponsorships

ECHO Technologies has asked a multitude of companies, those of which we are awaiting a response from such as L.A Galaxy and D.A.R.P.A. who many of our employees have had experience and connections with. In return of these sponsorship, many will be granted variety packages

3.4. Donations

At the start of the creation of ECHO Technologies, each member of the company donated money to a total of about $330. We have also set up a donation center using the crowdfunding site GoFundMe which will officially launch after the Media Team creates a promotional video for ECHO Technologies. We also plan to host events where we present our mission and our strategies in using the donated money to potential donation recipients.

4. Purchasing Strategy

Echo Technologies intends to utilize the formal budget and team research to purchase quality materials whilst being cost efficient through discussions with vendors for donations or discounts, ensuring the order procedure for departments are formal and taking into account tax, shipping, and other potential additional costs. All the funds that Echo Technologies raise and obtain through grants, donations, or sponsorships will be put into the checking account "EDD Blue Team 2019", which is supervised by Mrs. Jackie - the banker for the California Academy of Mathematics and Sciences (CAMS). In order to buy materials for our organization and our project, we will fill out the appropriate forms, such as the "Purchase Order" forms, and submit them to the staff of the CAMS office to legally withdraw money from our account directly to the company we are buying our parts from. Some companies we expect to buy materials from are McMaster-Carr, RobotShop, Blue robotics, Pelican, Polycase, and Amazon. To save money, we will also be requesting promotional deals -when applicable- from these companies. Parts in demand will be delegated by the financial team, and they will communicate with other employees of the company to organize what parts are needed by when, and will purchase them accordingly based on the level of necessity. Every order will go through the Project Manager, Ada Saing, and if it is approved, will be submitted in the "Purchase Order" form by the financial team. The financial team will ultimately make sure that all money earned is in the appropriate place, and that all money spent is properly exchanged.

BILL OF MATERIALS

SYSTEMS DEPARTMENT

Item No.	Vendor	Name	Part No.	Unit	QTY	Unit Price	Total Price
1	Blue Robotics	M200 Brushless Motors	M200	each	4	$95.00	$380.00
2	Amazon	Raspberry Pi Model B	RASPBERRYPI3-MODB-1GB	each	3	$37.30	$111.90
3	Amazon	eBoot Buck Converter	EXPSFD005794	each	1	$11.99	$11.99
4	Fox Tech	Tarot X4 Quadcopter Frame	1946	each	1	$234.99	$234.99
5	Amazon	CyclingDeal 20X Bike Bicycle Air Pump Inflator 16G Co2 Threaded Cartridges	CD-CO2-20	20	1	$24.00	$24.00

6	Amazon	Black CO2 Inflator for Bikes Tire By BriskMore, Presta and Schrader Valve Compatible, Bike Tire Pump for Mountain and Road Bicycles, Insulated Sleeve	BT-003A	each	1	$14.90	$14.90
7	Amazon	Revmega Tubeless Presta Valve Stem - Pair	VS02	each	1	$12.99	$12.99
8	Amazon	Nylon Vacuum Flexible Tubing	B0092L1MLE	each	1	$30.58	$30.58
9	Amazon	FLY5D 3Pcs Pump Air	FAW-02	each	1	$16.99	$16.99

		Wedge Alignment Inflatable Shim Air Cushioned Powerful Hand Tools					
10	Amazon	Logitech USB Camera	B000VTQ3LU	each	1	$7.89	$7.89
11	Amazon	Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout	ADA2472	each	1	$34.95	$34.95
12	Blue Robotics	Bar02 Ultra High Resolution 10m Depth/Pressure Sensor	BAR02-SENSOR-R1-RP	each	1	$88.00	$88.00
13	Amazon	Smallest Mini 50.0 Mega Pixel USB HD Video	NCOREJNJIJKKM362	each	1	$4.69	$4.69

		Camera Webcam					
14	Amazon	Pelican 1150 Camera Case With Foam	1150-000-110	each	1	$40.00	$40.00
15	Polycase	ML Series Outdoor NEMA Enclosures	ML-58F*1508	each	1	$42.00	$42.00
16	Blue Robotics	Cast Acryllic Tube (6" Series)	WTE6-ASM-R1-VP	each	1	$90.00	$90.00
17	Blue Robotics	O-Ring Flange	WTE6-ASM-R1-VP	each	2	$59.00	$118.00
18	Blue Robotics	Aluminum End Cap with 15 Holes (6" Series)	WTE6-ASM-R1-VP	each	2	$44.00	$88.00
19	Blue Robotics	Enclosure Vent and Plug	WTE6-ASM-R1-VP	each	1	$8.00	$8.00
20	Blue Robotics	T200 Thruster	T200-THRUSTER-R1-RP	each	4	$169.00	$676.00
21	Adafruit	USB Type-A	2225	each	15	$0.69	$10.35

		Jack					
22	Amazon	SunFounder 210Pcs Assorted M3 M2.5 Nylon Screws Nut Standoffs Spacers for DIY Aircraft Arduino Raspberry Pi FPV RC Drone PC mods	B06Y591NKK	210	2	$9.99	$19.98
23	Amazon	Mudder Black Aluminum Heatsink Cooler Cooling Kit for Raspberry Pi 3, Pi 2, Pi Model B+	LYSB01LXWK626-ELECTRNCS	10	2	$5.99	$11.98

24	Amazon	Sandisk Ultra 32GB Micro SDHC UHS-I Card with Adapter	1 A1 - SDSQUAR-032G-GN6MA	each	3	$9.59	$28.77
			Total				**$2,106.95**

MISCELLANEOUS

Item No.	Vendor	Name	Part No.	Unit	QTY	Unit Price	Total Price
1	Amazon	BookFactory Black Engineering Notebook	LIRPE-168-SGR-A-LKT4	each	1	$29.99	$29.99
2	namecheap.com	Website Domain (echotechnologies.org)	N/A	each	1	$11.69	$11.69
3	tiemart.com	Blue Staff Tie	AC58NW-0014	each	50	$2.50	$125.00
4	Bannerama	Team Canvas Banner		each	1	$154.80	$154.80
			Total				**$321.48**

INTERNS

Item No.	Vendor	Name	Part No.	Unit	QTY	Unit Price	Total Price
1	Amazon	ABS Plastic Sheet	B004UBWEVI	each	3	$9.98	$29.94
2	Blue Robotics	T100 Thruster	T100-THRUSTER-R1-RP	each	6	$119.00	$714.00
3	Alibaba	Waterproof IR Truck Security Side View Camera	720P AHD IP69K	each	2	$28.50	$57.00
4	Blue Robotics	Fathom ROV Tether R2	FATHOM-TETHER-NB-4P-26AWG-100-R2	each	1	$500.00	$500.00
5	Blue Robotics	Waterproof Servo	HITEC-D646WP	each	8	$56.00	$448.00
6	Arduino	ARDUINO UNO REV3	A000066	each	1	$22.00	$22.00
7	Blue Robotics	Basic ESC	BESC30-R3	each	1	$25.00	$25.00
8	Amazon	Raspberry Pi 3 Model B Motherboard	RASPBERRYPI3-MODB-1GB	each	1	$34.99	$34.99
9	Blue Robotics	Subsea Buoyancy Foam: R-3312	FLOAT-R3312-R1-VP	each	1	$21.00	$21.00
10	Amazon	Loctite Epoxy Quick Set	1395391	each	1	$6.65	$6.65
11	Amazon	MG Chemicals Silicone Modified Conformal Coating,	422B-55ML	each	1	$12.95	$12.95
			Total				**$1,871.53**

TOTAL COST

DEPARTMENT	TOTAL COST
SYSTEMS DEPARTMENT	$2,106.95
MISCELLANEOUS	$321.48
INTERNS	$1,871.53
TOTAL	$4,299.96

OUTREACH

PURPOSE

The purpose of Echo Technologies' Outreach team is to educate the youth about Science, Technology, Engineering, Art & Mathematics (STEAM) career pathways through interactive presentations and collaborative activities. We aim to provide a hands-on experience, to give the students the chance to be exposed to each STEAM field. Outreach also wishes to give back to the community by helping students develop meaningful skills that will aid them in their future endeavours.

ACTION

The Outreach Team will encourage the youth to discover their passions and talents through various STEAM-based activities. These activities will help them develop collaboration, technical, creative, and innovative skills through hands-on learning experiences. ECHO Technologies aims to have an impact in the community by providing resources for students to better understand engineering concepts.

An event called "Community Day" was held on November 3rd at CAMS. The purpose of this event was to encourage many 8th graders from multiple schools in the South Bay area to attend CAMS by showing them a tour of what we have to offer. EDD team ECHO Technologies played a part of the tour and educated students and their parents through informative slides about the purpose of EDD and our mission to provide for the communities around us.

This year, ECHO technologies outreach team has chosen the intended theme of the STEAM events to be Finding Nemo. These stations will include mini-lessons and activities, separated by the following subfields: science, technology, engineering, art, and mathematics. The booths would be decorated surrounding Finding Nemo and completing them would be similar to a scavenger hunt and puzzle as they gather character puzzle pieces from the movie to "find" Nemo.

Once a student collects every character puzzle piece and completes the puzzle, they will receive a prize.

SCIENCE

Our officers would educate students about surface tension of water through an activity involving bubbles. By showing them how atoms in bubbles represent the properties of cohesion and adhesion to create surface tension, not only do the students remain engaged, but they also learn basic principles of chemistry.

TECHNOLOGY

we would utilize a maze game to explain algorithms and pseudocode through blocks. Students first plan their actions using coding language then demonstrate their written code through the maze. Using spaghetti and marshmallows, we will explain center of mass.

ENGINEERING

We will engage the youth with a catapult game where they must launch an object into baskets for a certain amount of points. By creating a competitive environment, the students would be more motivated to think in new, innovative ways to launch their object the farthest.

ART

To promote creativity, we would make slime using household materials including glue, corn starch, and glitter. Ideally, this would open the eyes of the student to see the world through a creative and fun lense.

MATHEMATICS

Finally, to improve mental math proficiency we would engage the youth with a bean bag toss, using the rows and columns to form simple equations for them to solve.

These are only a few examples of interactive activities that we intend to use with students. The Outreach Team of ECHO Technologies will continue to add to our list of activities and events as the year proceeds, hoping to work with multiple schools in our area.

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ACRONYMS

ASB: Associated Student Body

BOM: Bill of Materials

CAD: Computer- Aided Design

CAMS: California Academy of Mathematics & Science

CARPA: CAMS Advanced Research Projects Agency

CIA: Central Intelligence Agency

CFO: Chief Financial Officer

CDR: Critical Design Review

CNC: Computer numerical control

CS: Chief Scientist

DARPA: Defense Advanced Research Projects Agency

DPM: Deputy Project Manager

FAA: Federal Aviation Administration

GD&T: Geometric Design & Tolerance

EDD: Engineering Design & Development

ESC: Electronic Speed Controller

IPR: In Process Review

LIPO: Lithium Polymer

NEMA: National Engineering Manufacturers Association

PDB: Power Distribution Board

PDR: Periodic Design Review

PM: Project Manager

POC: Proof Of Concept

ROV: Remotely Operated Vehicle

SALT: Strategic Arms Limitations Treaty

SPS: Systems Performance Specifications

TDP: Technical Data Package

IDP: Interdisciplinary Project

UV: UltraViolet

UAV: Unmanned Aerial Vehicle

UUV: Unmanned Underwater Vehicle

WIFI: Wireless Fidelity

2D: Two Dimensional

3D: Three Dimensional

CARPA APPROVAL

Rules, conditions, and requirements are subject to change by the CARPA authority. All changes will be discussed in class, and be presented to the company teams in writing. Changes are negotiable and deadline extensions must be agreed upon by all parties.

Project Manager Date

Deputy Project Manager Date

Deputy Project Manager Date

Chief Financial Officer Date

Chief Scientist Date

Director of Media Date

Director of Publications Date

Director of Outreach Date

Director of Mechanical Engineering Date

Director of Electrical Engineering Date

Director of Systems Engineering Date

Director of Programming Date

Director of Interns Date

Director of Manufacturing Date

CARPA Authority Date